Subsidy Project of Decommissioning and Contaminated Water Management in the FY 2021

Development of Technology for Detailed Investigation inside PCV

FY2021 Accomplishment Report

August 2022

International Research Institute for Nuclear Decommissioning (IRID)

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1. Research Background and Purpose

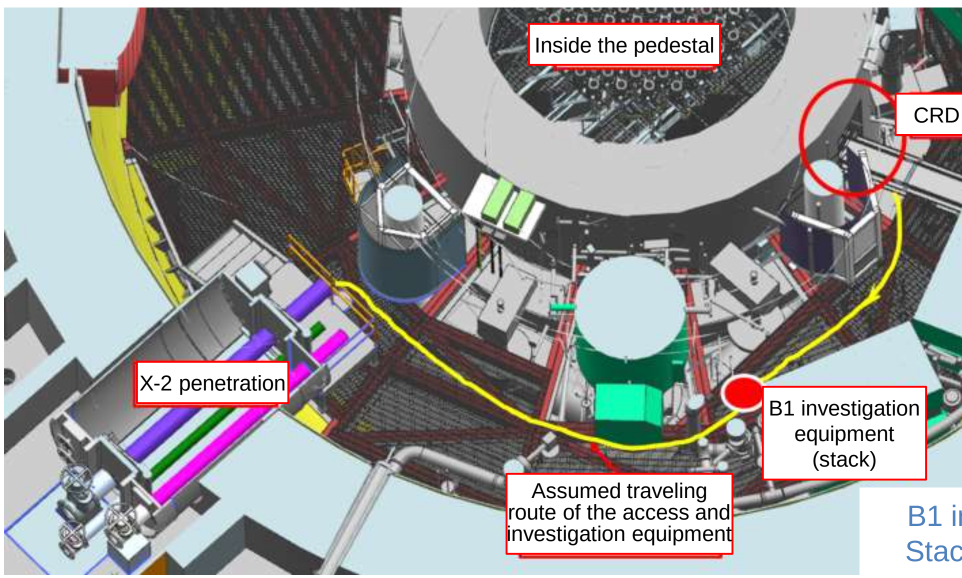
[Purpose of this project]

The purpose of this project is to develop an access and investigation equipment and investigation technology for obtaining information on the upper section of the pedestal from the CRD opening to the area in the vicinity of the inner center of the pedestal, which is important in studying the details of the status inside the pedestal, especially, the viability of the bottom access investigation method for investigating the inside of the Reactor Pressure Vessel (hereinafter “RPV”), based on the results of previous projects; and to implement the following.

(1) Planning and update of investigation and development for detailed investigation inside the pedestal
(2) Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

[Reflections of this project]

The information obtained from this project (status of structures inside the pedestal, status of fuel debris distribution, dose rate) will be reflected in the detailed study of the bottom access method and equipment for investigation inside RPV which is part of a different project. And, it will be reflected in the detailed study of fuel debris retrieval method and equipment as well.



B1 investigation equipment: Stack during investigation in April 2015

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

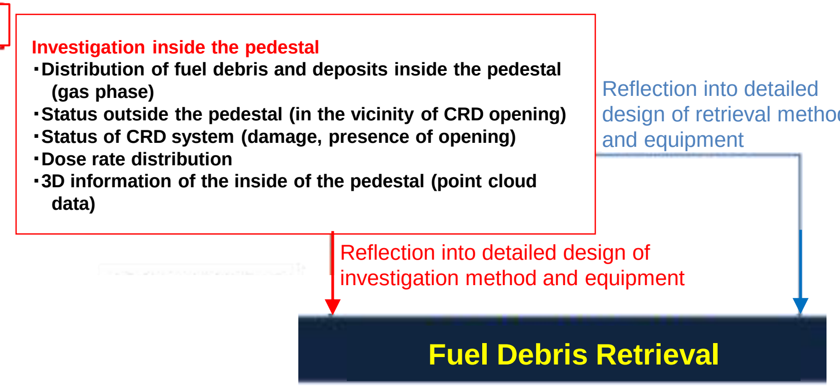


Figure 2: Assumed data to be acquired

2. Project Goals

(1) Planning and update of investigation and development for detailed investigation inside the pedestal

This project aims to create a plan for developing the access and investigation equipment with additional necessary functions, and a plan for detailed investigation using the developed equipment, in reference to the plans for developing the access and investigation equipment and for the investigation equipment, which were developed in the previous project.

Furthermore, these plans are continuously revised and updated as required while taking into consideration the latest site information, results of internal investigation, etc.

(2) Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

This project also aims to design and manufacture the access and investigation equipment, in reference to the studies in the previous project, and to carry out in-plant verification (unit test) of the equipment, as well as the investigation technology for verifying applicability in internal investigation, based on the plan for developing the access and investigation equipment described in (1) above.

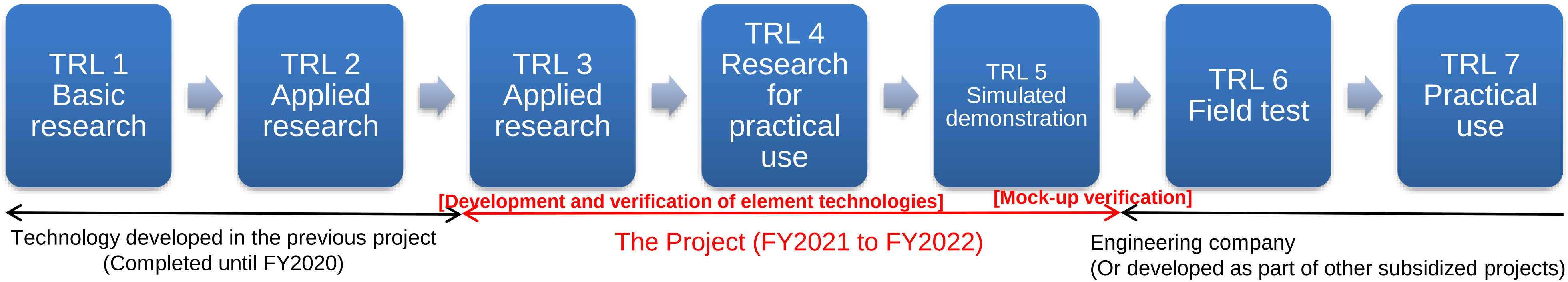
Furthermore, mock-up tests that are simulated actual equipment are conducted to verify the site applicability.

2. Project Goals

This project aims to plan investigation and development related to detailed investigation inside the pedestal as well as to develop the access and investigation equipment, based on technologies Developed in the previous project (completed until FY2020).

TRL: Technology Readiness Level

Table 1: Goals pertaining to the investigation inside the pedestal



Items	Goal of this project	TRL
(1) Planning and update of investigation and development for detailed investigation inside the pedestal	･Planning of the pedestal investigation ･Overall plan pertaining to the investigation equipment, equipment and machines ･Development of investigation equipment and investigation technology ･On-site demonstration (plan for onsite-investigation)	3 to 4 3 to 4 3 to 4 3 to 4
(2) Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal	･Detailed designing and manufacturing of the investigation equipment and investigation technology ･In-plant verification (unit test) ･Mock-up tests (testing facility, tests)	3 to 4 3 to 4 5

3. Implementation Items and Relation with Other Projects

The scope of investigation (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 the Development of Detailed Investigation Inside Pedestal (Deposits) Project, is the main scope of investigation of this project.

It is assumed that the projects will be carried out in the order of Development of Technology for Detailed Investigation Inside PCV project ⇒ This Project ⇒ Development of Technology for Investigation Inside RPV project, and the results of each step will serve as Input for the following step.

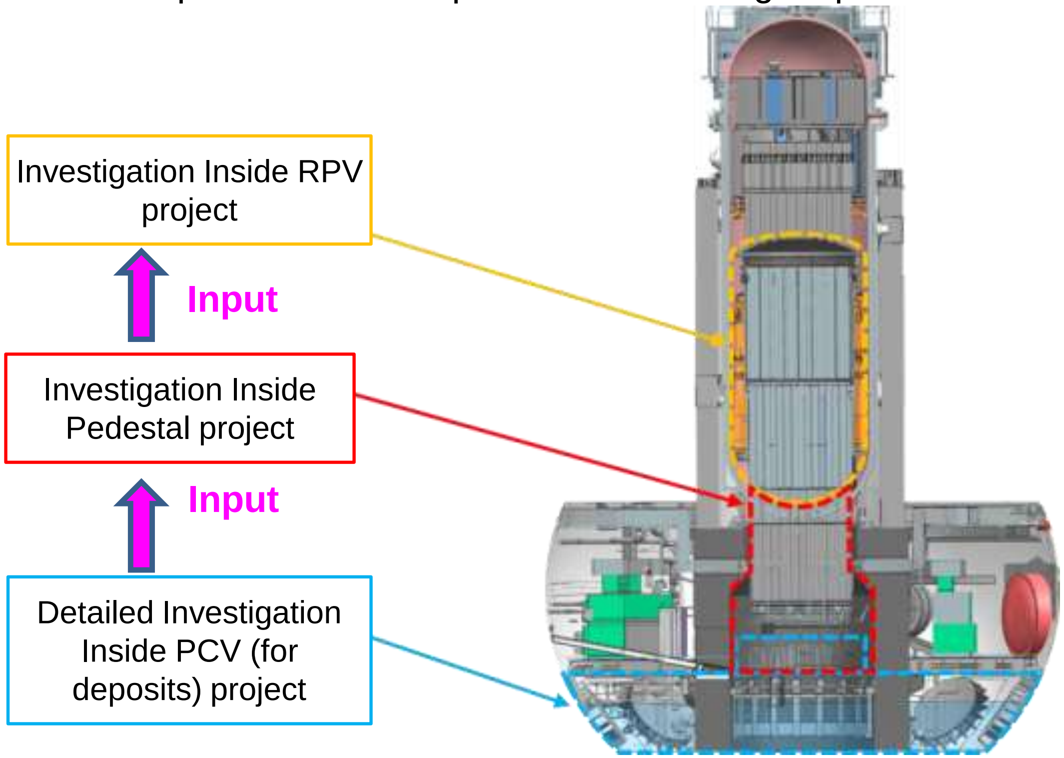


Figure 3: Relation with other projects

Table 2 : Scope of investigation of each project (for Unit 1)

Project name	Scope of investigation	Method of investigation
Development of Technology for Investigation Inside RPV [Other subsidized project]	Inside RPV (Mainly inside the shroud)	Investigation by means of a drone is being considered
Development of Technology for Investigation Inside Pedestal [This project]	Inside the pedestal (Mainly the air part, and the underwater area only to the extent that is visible from the air part)	Studied as part of this project
Development of Technology for Detailed Investigation Inside PCV (Deposits) [In-house project]	Inside the pedestal (Mainly the underwater area, and the air part only to the extent that is visible from the underwater area)	ROV

4. Schedule

Refer to Table 2 for the proposed implementation schedule. Detailed design and manufacturing of the access and investigation equipment/in-plant verification (unit test)/mockup tests/work training/on-site demonstration will be implemented based on the results of this term.

Table 3 Proposed implementation schedule (FY2021 onwards)

Item			FY2021 1Q	FY2021 2Q	FY2021 3Q	FY2021 4Q	FY2022 1Q	FY2022 2Q	FY2022 3Q	FY2022 4Q	FY2023 onwards
Master schedule **The work indicated by the alternate long and short dashed line is outside the scope of this project.** The work indicated by dotted line is implemented as needed.				IRID in-house project Detailed Investigation Inside PCV (Deposits PJ)	MRI (Interim report)		▽ MRI* (Interim report)			▽	MRI (Final report) Work training On-site demonstration
Development of technology for detailed investigation inside pedestal through the pedestal CRD opening (R&D)	1. Planning and update of the investigation and development for detailed investigation inside the pedestal	(i) Planning of the investigation plan	Investigation planning								
		(ii) Development planning	Development planning								
	2. Development of access and investigation equipment and investigation technology for detailed investigation inside the pedestal	(i) Detailed designing, manufacturing and unit tests of the access and investigation equipment	Detailed designing of the access and investigation equipment and investigation technology	Manufacturing of the access and investigation equipment				In-factory verification (unit test)			
		(ii) Mock-up tests				Designing and fabrication of mock-up test facility			Mock-up tests		
		(iii) Planning for on-site demonstration (onsite investigation)						Development of the plan for on-site demonstration (onsite investigation)			

MRI*: Mitsubishi Research Institute, Inc.

5. Project Organization

Figure 4 shows the project organization of this project.

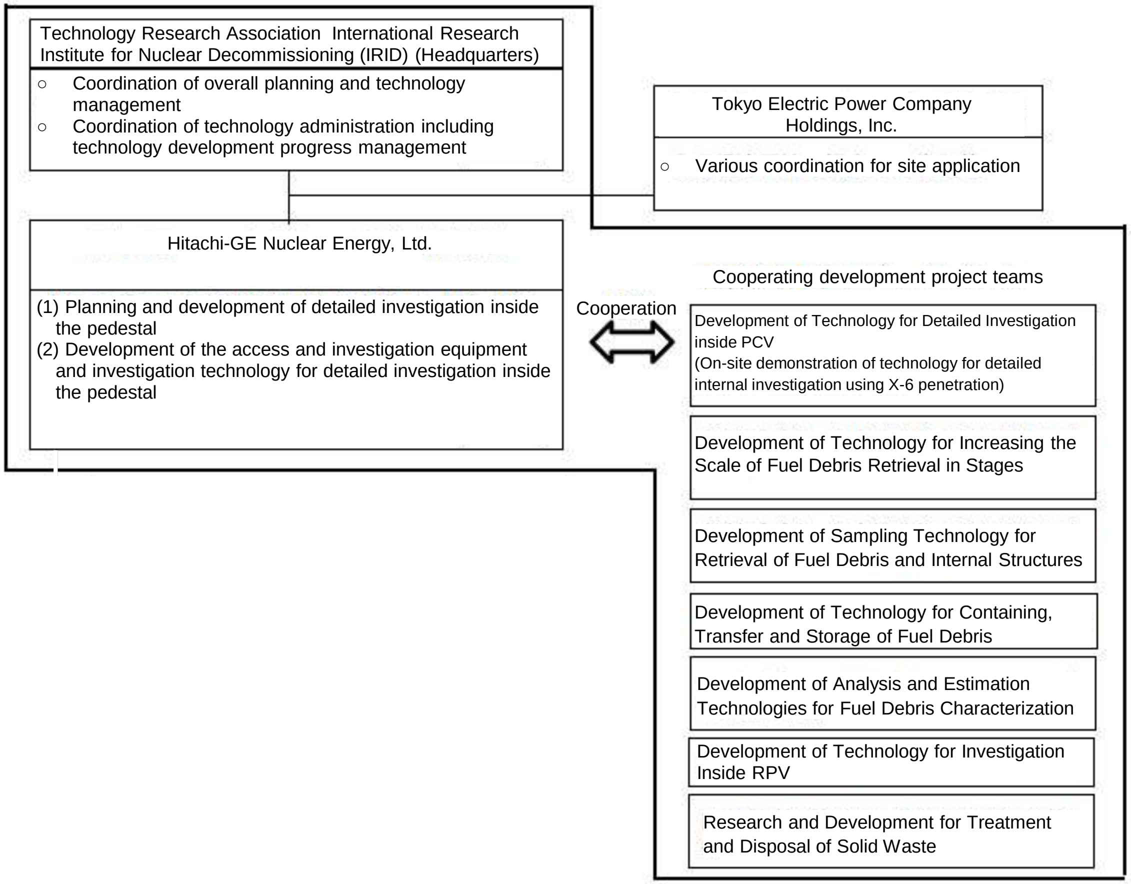


Figure 4: Project Organization

6. Implementation Details

6.1 Planning and update of investigation and development for detailed investigation inside the pedestal

A conceptual study for moving the access and investigation equipment from the X-2 penetration to the CRD opening and investigating the inside of the pedestal was carried out in previous project. Based on the results of the previous project, the project involves planning for investigation inside of the pedestal and for development of the access and investigation equipment, etc. and updating as required.

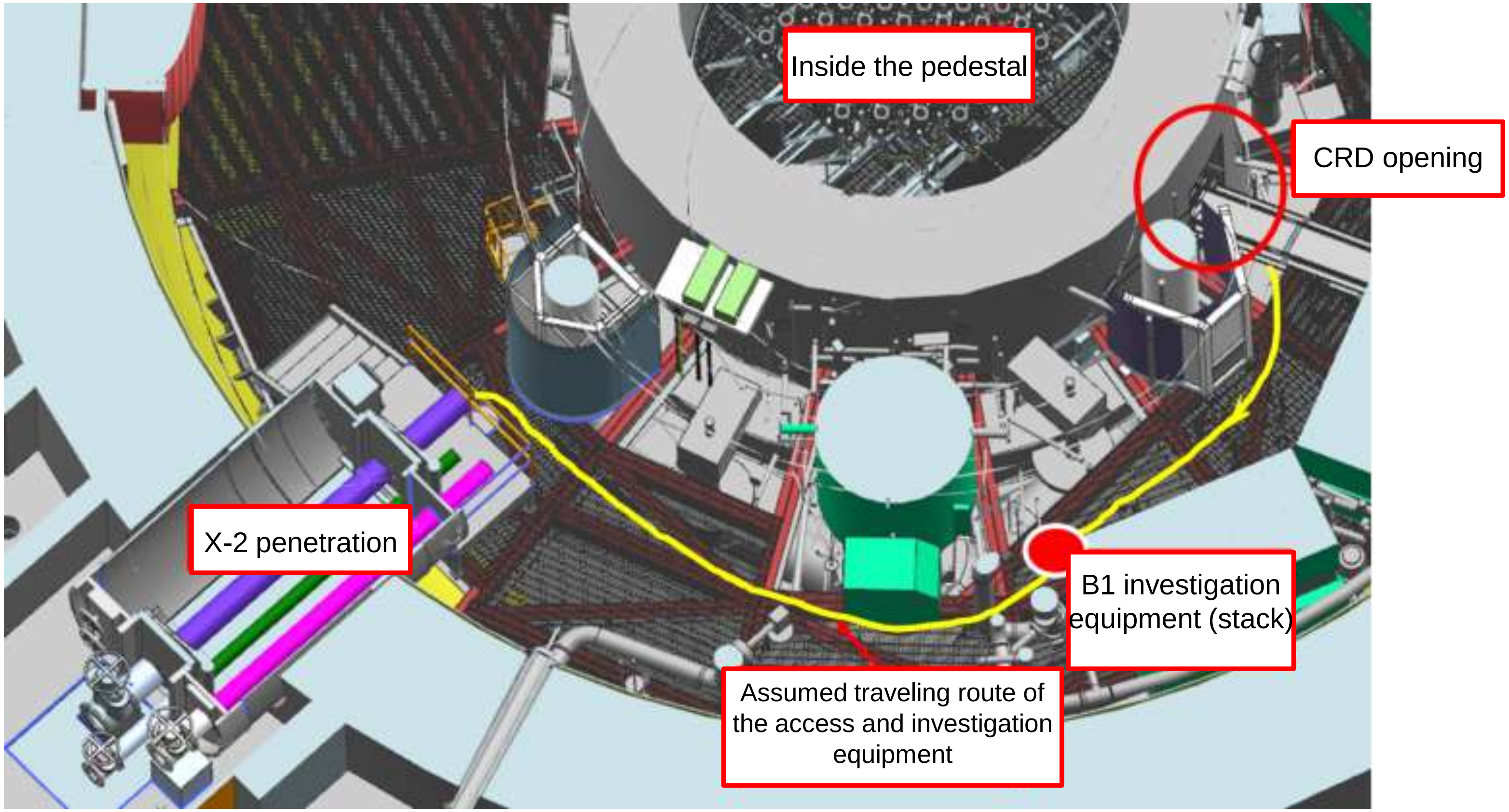


Figure 5: Estimated traveling route of the access and investigation equipment inside PCV

6. Implementation Details

6.1 Planning and update of investigation and development for detailed investigation inside the pedestal

Based on the investigation plan and results of development plan studied in the previous project, planning and update of investigation as shown below are carried out as part of this project.

Table 4: Investigation planning and development plan

Study items	Study details	Study results
Investigation planning	Planning for investigating inside the pedestal	① Setting and updating of the investigation goals according to the investigation needs ② Verification of the design conditions (temperature, humidity, radiation, CRD opening dimensions, presence of interfering objects, dimension conditions, etc.) inside the PCV and inside the pedestal ③ Verification of the details (images, radiation dose, point cloud data, etc.) of the investigation inside the pedestal ④ Planning and updating for investigating inside the pedestal based on ② and ③ mentioned above.
	Overall plan pertaining to the investigation equipment, equipment and machines	① Identification of the technological requirements and design specifications required for the access and investigation equipment ② Identification of support equipment (cable feeding equipment, installation equipment, seal box, etc.) required for the investigation, and study of the design and specifications
Development planning	Development of investigation equipment and investigation technology	① Details of equipment development ・Detailed designing of the equipment based on test manufacturing results from previous project ・Study of unit tests and mock-up test details, and study of the testing facility overview ② Equipment development schedule ・Equipment manufacturing schedule, unit tests, mock-up test schedule ③ Risk assessment concerning equipment development
	Planning of on-site demonstration (onsite investigation)	① Plan for functional requirements of equipment (boundary function, emergency collection function, shielding function,dust prevention and waterproofing, remote operation function, etc.) ② Field work planning for investigating inside the pedestal (the number of working days and workers, etc.)

6. Implementation Details

6.1 Planning and update of investigation and development for detailed investigation inside the pedestal

≪Setting the investigation goals according to the investigation needs≫

Table 5 shows the investigation goals (proposed) and use application of the results studied in the previous project. In the project, Table 5 is updated as required, and the final investigation goals are set.

Table 5: Investigation goals (proposed) and use application of results

Investigation location	Investigation items	Investigation goals (proposed)	Use application of results
CRD opening, above the CRD rail, inside the X-6 penetration	Visual observation Radiation (γ)	・Checking for presence of interfering objects ・Checking whether or not entering inside the pedestal is possible ・Verification of radiation dose	・Study of the viability of side access method ・Designing of the fuel debris retrieval equipment
Equipment for replacing CRD inside the pedestal	Visual observation Radiation (γ) Point cloud data	・Checking the status of damage of platform ・Verification of interfering objects and fallen objects ・Verification of radiation dose ・Assessment of the 3D structure	・Designing of the fuel debris retrieval equipment
Upper part inside the pedestal	Visual observation Radiation (γ) Point cloud data	・Verification of the status of damage of RPV bottom ・Verification of radiation dose ・Assessment of the 3D structure	・Designing of the fuel debris retrieval equipment ・Verification of the viability of bottom access for investigation inside RPV
Lower part inside the pedestal (partially submerged)	Visual observation Radiation (γ) Point cloud data	・Verification of interfering objects and fallen objects ・Verification of radiation dose ・Assessment of the 3D structure	・Designing of the fuel debris retrieval equipment

6. Implementation Details

6.1 Planning and update of investigation and development for detailed investigation inside the pedestal

《Prospect of investigation inside the pedestal (1/2)》

The following visual data were obtained in the previous project, which helps to understand the situation inside the pedestal.

① Status of damage of CRD system, status of adhering of fuel debris, status of opening till the RPV bottom [Figure 6, 7]

② Water surface of accumulated water [Figure 8]

<u>The purpose of this project is to develop technology for acquiring information including radiation dose, point cloud data and visual datas.</u>

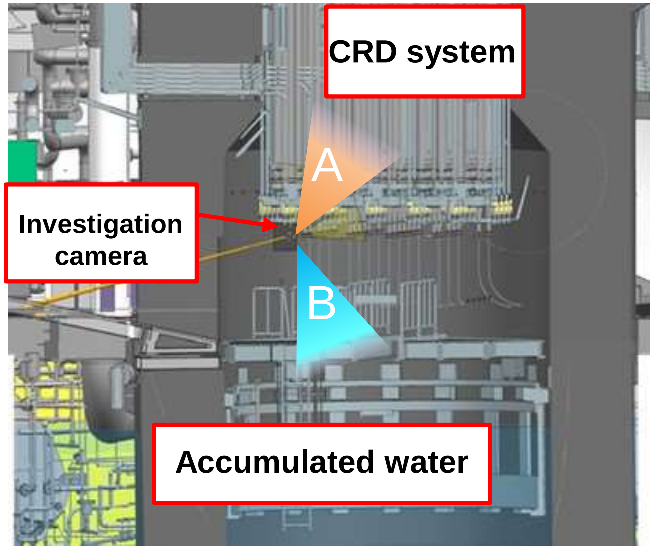


Figure 6: Illustration of the inside of the pedestal

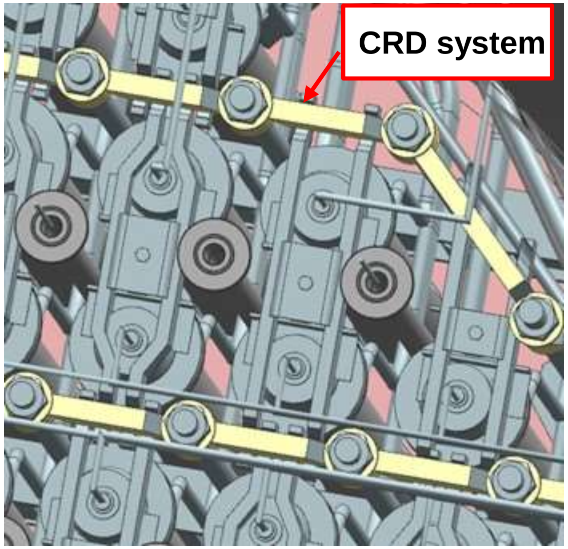


Figure 7: Illustration of a view seen from the A position

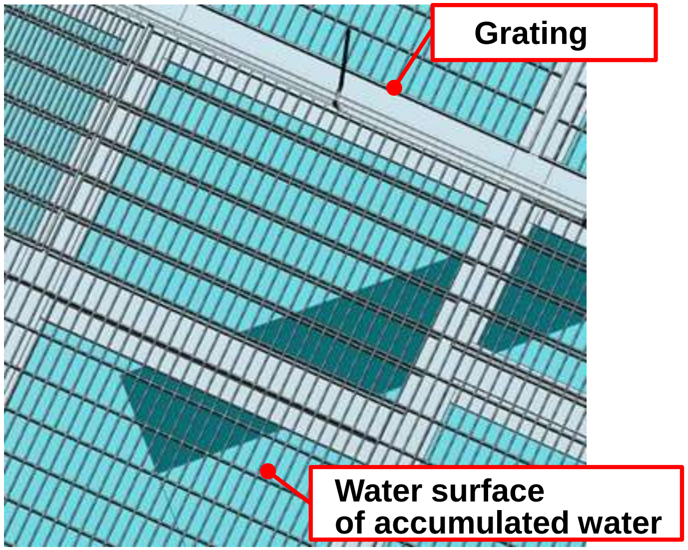


Figure 16: Illustration of a view seen from the B position

6. Implementation Details

6.1 Planning and update of investigation and development for detailed investigation inside the pedestal

《Image of investigation inside the pedestal (2/2)》

The investigation inside the pedestal is conducted to acquire images from all directions inside the pedestal are acquired using the pan-tilt camera at the tip of the extension rod.

Moreover, three-dimensional structural information is acquired by mounting a sensor for measuring point cloud data.

: Area that can be investigated

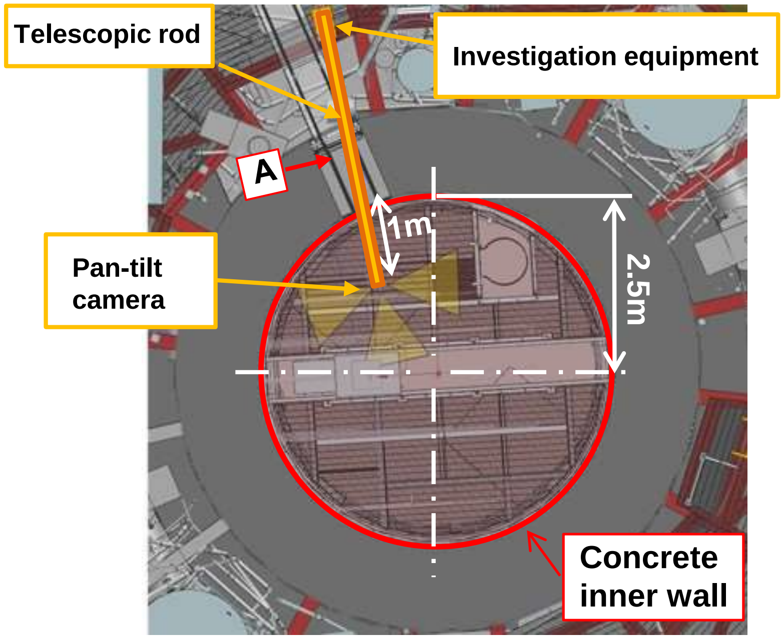


Figure 9: Area that can be visually confirmed by the equipment for investigating inside the pedestal (horizontal)

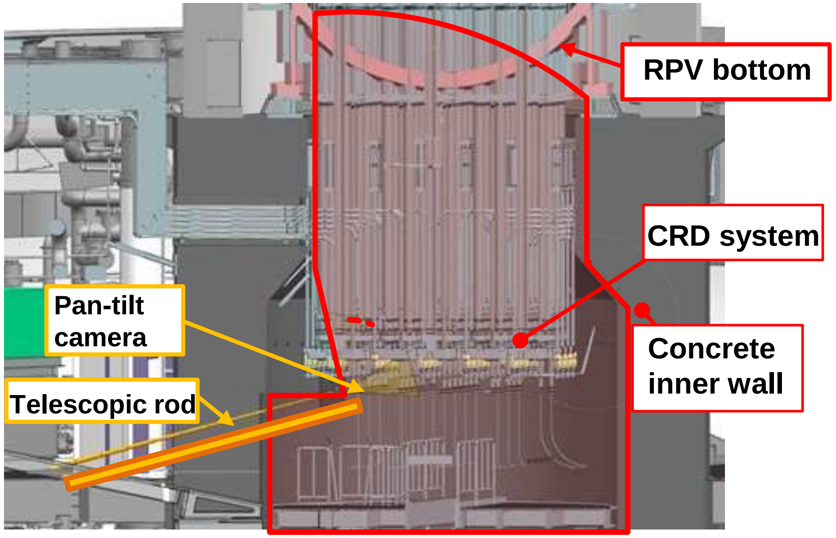


Figure 10: Area that can be visually confirmed by the equipment for investigating inside the pedestal (A view / Upper part of the pedestal)

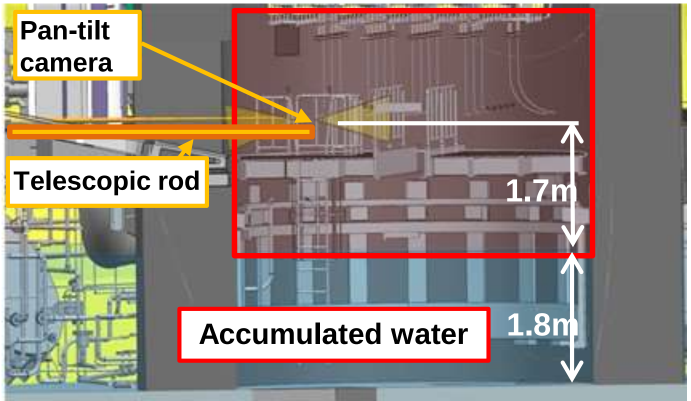


Figure 11: Area that can be visually confirmed by the equipment for investigating inside the pedestal (A view / Lower part of the pedestal)

6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

《Implementation overview of the development of access and investigation equipment and investigation technology》

The following items concerning the access and investigation equipment and investigation technology are implemented in this project, based on the results of the conceptual study on the access and investigation equipment conducted in previous project.

Table 6: Study items and implementation overview

Study items	Study details	Implementation overview
Detailed designing & manufacturing	Design specifications	All equipment used for on-site demonstration are designed and manufactured based on the test manufacturing results from previous project, such that they meet the required specifications (performance, reliability, emergency retrieval, contamination countermeasures, etc.).
In-plant verification (Unit tests)	Verification items	In-plant verification is conducted to verify that all equipment used for on-site demonstration meet the required specifications (performance, reliability, emergency retrieval, contamination countermeasures, etc.). Then, the required equipment improvements are made.
Mock-up test	Testing facility	The area that the workers and equipment can access is manufactured at full-scale during the investigation inside the pedestal. (Length 20m x width 10m x height 10m)
	Mock-up test	It is confirmed that detailed investigation inside the pedestal can be conducted by simulating the actual equipment conditions and following the same procedures as those for actual equipment. The number of estimated workers are 10 to 20 (based on past record of the previous project).

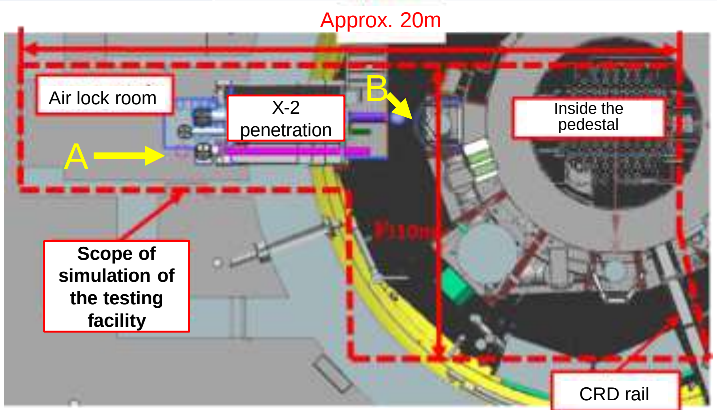


Figure 12: Scope of simulation of test equipment

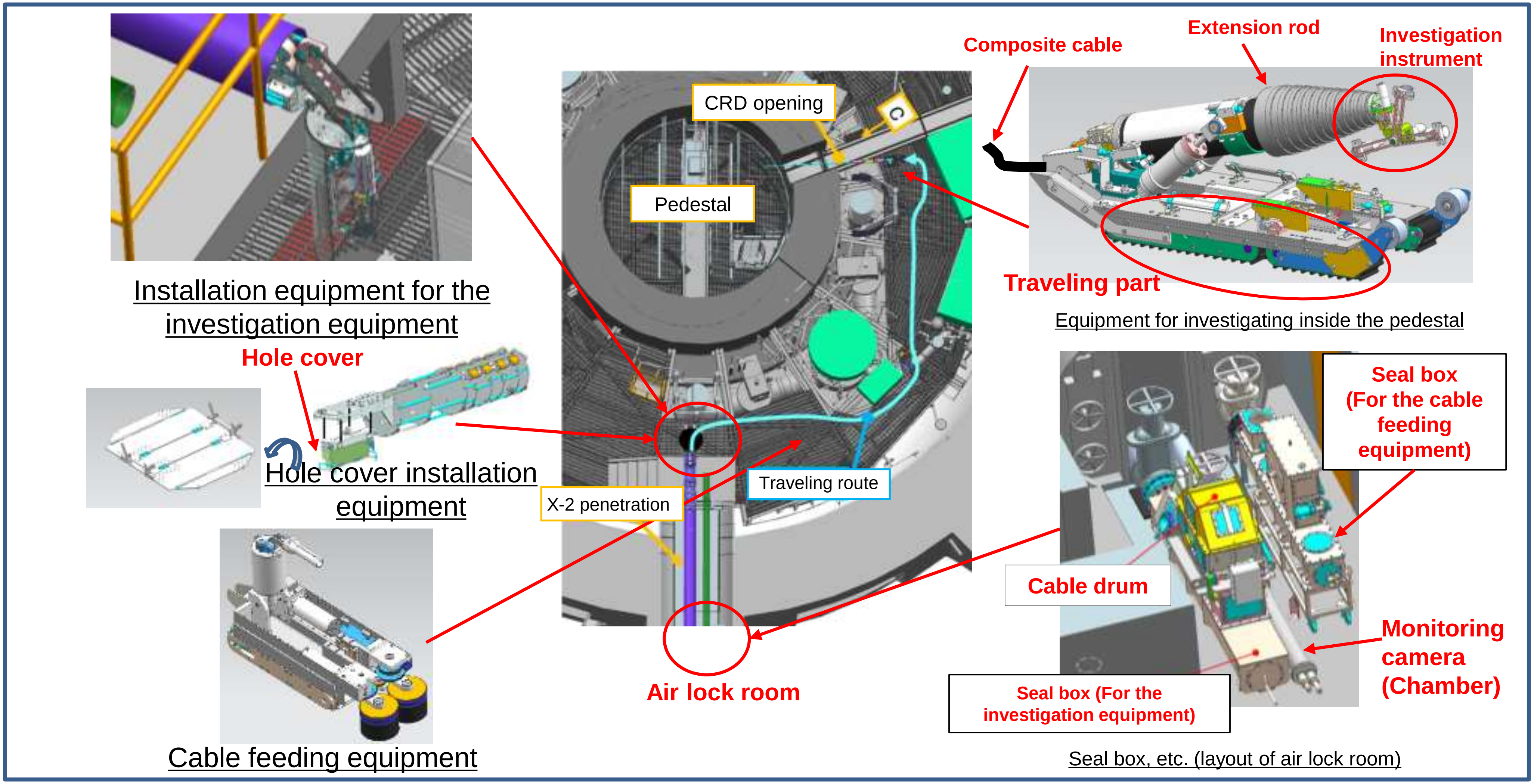

Figure 13: View seen from A (access route)


Figure 14: View seen from B (PLR shielding: before the earthquake disaster)

6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

Table 7: Illustration of the configuration of the equipment for investigation inside the pedestal



6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

In the previous project, a prototype of the equipment for investigating inside the pedestal was manufactured, and functional verification tests were conducted. In this project, detailed design and manufacturing of the equipment is performed for a practical use.

Table 8: Equipment specifications for the equipment for investigating inside the pedestal

Site on the equipment	Required specifications (functions)
Traveling part	・Should be able to cross over the B1 investigation equipment left behind, and reach the area in the vicinity of the CRD opening
Extension rod	・Should be able to extend and retract the extension rod (air type) to 5m ・Should be able to control the length of the extension rod ・Cable should be embedded in the extension rod
Investigation instrument	・Should investigate the fuel debris and structures inside the pedestal with the help of a pan-tilt camera ・Should measure the dose rate inside the pedestal by mounting a sensor for measuring the dose rate ・Should measure three-dimensional point cloud data using a sensor (stereo-camera, etc.) for acquiring the point cloud data

B3 investigation: Detailed Investigation inside PCV (Deposits)

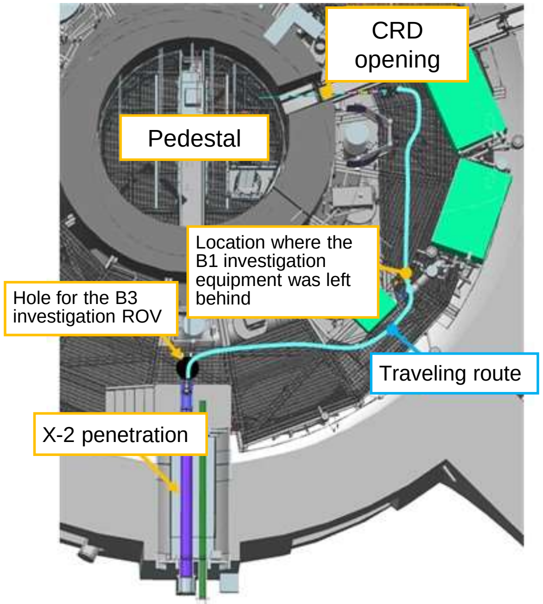


Figure 15: Traveling route of the investigation equipment inside PCV (assumed)

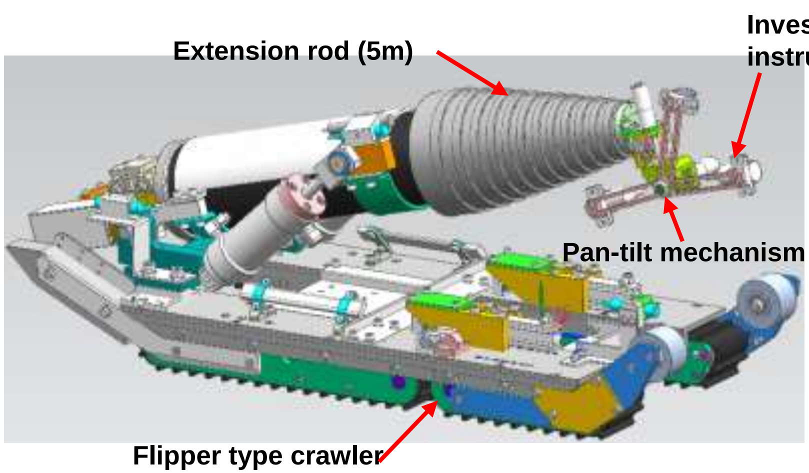


Figure 16: Equipment for investigating inside the pedestal

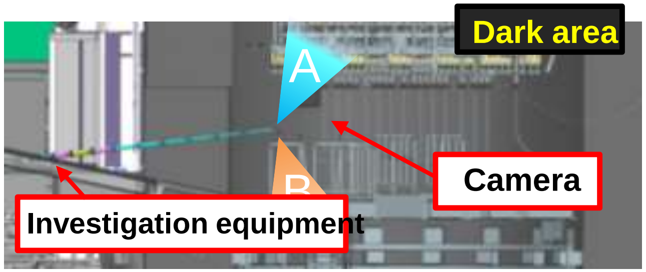
Figure 17: Equipment for investigating inside the pedestal

6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

In previous project, the inside of the pedestal was simulated as a dark area and it was verified that simulated structures and fuel debris can be observed. In this project, acquiring data including images, dose rate from inside the pedestal is studied.

Table 9: Visual images being captured by the equipment for investigation inside the pedestal

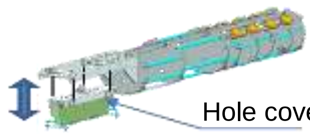
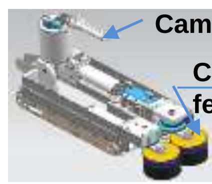
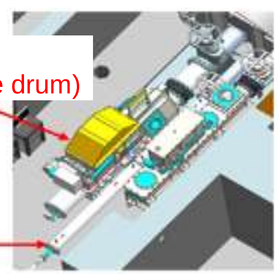
Scope of capturing the image (photo of the test piece)	Example of capturing the test image (result of the previous project)
Photographed by inserting the camera into the pedestal (View A, B)   Simulated fuel debris Simulated CRD  Assumed water level (Height of the sand bags) Inside the pedestal Test simulation	The simulated structures and fuel debris are clearly visible even in the dark.   Simulated fuel debris Visual data captured by the investigation instrument (camera) (Image from View A)  Assumed water level (Height of the sand bags) Visual data captured by the investigation instrument (camera) (Image from View B)

6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

In previous project, a prototype of the ancillary equipment for investigating inside the pedestal was manufactured, and functional verification tests were conducted. In this project, detailed design and manufacturing of the ancillary equipment is performed.

Table 10: Required specifications for the ancillary equipment for investigating inside the pedestal

No.	Equipment		Preconditions
1	Hole cover installation equipment		･Should be able to remotely install and retrieve the cover for the hole for ROV by means of remote operation. ･The investigation equipment should be able to travel over the hole cover.
2	Installation equipment		･Should be able to insert the investigation equipment from the X-2 penetration, install it on the first floor grating inside PCV and retrieve it, by means of remote operation.
3	Cable feeding equipment		･Should be able to grab and move (including correction of the cable route) the cables of the investigation equipment by means of remote automatic operation. ･Should be capable of feeding cable into the investigation equipment by means of remote operation. ･Should be able to monitor the movement of the investigation equipment and the status of the surrounding area by means of the camera provided.
4	Seal box (Including cable drum)		･Should be able to maintain the PCV boundary for the investigation equipment and other equipment. ･ Dimension should be such that it can be carried into and installed inside the air lock room.
5	Monitoring camera (Including the chamber)		･Should be able to be inserted from 200A (through hole of diameter 200mm opened in the X-2 penetration) and monitor various works inside the PCV. ･Should be able to maintain the PCV boundary, and the dimensions should be such that it can be carried in and installed inside the air lock room.

6. Implementation Details

6.2 Development of the access and investigation equipment and investigation technology for detailed investigation inside the pedestal

The status of progress of FY2021 is given below.

Table 11: Status of development of the equipment for investigating inside the pedestal and other items

No.	Equipment	Required specifications		FY2019 to FY2020 (preceding project)		FY2021 (April 2021 to March 2022)	Remarks
				Initial plan	Advancement	Designing & Manufacturing	
1	Equipment for investigating inside the pedestal	Back and forth traveling of the investigation equipment (including crossing over the B1 investigation equipment)		● (Crawler)	● (Flipper type crawler)	● (Additional improvements)	Item 6.2.1
		Access to the inside of the pedestal (Extension rod)		● (4m)	● (5m, enclosed in the cable, can halt arbitrarily)	● (Additional verification tests)	Item 6.2.2
		Composite cable		—	—	● (Structural study / verification test)	Item 6.2.3
		Investigation instrument	Camera	- (B2 investigation results available)	- (B2 investigation results available)	- (B2 investigation results available)	-
			Point cloud data sensor	—	—	● (Method selection, conducting elemental tests)	Item 6.2.4
			Radiation sensor (dosimeter)	- (B2 investigation results available)	- (B2 investigation results available)	● (Conducting elemental tests, cable selection)	Item 6.2.5
2	Hole cover installation equipment	Installation and retrieval of cover for closing the hole for ROV on first floor grating		●	● (Improvement)	● (Additional improvements)	Item 6.2.6
3	Installation equipment for the investigation equipment	Insertion of the investigation equipment into the first floor grating inside the PCV from the X-2 penetration, and its retrieval		●	● (Improvement)	● (Additional improvements)	Item 6.2.7
4	Cable feeding equipment	Investigation equipment cable adjustment		●	● (Improvement)	● (Verification using the composite cable for the actual equipment)	Item 6.2.8
5	Seal box (Including cable drum)	Maintaining the PCV boundary for the investigation equipment and other equipment		—(Results are available)	—(Results are available)	● (Considering the structure, manufacturing)	Item 6.2.9
6	Monitoring camera	Ancillary equipment required for investigation with actual equipment		—(Results are available)	—(Results are available)	● (Improvement and verification test)	Item 6.2.10

Legend ●: Method determination and improvement, —: Utilization of existing developed products

6.2.1 Status of improvement in the traveling part

(1) The following improvements in the investigation equipment were made in response to the issues persisting after previous project and for further functional enhancement.

① Addition of a guide at the back for enhancing traversing efficiency
② Review of the rear motor part for reducing interference while traversing (adjustment of the motor layout)
③ Reduction in weight for enhancing traversing efficiency (Changed the material from SUS (42kg) ⇒ Duralumin (33kg)
④ Increase in the tip roller diameter fro enhancing traversing efficiency
⑤ Improvement in the crawler for enhancing traversing efficiency (Motor output increased 1.6 times, width of the belt increased from 30mm ⇒ 60mm)

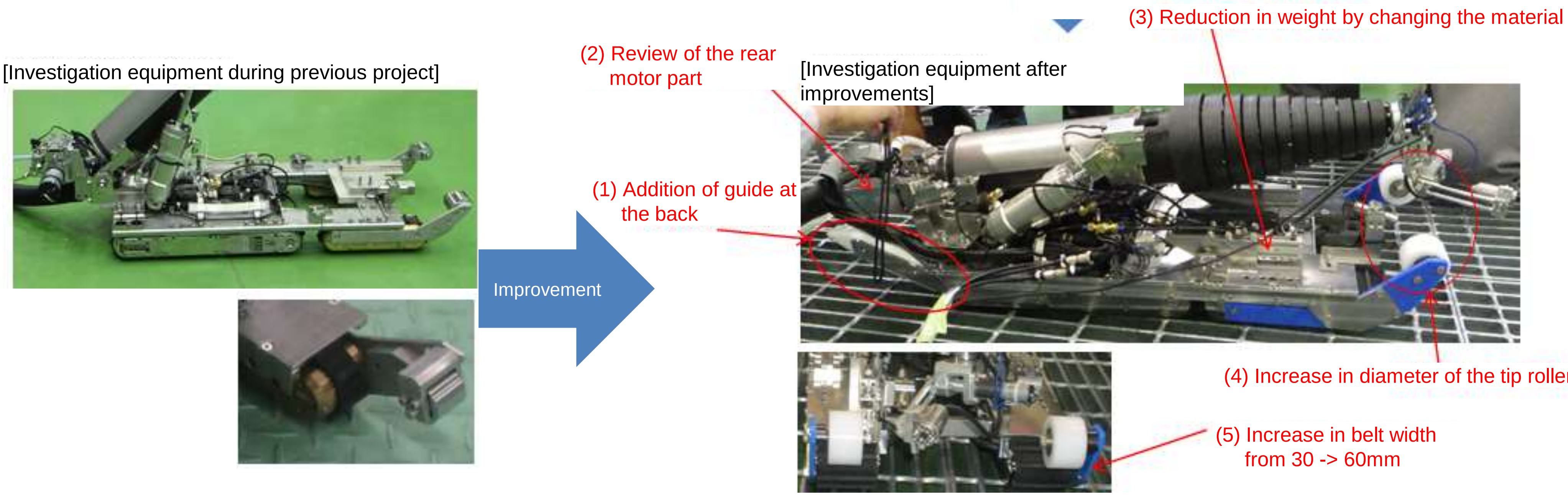


Figure 18: Improvements in the investigation equipment

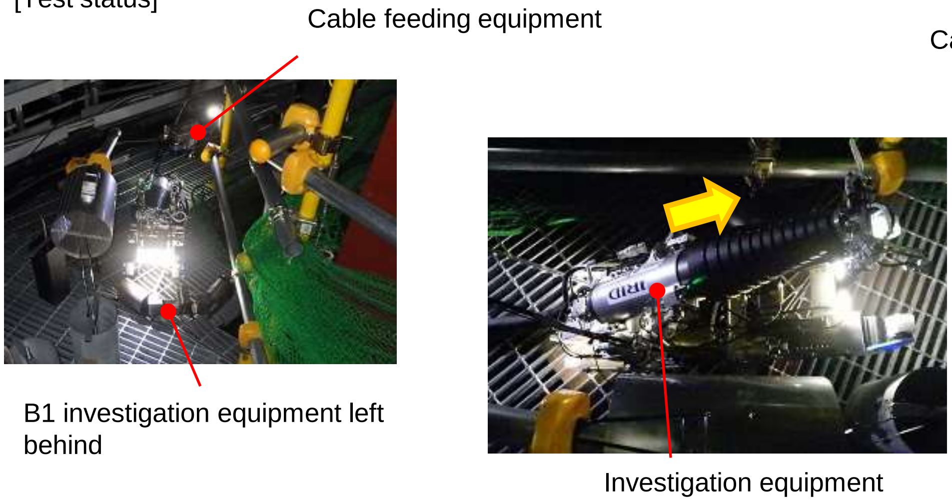
6.2.1 Status of improvement in the traveling part

(2) The results of the test on back and forth traveling of the investigation equipment are indicated below.

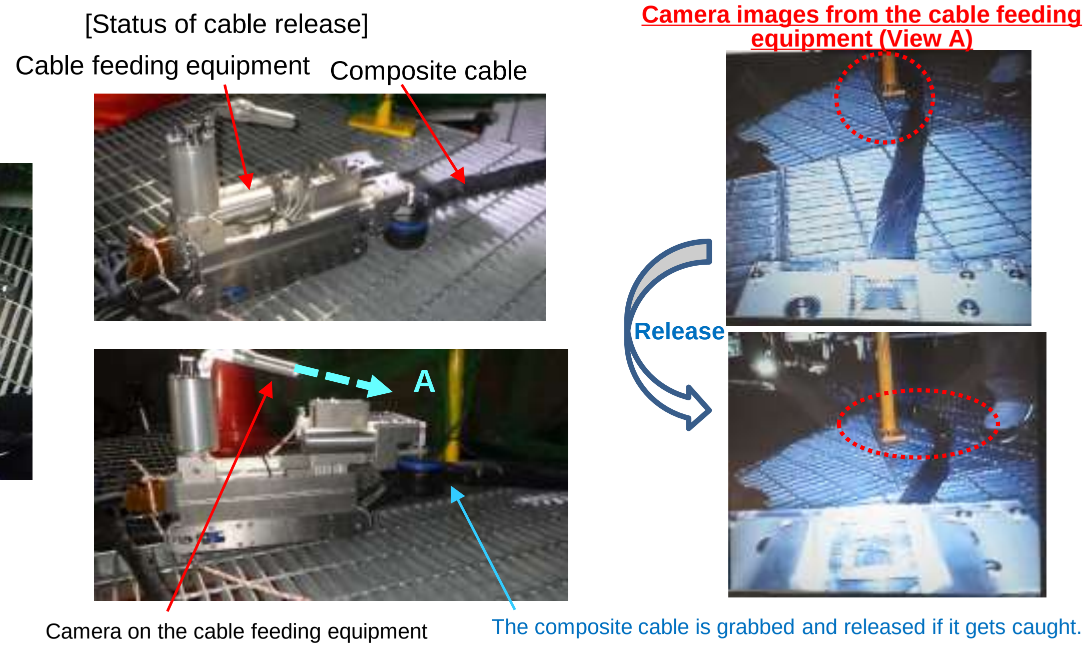
Table 12: Result of verifying back and forth traveling

Test item	Test details	Test results	
Traveling test of the investigation equipment	The movement and cable behavior when the investigation equipment travels (including crossing over the B1 investigation equipment left behind) is verified.	**Good**	･The equipment was able to travel by moving forward while checking the status by means of the camera on the cable feeding equipment and the camera image from the investigation equipment. ･Even if the cable got caught, it was released with the help of the cable feeding equipment. ･The B1 investigation equipment left behind crossed over. (onward route/return route) ･The B1 investigation equipment left behind crossed over even if it was wet due to water droplets (assuming the conditions when using actual equipment).

[Test status]



[Status of cable release]



6.2.2 Status of improvement in the extension rod

(1) Status of the previous project

① Duration of extending (retracting) 5meter-extension-rod is approx. 3 minutes. Air leaked from the seal part therefore the movement was not stable.

② Deflection arisen when extending the rod.

- Rod angle 20.6° : Deflection 1.76meters
- Rod angle 43.5° : Deflection 0.9meters

③ The length of the rod was controlled by direct visual confirmation.

⇒ The structure needs to be revised with respect to countermeasures for air leak and deflection reduction, reduction in time required for extension, and rod length control by remote operation.

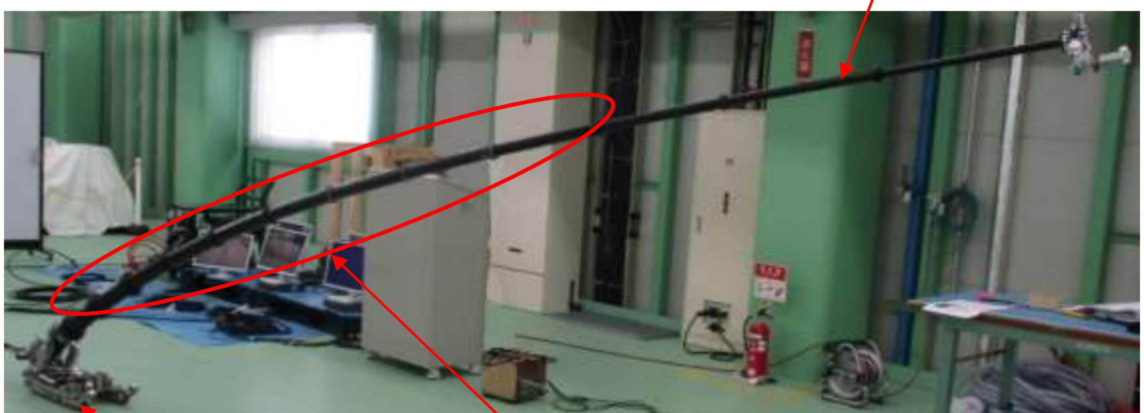


Figure 19: Extending of the extension rod (5 meters)

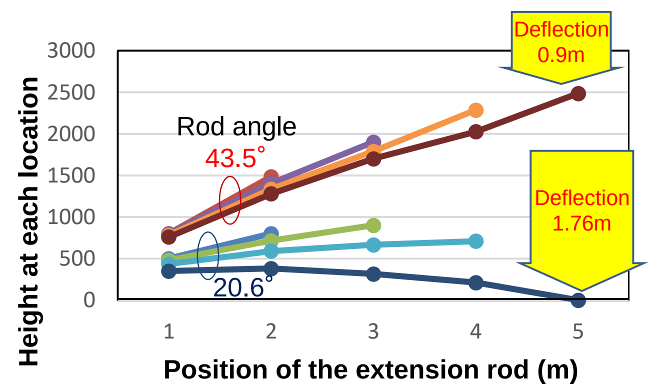


Figure 20: Status of deflection when the rod is extended

6.2.2 Status of improvement in the extension rod

(2) Improvements in the extension rod are given below.

① [Countermeasures for deflection and air leak] Review of the seal part structure ⇒ Enhancement of leakage prevention performance of the seal part

- The packing was deformed due to the load applied to the guide part (the part overlapping with the extension rod) resulting in an air leak. The structure was improved so that the packing does not get pushed in the axial direction,
- The hardness of the packing was reduced (A85⇒A65), so that it can accommodate the change in shape when the rod is extended.

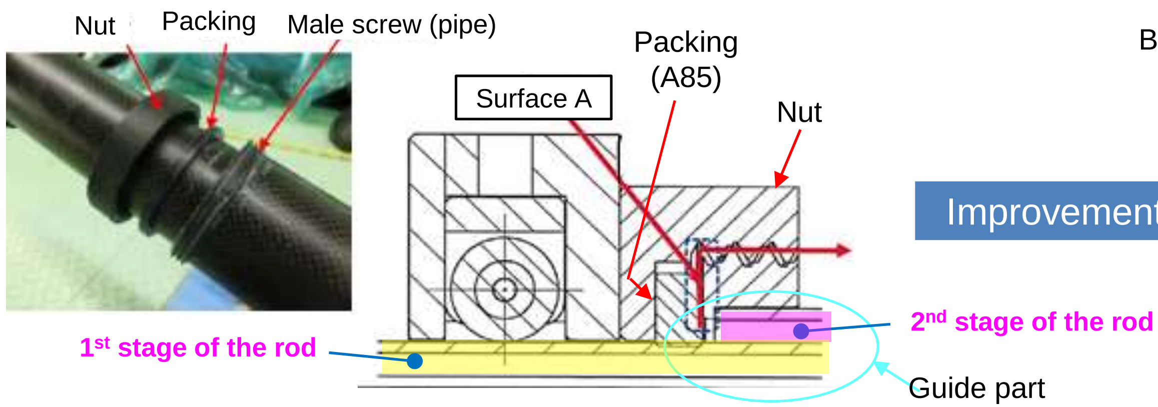


Figure 21: Seal part developed in the previous project

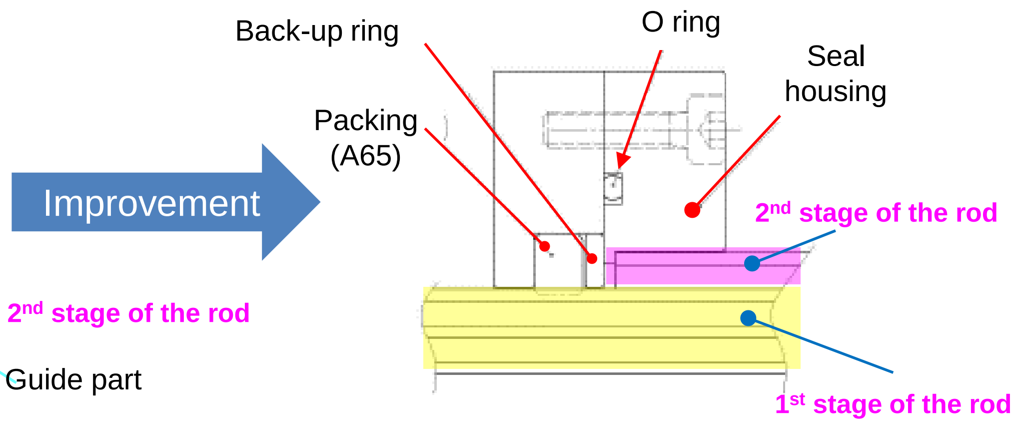


Figure 22: Improvements in the seal part packing

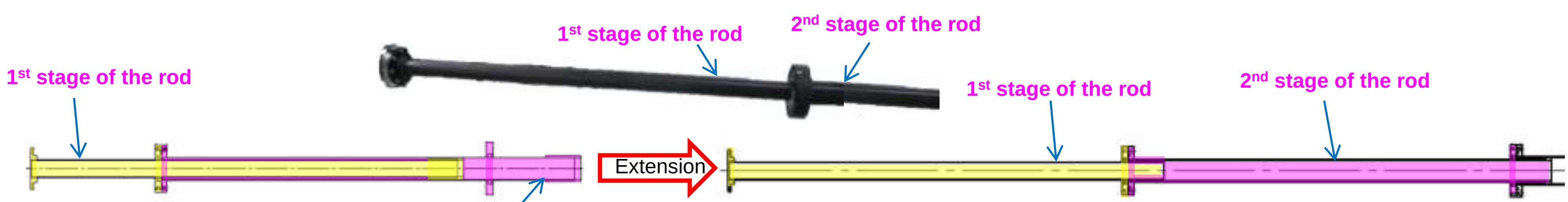


Figure 23: Extending of the rod

6.2.2 Status of improvement in the extension rod

The test results for confirming deflection after improvements is indicated below.

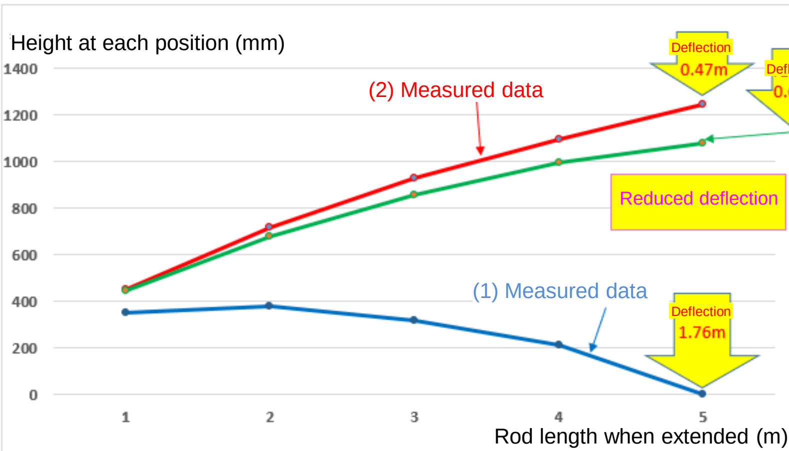
Table 13: Results of the extension rod extension confirmation (deflection confirmation)

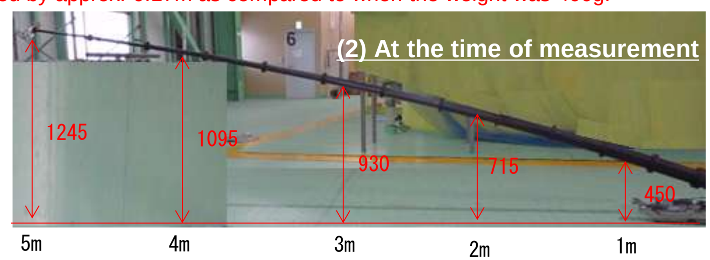
Test item	Test details	Test results	
Extension rod extension confirmation test	③ Deflection confirmation ・Rod angle: approx. 20° ・Weight at the tip: 400g(*1) or 900g(*2)	**Good**	Before improvement: Deflection 1.76m ⇒ After improvement: Deflection 0.47m ⇒ The deflection could be reduced.

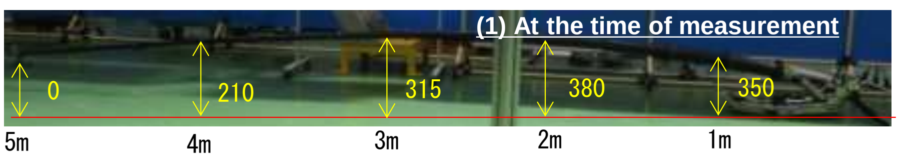
Test status

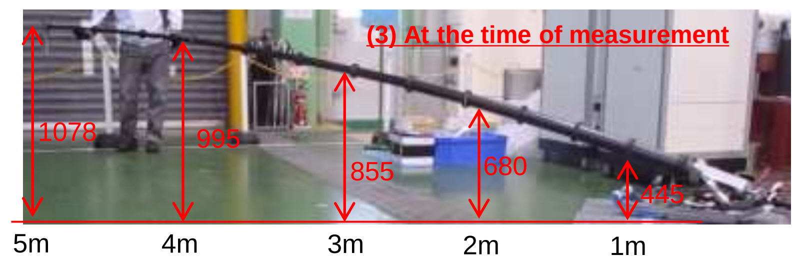
Measured on	Rod angle	Weight at the tip	1m	2m	3m	4m	5m
(1)2021/3/18	20. 6°	400g	350	380	315	210	0
(2)2021/7/8	20°	400g	450	715	930	1095	1245
(3)2021/10/14	20°	900g	445	680	855	995	1078

(1): Deflection to the extent that the tip touches the floor
(2): Secured a height of approx. 1.25m to reduce bending ⇒ ***Reduced deflection***
(3): Secured a height of approx. 1.08m ⇒ The weight at the tip was 900g and hence the deflection increased by approx. 0.17m as compared to when the weight was 400g.









(*1) The weight of the instruments (camera + radiation sensor or camera + point cloud data sensor) planned to be mounted at the rod tip is assumed for the 400g weight at the tip.
(*2) The weight of the instruments (camera + radiation sensor + point cloud data sensor) planned to be mounted at the rod tip is assumed for the 900g weight at the tip.

6.2.2 Status of improvement in the extension rod

② [Measures to reduce the time required for extension] The structure of the rear end of the investigation equipment was reviewed and the air inlet of the extension rod was enlarged.

⇒ Increase in flow rate of air supplied into the rod

- Inner diameter of air tube：Φ6.5 ⇒ Φ7.5
- Air tube joint: Φ2.5 ⇒ Φ7.5

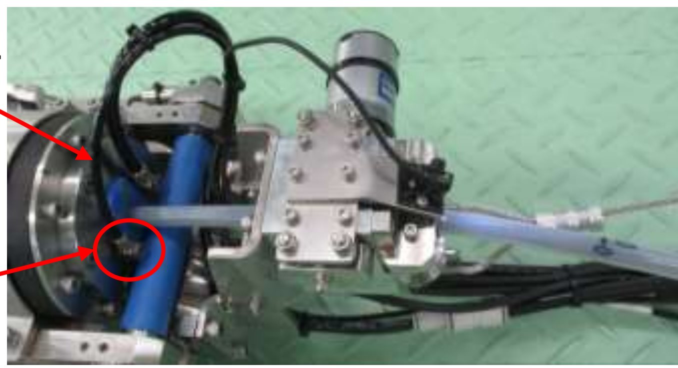


Figure 24: Air inlet developed in previous project

Improvement

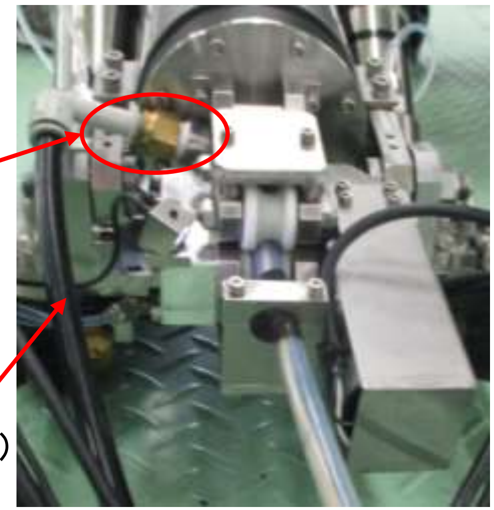


Figure 25: Improvements in the air inlet

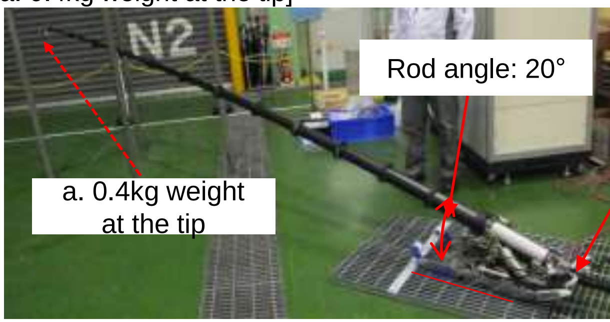
6.2.2 Status of improvement in the extension rod

The results of the test for verifying extension movement after improvements is indicated below.

Table 14: Verification of the extension rod movement in each instance of weight at the tip (in combination with the cable drum)

Test Item	Test details	Test results	
Extension rod extension verification test	Verification of time required for the extension movement ・Rod angle: 20° ・Weight at the tip: 0.4kg/ 0.9kg/ 1.5kg	Good	Extension (retraction) time: approx. 1 minute 20 seconds a. When weight at the tip is 0.4kg: The posterior end of the crawler does not get lifted b. When weight at the tip is 0.9kg: The posterior end of the crawler does not get lifted (the rod gets deflected) c. When weight at the tip is 1.5kg: The posterior end of the crawler gets lifted and it could get overturned. **⇒ Maximum weight on the tip to be up to 0.9kg.**

[a. 0.4kg weight at the tip]



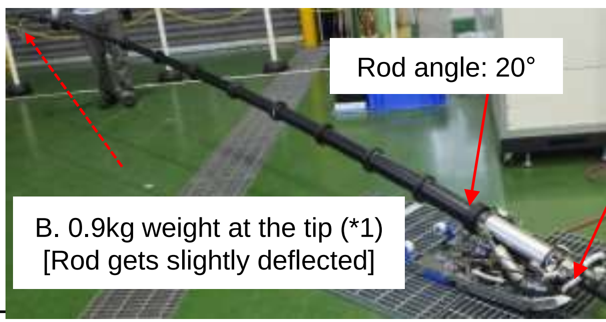
Posterior end of the crawler does not get lifted

[c. 1.5kg weight at the tip]

The tip touches the ground

Posterior end of the crawler gets lifted (Risk possibility of being overturned)

[b. 0.9kg weight at the tip]



Posterior end of the crawler does not get lifted

(*1)
The weight of the instruments (camera + radiation sensor + point cloud data sensor) planned to be mounted at the rod tip is assumed for the 0.9kg weight at the tip.

Cable drum

Composite cable

Investigation equipment

IRID

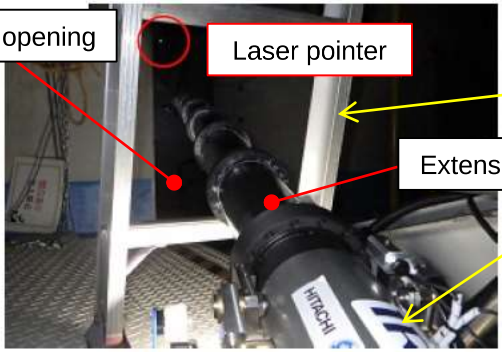
6.2.2 Status of improvement in the extension rod

The results of verifying the range of visibility at the time of extension are indicated below.

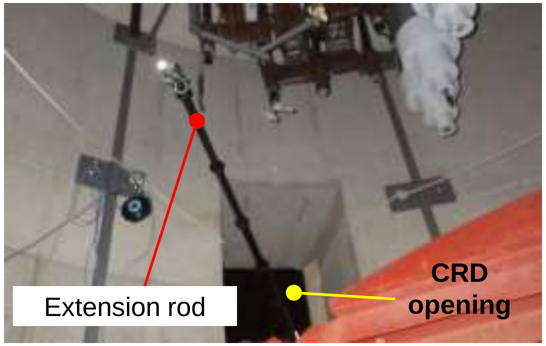
Table 15: Results of the extension rod extension verification (range of visibility)

Test item	Test details	Test results	
Extension rod extension verification test	Insertion verification and verification of range of visibility	**Good**	・Structures that were 5m ahead were visible in a dark environment. ・The rod could be extended inside the pedestal while checking the position of the laser point on the camera image. In this case, it was confirmed that the rod can be extended through the ladder, which was an on-site interfering object.

Test status

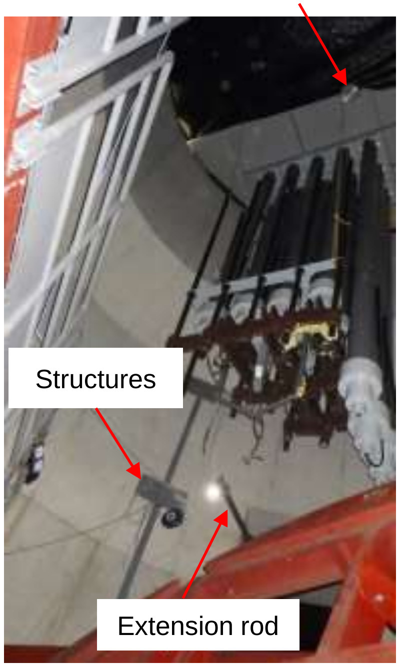


(a) Status of the test (outside the pedestal)

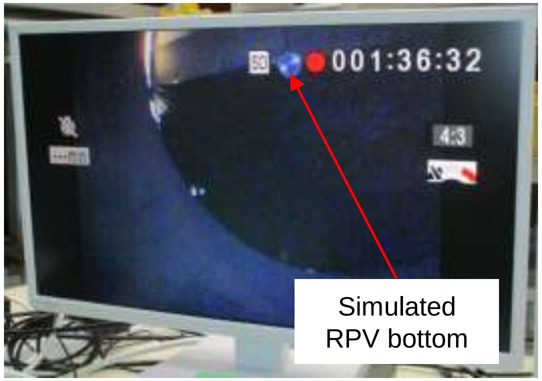


(b) Status of the test (inside the pedestal)

(c) Status of the test (cable drum)



(d) Status of the test (from the bottom inside the pedestal)



(e) Visual data obtained from the mounted camera (above position (d))

(f) Visual data obtained from the mounted camera (in front of position (d))

6.2.3 Status of the study of composite cables

(1) Composite cable for the investigation equipment

An overall outline of the composite cable for the investigation equipment is given below. The investigation equipment power cable and the cable for the extension rod (including the cable for the investigation instruments inside the rod) were combined to form a composite cable.

A cable drum for the composite cable and for the extension rod are installed in the seal box to facilitate the in and out movement of the cables.

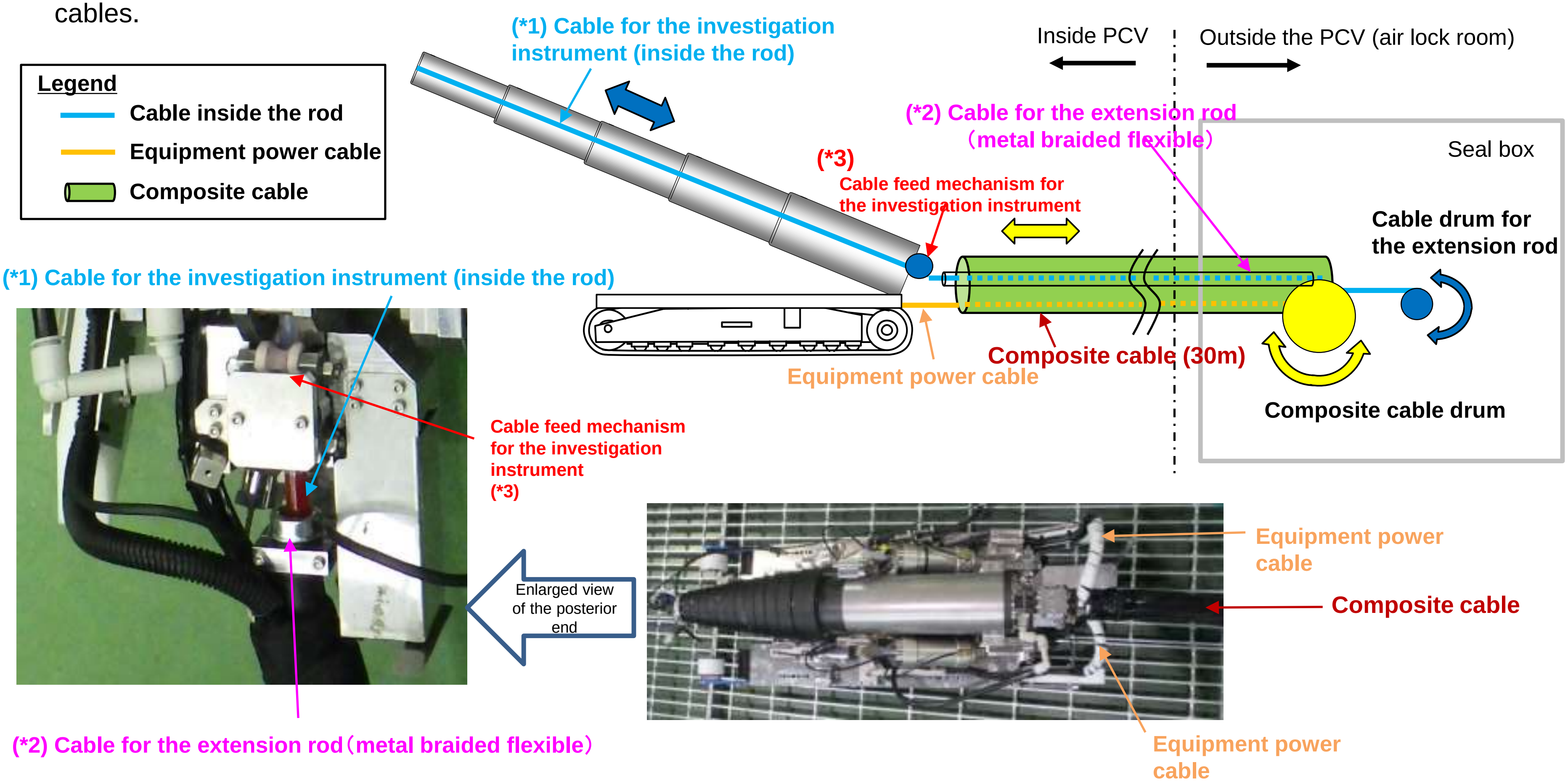


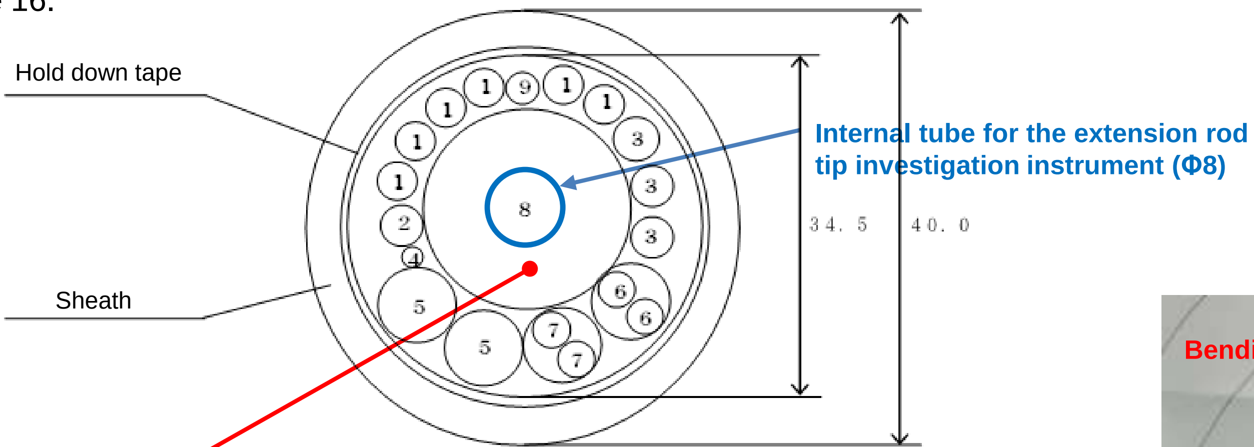
Figure 26: An overview of the investigation equipment composite cable

6.2.3 Status of the study of composite cables

(2) Configuration of the composite cable for the investigation equipment

An overall outline of the composite cable for the investigation equipment is given below. The composite cable is made by placing the cable for the extension rod（metal braided flexible) at the center with the other cables placed around it, taping it together and then covering it with a sheath.

Further, the status of the test in which the investigation equipment and cable drum are combined with the composite cable is indicated in Table 16.



Cable	1	SS300R AWG22×2C	Φ 4.4
	2	SS300R AWG22×3C	Φ 4.6
	3	Φ13 camera cable	Φ 5.0
	4	Φ8 camera cable	Φ 2.3
	5	Air tub TS0806	Φ 8.0
	6	Air tube Φ .4.4	Φ 4.0
	7	Air tube TS0425	Φ 4.0
	8	Flexible metal hose KIH16	Φ 21.1
	9	Stainless steel	Φ 3.0

Figure 27: Configuration of the composite cable

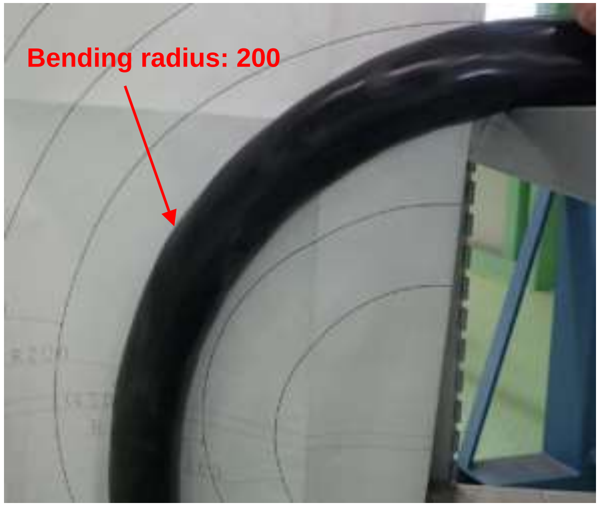


Figure 28: Creating of the composite cable

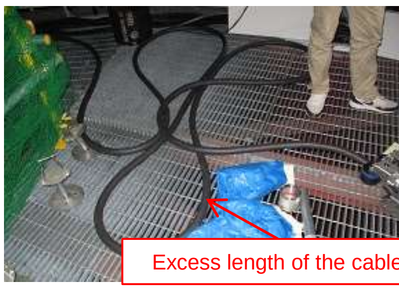
6.2.3 Status of the study of composite cables

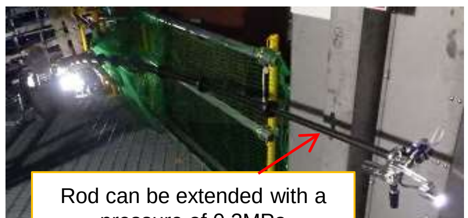
(3) Investigation equipment, composite cable and cable drum combination test

Table 16: Investigation equipment, composite cable and cable drum combination test results

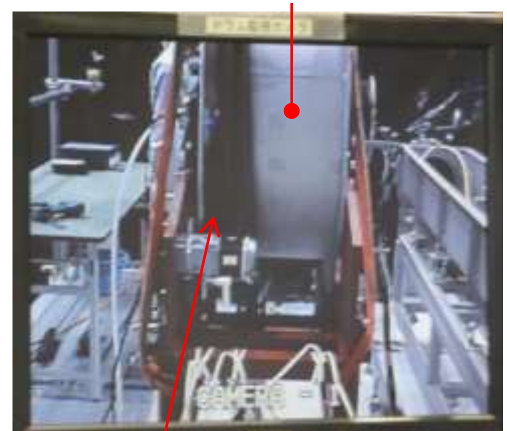
Test item	Test details	Test results	
Extension rod extension verification test	Test for verifying the rod extension when the investigation equipment, composite cable and cable drum are present in combination (Weight at the tip: 0.4kg)	**Finding issues**	① 1 drum winding: The extension rod **can be extended and retracted** ② 2 drum windings: The extension rod **cannot be extended and retracted (operational failure)** (Issue) If there are more than one cable drum winding, it would cause operational failure of the extension rod. Hence, in order to reduce the number of drum windings (excess cable length) as much as possible, the length of the composite cable was reviewed (30 → 25m)

① Status of rod extension in the case of 1 cable drum winding: **Can be extended and retracted**



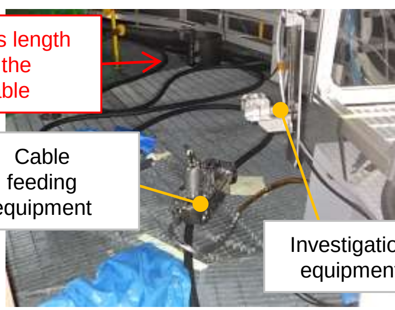


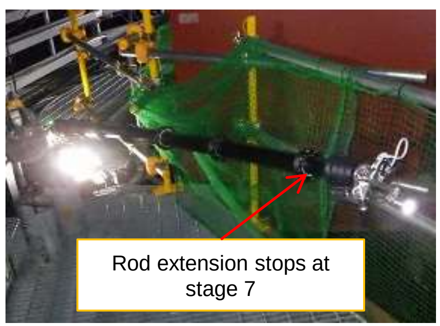
Cable drum (1 winding: 2.5m)



Number of windings of the remaining composite cable on the cable drum

② Rod extension in the case of 2 cable drum windings: **Cannot be extended and retracted (operational failure)**





6.2.4 Status of study of point cloud data sensor

(1) Measurement range of point cloud data sensor

During the investigation inside the pedestal, measurement (radius 5m or more) is performed using the measuring instrument (point cloud data sensor) mounted at the tip of the extension rod of the investigation equipment as shown in the figure below.

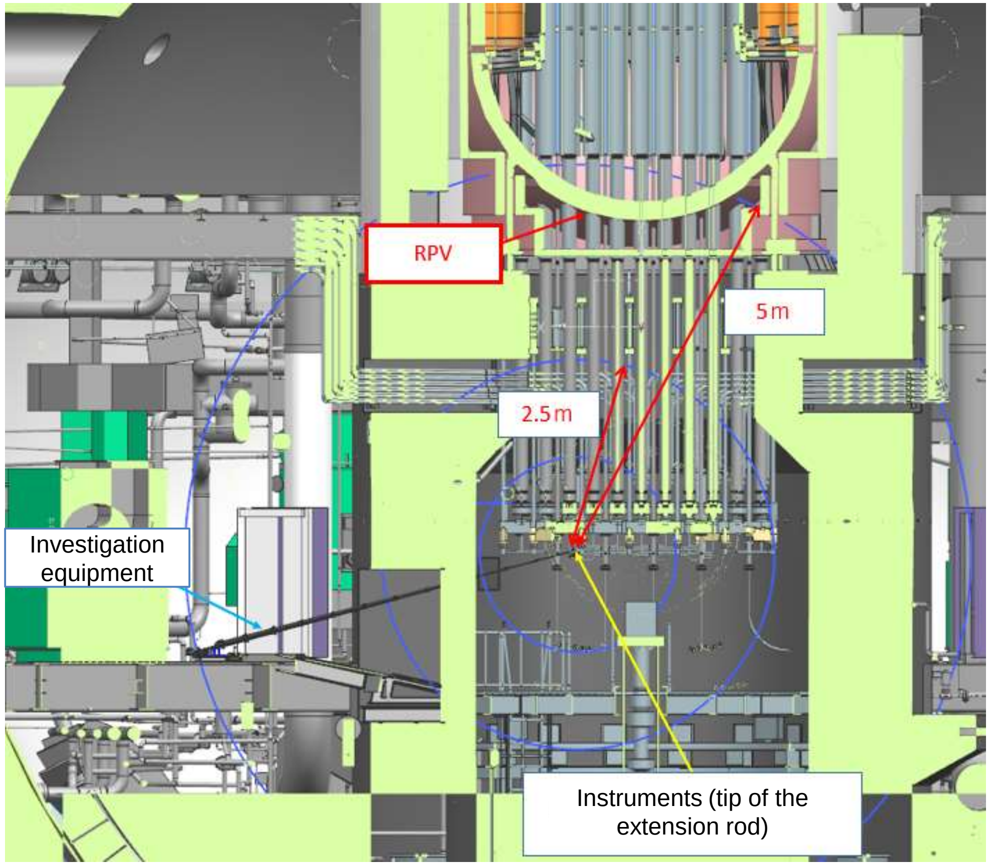


Figure 29: Range of measurement during the investigation inside the pedestal

6.2.4 Status of study of point cloud data sensor

(2) Assumed cumulative dose during the investigation inside the pedestal

Based on the duration of work of the investigation equipment inside the PCV and the dose rate (including assumptions) inside the PCV, the cumulative dose of the γ rays received by the investigation equipment was assumed to be 140 to 240Gy.

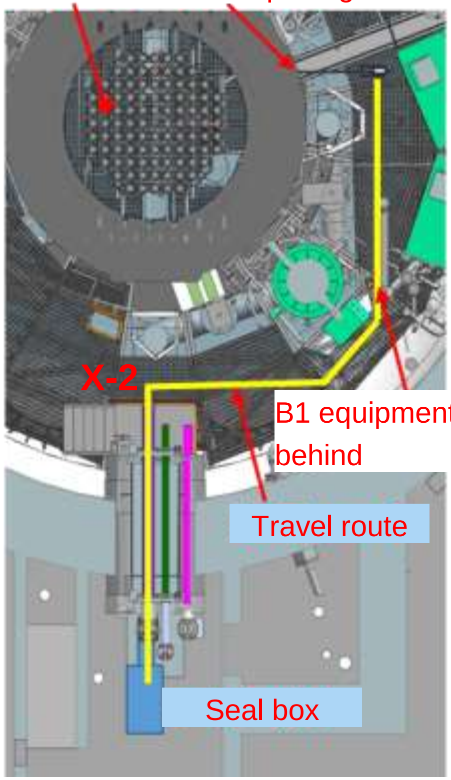


Figure 30: Investigation route inside the pedestal (assumed)

Table 17: Duration of investigation inside the pedestal and dose rate (assumed)

No.	Item	Time required for work (hr)	Dose rate (Gy/h)	Accumulated dose (Gy)
1	Installation	1	1	1
2	X-2 penetration to B1 investigation equipment left behind	0.5	8 (*1)	4
3	Investigation of the area in the vicinity of B1 investigation equipment left behind	0.5	8 (*1)	4
4	B1 investigation equipment left behind to the CRD opening	1	8 (*1)	8
5	Investigation inside the pedestal	1 to 2	100 (*2)	100 to 200
6	Return route	3	8 (*1)	24

***1: Measurements from the B1 investigation (measured in April, 2015)**
***2: Estimated value**

Estimated dose rate: 140 to 240Gy

6.2.4 Status of study of point cloud data sensor

(3) Ease of mounting the point cloud data sensor

① Mounting on the equipment tip (Refer to Figure 31)

The equipment needs to be as small as possible considering the risk of interference while installing and retrieving, since there are space constraints at the access location.

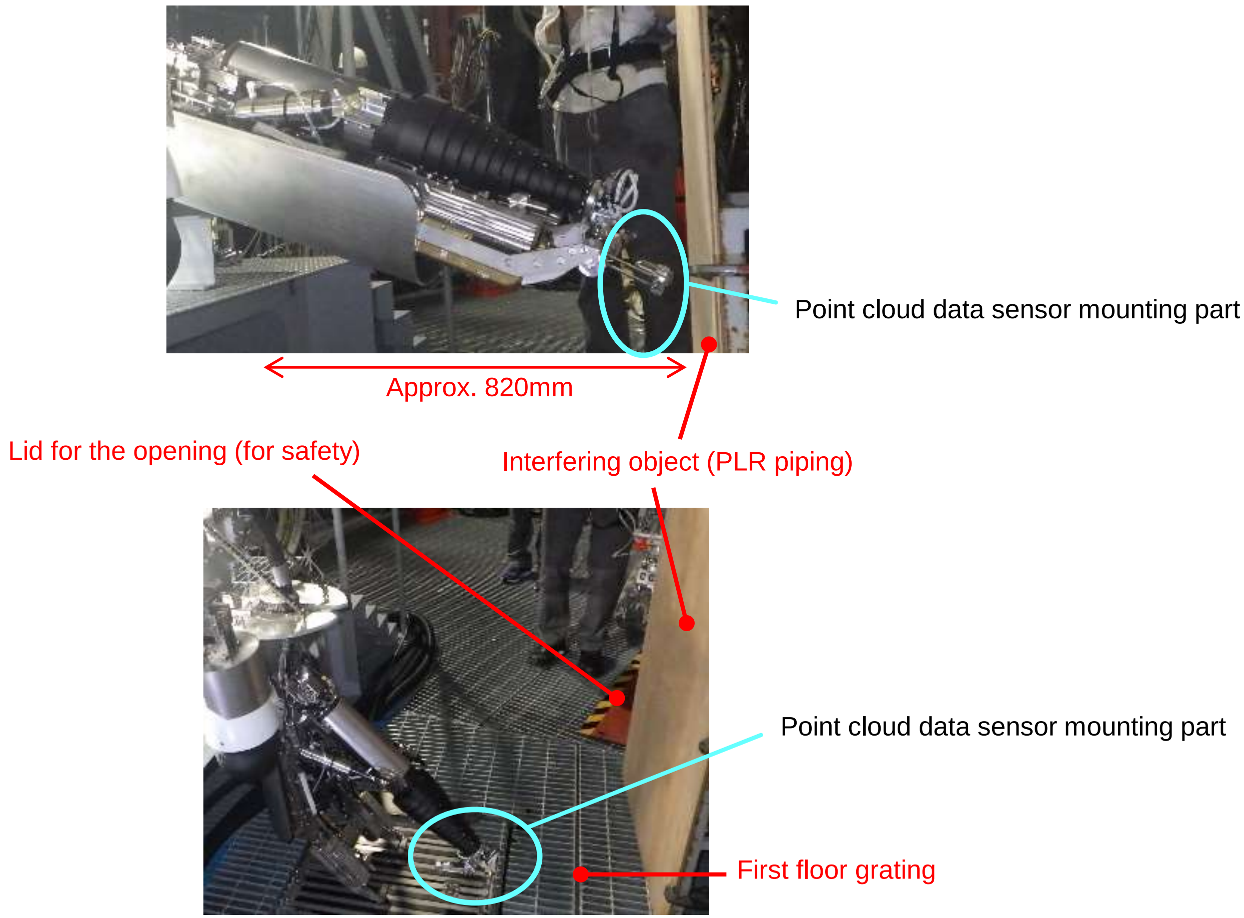


Figure 31: Status while installing the investigation equipment

6.2.4 Status of study of point cloud data sensor

② Layout inside the cable (Refer to Figure 32 and 33)

Since th camera cable, etc. are inserted simultaneously into the internal cable (Φ8) for the investigation instrument on the tip of the extension rod, the point cloud data sensor cable needs to be Φ5 or smaller. Hence the connection (*) is done using a LAN cable (Φ3.7).

Note that, a USB2.0 can be converted to a LAN cable using a LAN converter and then connected.

(*) As the LAN cable connector cannot be smaller than Φ5, it is necessary to cut off the connector from the cable ⇒ insert the cable into the internal cable ⇒ and then reconnect the connector.

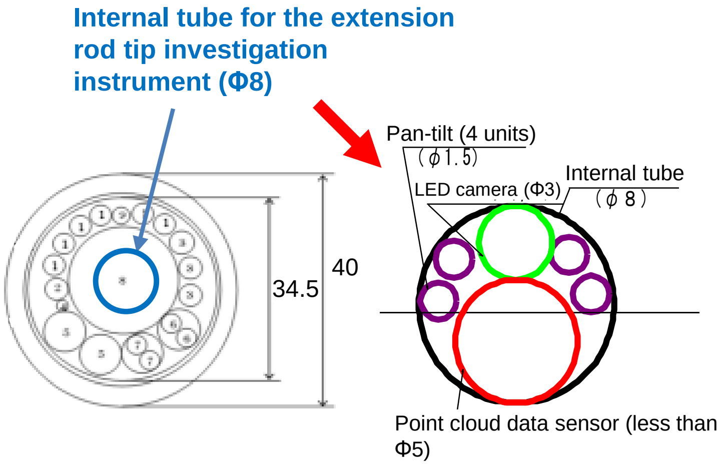


Figure 32: Cross-section of the investigation equipment composite cable

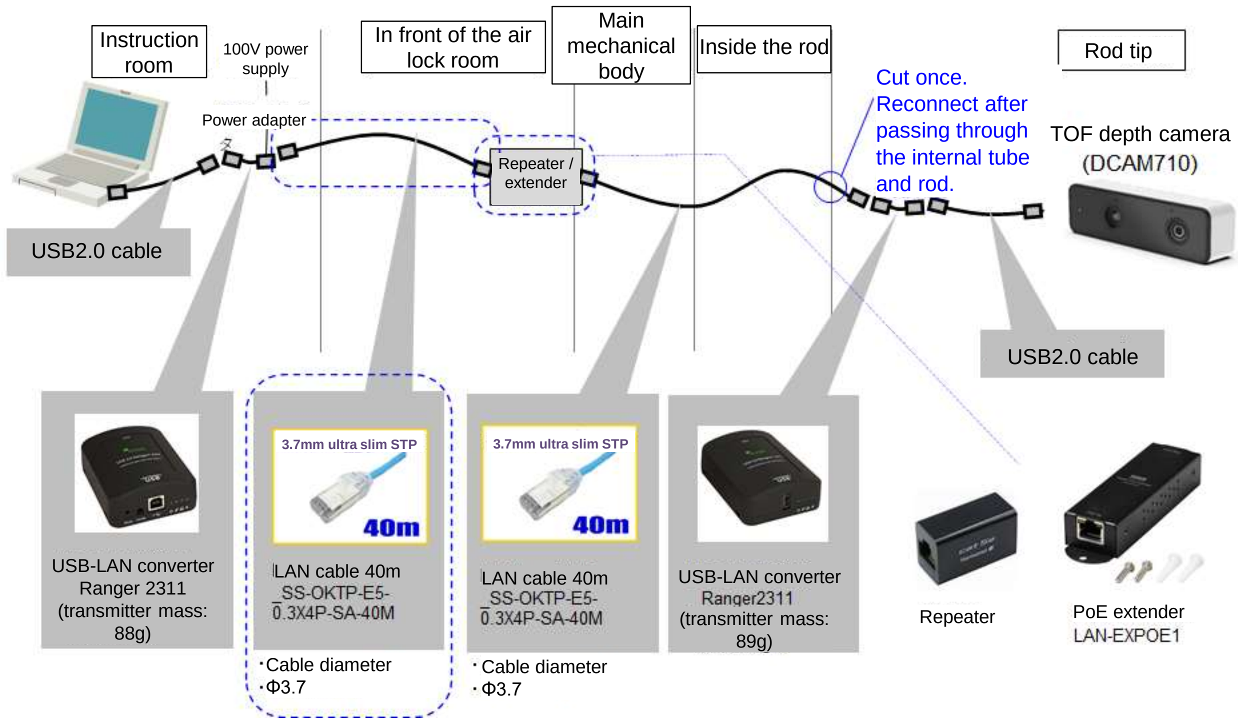


Figure 33: Example of mounting on the investigation equipment

6.2.4 Status of study of point cloud data sensor

(4) Selection of point cloud data sensor

The depth camera listed as No. 9 and the stereo camera listed as No. 10 from among the sensors indicated below, are the primary choices from the perspective of mounting capability (mounting at the tip of the equipment and inserting into the cable) on the equipment. In the future, radiation resistance, etc. will be confirmed, and the plan for mounting on the investigation equipment will be designed.

Table 18: Point cloud data sensor selection results

No.	Classification	Product name/Model	Manufacturer	Weight (Less than 400g)	Dimensions (Around 100mm)	Measurement distance (5m or more)	Radiation resistance (140 to 240Gy)	Cable	Evaluation result
1	LRF	UTM-30LX-EW (2-dimensional)	HOKUYO	300g (○)	62×62×88 (○)	60m (○)	(130) (×)	100Mbps Ethernet (○)	× (Weak anti-fogging performance)
	LRF + pan unit (3-dimensional)			1kg (×)	120×62×88 (○)				
2	Stereo camera	ZED 2 Stereo Camera	ASK Corporation	124g (○)	175×30×33 (○)	0.2 to 20m (○)	215 (○)	USB3.0 (×)	
3	Stereo camera	ISC-100XC (Color) ISC-100VM (Monochrome)	Minato Advanced Technologies, Inc.	450g (○)	169×53×52 (○)	1 to 12m (○)2 to 25m (○)	-	USB3.0 (×) USB2.0 (○)	
4	Depth camera	SCS-Color or SCS-Mono	ARGO Corporation	53g (○)	109×18×24 (○)	0.3 to 10m (○)	-	USB3.0 (×)	USB3.0 × (Cable/connector cannot be reconnected) USB2.0 ○
5	Depth camera	REALSENSE D435	Intel	75g (○)	99×25×25 (○)	0.2 to 10m (○)	290 (○)	USB3.0 (×)	
6	Omnidirectional camera	Omni-60	ARGO Corporation	377g (○)	Φ106×54 (○)	-	-	USB3.0 (×)	
7	Millimeter wave radar	T18PE_01030103_2D	Marubun Corporation	62g (○)	55×15×90 (○)	10m or more (○)	130 (×)	USB3.0 (×)	
8	Millimeter wave radar	T18PE_01030103_3D	Marubun Corporation	62g (○)	55×15×90 (○)	10m or more (○)	130 (×)	USB3.0 (×)	
9	TOF depth camera	DCAM710	Vzense Technology	73g (○)	103×33×22 (○)	0.2 to 8m (○)	200 or more (○) (tests completed 3/30)	USB2.0 (○) (LAN conversion)	○ (light)
10	Stereo camera (+RGB camera)	OAK-D OpenCV DepthAI camera (PoE)	Luxonis	361g (○)	130×101×31(△)	0.2 to 38.4m (○)	200 or more (○) (tests completed 3/30)	1Gbps Ethernet (○)	○

Primary choice (Nos. 9 and 10)

Mounting capability of equipment

6.2.4 Status of study of point cloud data sensor

(5) Measurement principle of the point cloud data sensor

The measurement principle of the TOF (Time Of Flight) depth camera and the stereo camera from among the point cloud data sensor selection results (Table 18) is indicated below.

① Measurement principle of the TOF depth camera

The TOF depth camera obtains the distance by means of a technology that uses infrared light to measure the distance. When infrared light hits the object to be photographed, the time required for the reflected light to return is used to obtain the distance with the formula "Distance = Speed of light x Time".

Figure 34: Measurement principle of the TOF depth camera

② Measurement principle of the stereo camera

The stereo camera is able to obtain the distance up to the target object. It calculates the distance using the principle of triangulation, based on the pixel information of the target object obtained from 2 cameras.

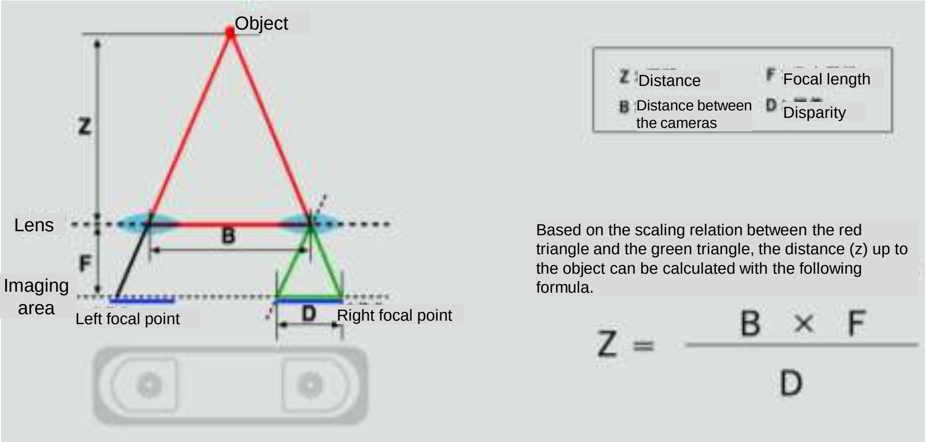


Figure 35: Measurement principle of the stereo camera

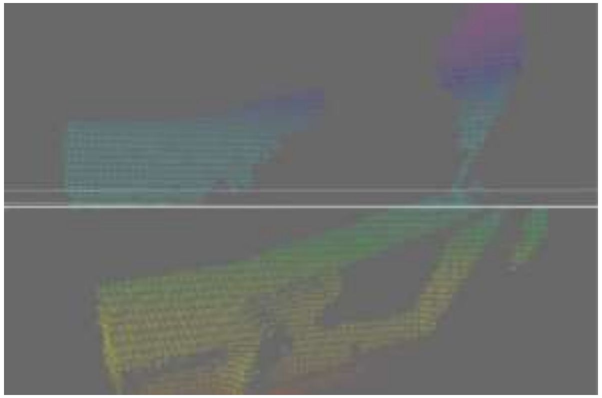
6.2.4 Status of study of point cloud data sensor

(6) Point cloud data measurement using the TOF depth camera (Example)

Sample data from the point cloud data on structures inside the pedestal measured using the TOF depth camera is given below. In the future, multiple point cloud data inside the pedestal will be measured and study of generating point cloud data on the entire area inside the pedestal will be conducted by connecting the point cloud data.

Image obtained from the camera

*** Reference image captured in the same direction as the point cloud data on the right.**



Point cloud data

Figure 36: Point cloud data using the TOF depth camera (Sample)

6.2.4 Status of study of point cloud data sensor

(7) Point cloud data measurement using the stereo camera (Example)

Sample data from the point cloud data on the CRD opening measured from inside the pedestal using the stereo camera is given below.

Image depicting the point cloud data "from the upper left" obtained by manipulating the point cloud data

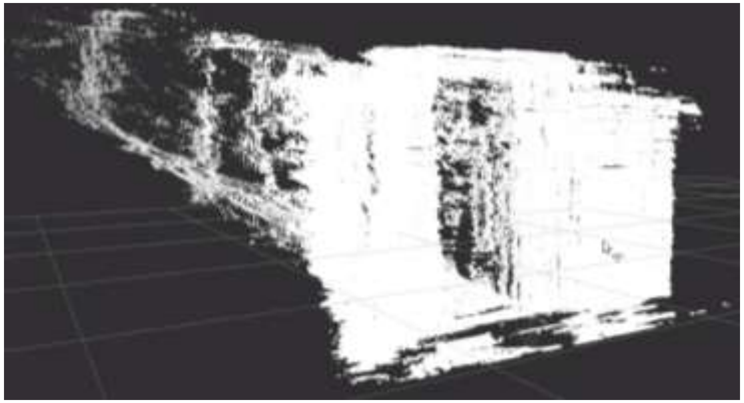


Figure 37: Point cloud data using the stereo camera (Sample)

6.2.5 Status of study of radiation sensor

(1) Radiation sensor

The applicability of the Self-Powered Gamma Ray Detector (SPGD), which is a prime probable option for the radiation detector to be used for the investigation inside the pedestal, was verified.
Further, as shown in the figure below, SPGD is a passive detector that can measure even if the power supply to the detector is interrupted.

<Basic structure of the Self-Powered Gamma Ray Detector (SPGD)>

① Composed of an emitter, insulating material, and collector
② Voltage impression and amplification is not needed.

<Measurement principle>

① γ rays collide with the electrons in the emitter
② In order supplement the deficient electrons, electrons flow from the ground into the emitter.
③ The electric current generated as a result of the movement of electrons is measured.

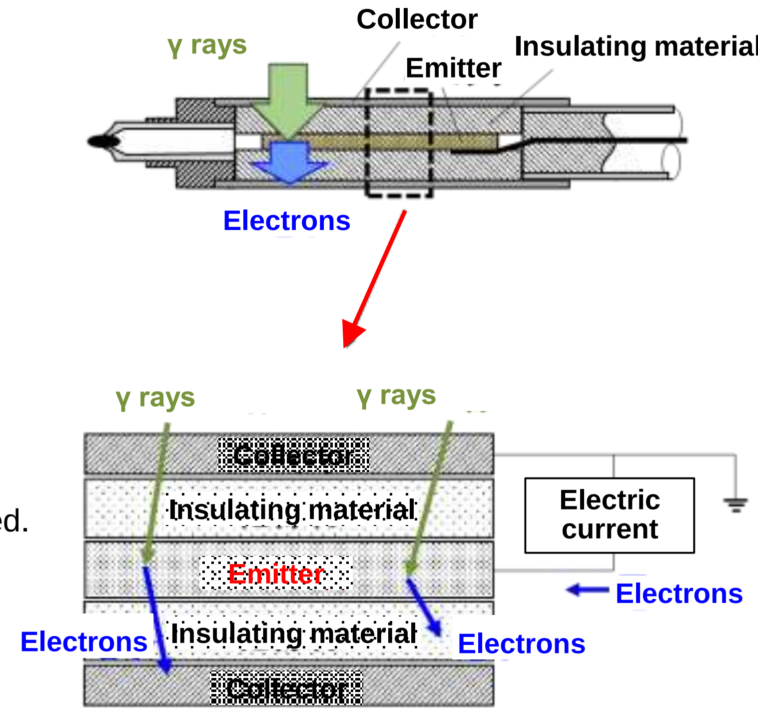


Figure 38: Structure of SPGD and its measurement principle

6.2.5 Status of study of radiation sensor

Transmission distance: There is minor attenuation depending on transmission distance. It is constant with a margin of error even with 300m transmission.

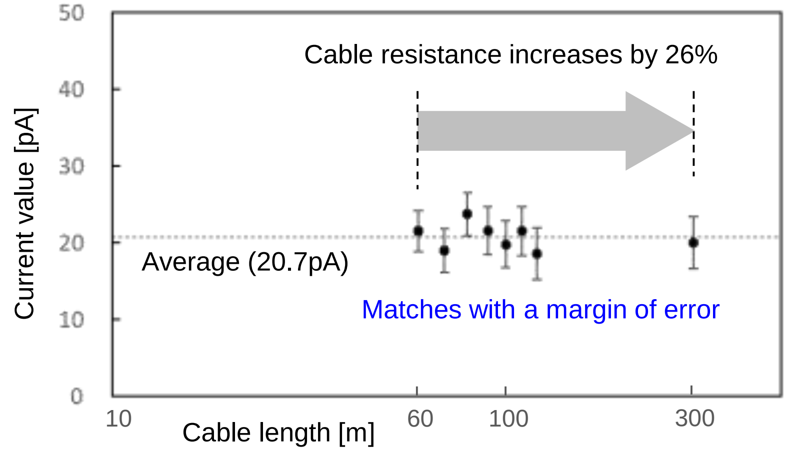


Figure 39: Transmission distance of the SPGD

Noise resistance: Induced noise is likely to result in an error of 5% or less while measuring 100Gy/h. (High-sensitivity type)

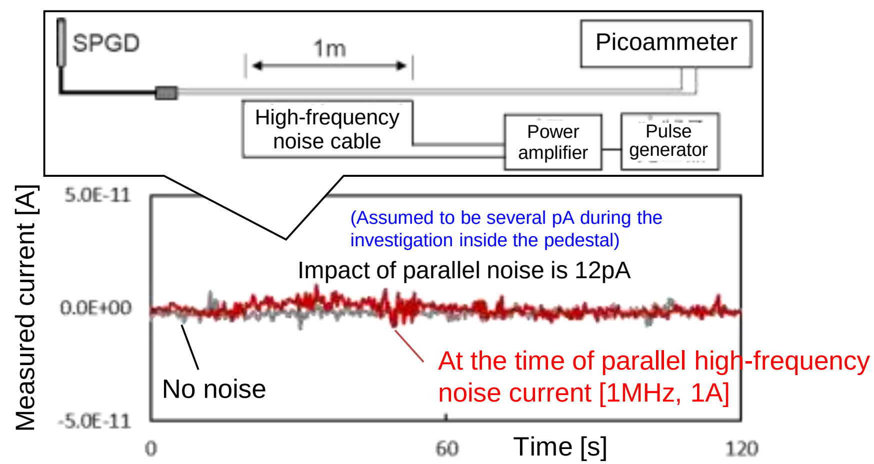


Figure 40: Noise resistance of the SPGD

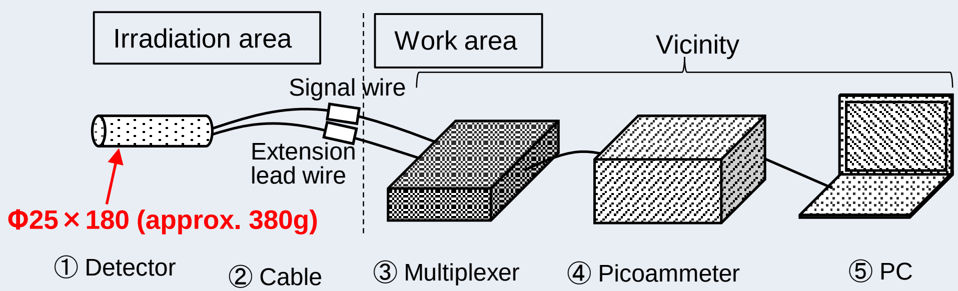
6.2.5 Status of study of radiation sensor

(2) The results of elemental tests of the radiation sensor are given below.

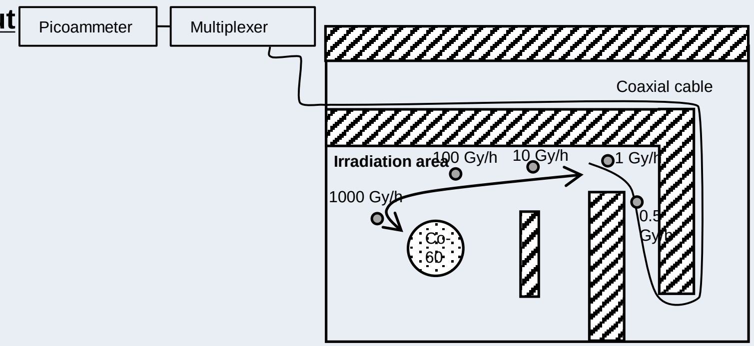
Table 19: Results of performance tests of the radiation sensor

Test overview and results

Configuration of apparatus



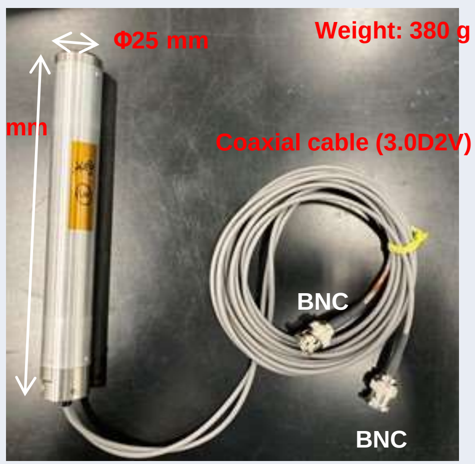
Test layout



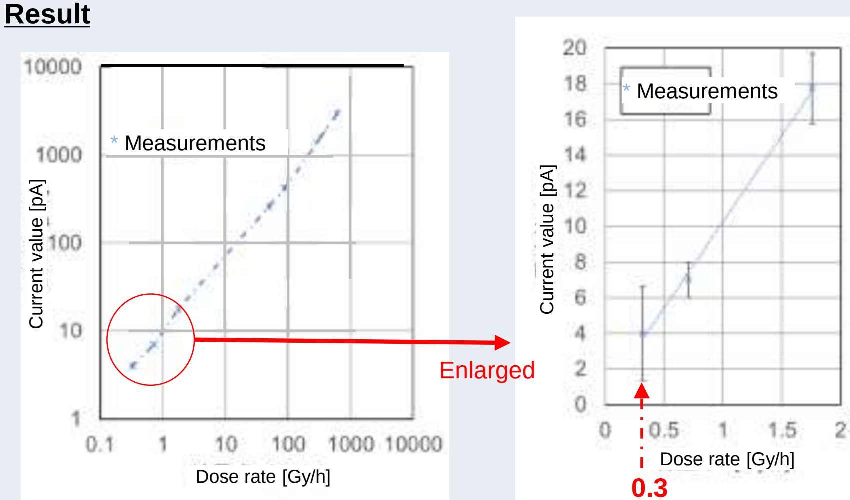
Detector conditions

Items	Specifications
Material of the outer collector	Aluminum
Outer diameter of the material of the outer collector [mm]	25
Outer thickness of the material of the outer collector [mm]	1.0
Insulating material (polyimide) thickness [mm]	0.2
Thickness of inner collector (Al) [mm]	0.05
Thickness of emitter (Pb) [mm]	0.3
Diameter of the shaft emitter (steel) [mm]	5
Total length of SPGD [mm]	180
Length of sensing part [mm]	100

External appearance of the detector



Result



・Expected to be able to measure 0.3Gy/h as the minimum measurement accuracy

* Since the dose rate inside the PCV is assumed to be 1Gy/h or more, it is believed that there will not be any issues with the numerical values mentioned above.

6.2.5 Status of study of radiation sensor

(3) The results of selecting the cable for the radiation sensor are given below.

In order to mount the sensor on the equipment for investigating inside the pedestal, the radiation sensor cable needs to be inserted into the inner tube (Figure 42: inner diameter Φ8) for the investigation instrument that is present inside the composite cable (Figure 41), and for that the cable needs to be thinned further (Φ2.5 or smaller: currently Φ3).

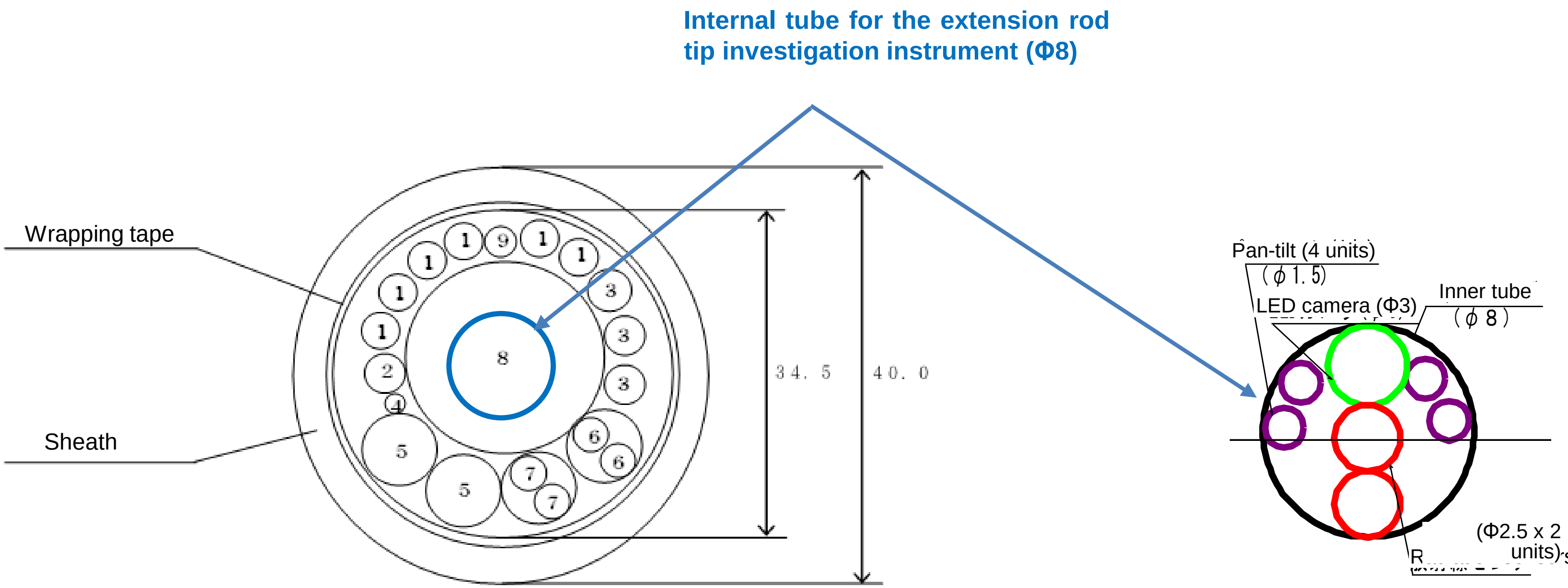


Figure 41: Cross-section drawing of the investigation equipment composite cable

Figure 42: Cross-section drawing of the inner tube

6.2.5 Status of study of radiation sensor

Hence, in order to select a thinner cable with the same performance as the current cable (Φ3: 1.5D2V), a cable thinning verification test (Table 20) was conducted and the sensitivity (current value at the time of irradiation), impact of cable vibrations, and impact of induced noise were evaluated

As a result, the Φ2.5 cable (RG316/U) was selected. (Fig. 43)

Table 20: Results of the radiation cable thinning verification test

Item	Summary
(1)Sensitivity	Little variation in the 1/12 second sampling (measurement) in the case of RG-316U, and little variation in the 1 second sampling (estimation) in the case of RG-178B/U
(2)Vibrations	Little impact in the case of RG-316/U
(3) Induced noise	No significant impact was seen in both cases

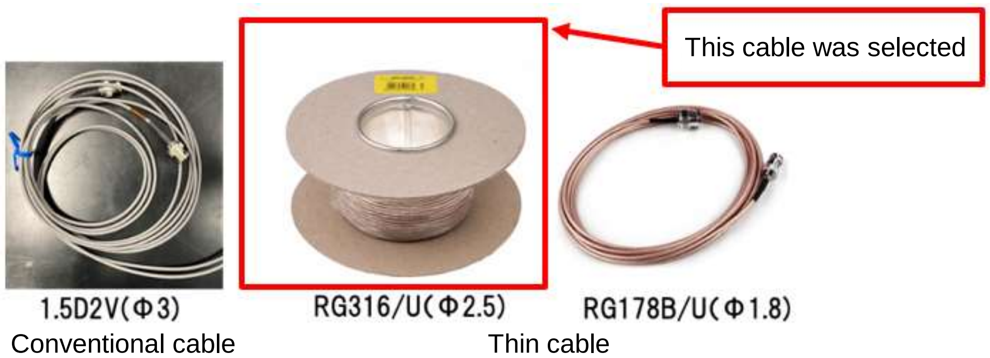


Figure 43: Probable options for the radiation sensor cable

6.2.5 Status of study of radiation sensor

(4) Radiation sensor manufacturing, evaluation test

Table 21: Specifications of radiation sensor

Items	Before the change	After the change
Material of the outer collector	Aluminum	Aluminum
Outer diameter of the material of the outer collector [mm]	25	25
Outer thickness of the material of the outer collector [mm]	1.0	1.0
Insulating material (polyimide) thickness [mm]	0.2	0.2
Thickness of inner collector (Al) [mm]	0.05	0.05
Thickness of emitter (Pb) [mm]	0.3	0.3
Diameter of the shaft emitter (steel) [mm]	5	5
Total length of SPGD [mm]	180	100
Length of sensing part [mm]	100	50

The length was reduced so that it can be mounted on the equipment
(The length of the sensing part reduced as the overall length reduced)

[Required specifications of radiation sensor]

・Measurement range: 1 to 100Gy/h
Estimated dose rate Outside the pedestal (8Gy/h(*), inside the pedestal (100Gy/h)
***1: Measurements from the B1 investigation (measured in April, 2015)**

・ Dimensions / mass: Total length 100mm or less / Mass 0.5kg or less
(Can be mounted on the extension rod of the investigation equipment)

[Manufacturing of the radiation sensor]

・The lower measurement limit of 0.6Gy/h was verified. (The upper limit of 100Gy/h or more has been confirmed)

・ In order to achieve dimensions that enable mounting on the extension rod of the investigation equipment, a radiation sensor with reduced total length and reduced weight (100mm / mass 0.3 kg) was designed and manufactured.

[Evaluation test overview]

・ The sensor is mounted on the investigation equipment, assembly such as inserting the cable inside the composite cable, etc. is performed, and verification is carried out.

・Also, measures against impact of noise on the radiation sensor are verified through tests.

6.2.5 Status of study of radiation sensor

(5) The risks pertaining to the development of the radiation sensor, and countermeasures are given below.

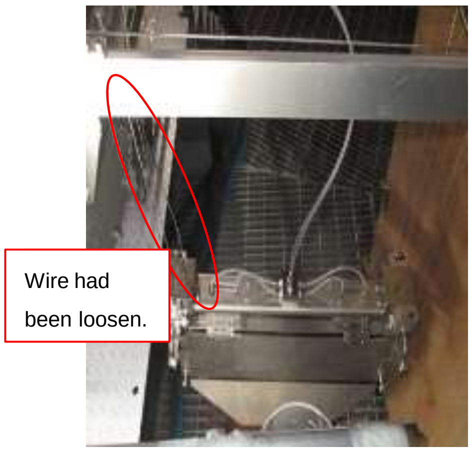
Table 22: Radiation sensor development risks and countermeasures (planned)

No.	Risk	Countermeasures and verification method
1	Decrease in current value due to long distance transmission	Verification method: Transmission distance impact test (measurement of current value for each transmission distance)
2	Drift in current value due to induced noise from the cable that is adjacent at the time of composite cable	Countermeasure: Reducing error by extending the time constant (* if there is an impact) Verification method: Induced noise test (current value/frequency of the adjacent cable is changed and measured)
3	Generation of noise along with vibrations	Countermeasure: Measuring when it is stationary Verification method: Combination test with the investigation equipment (noise level is evaluated under stationary condition assuming measurement is performed)
4	Generation of noise due to switching of signal wire and extension lead wire	Countermeasure (system): Developing a differential measurement system that measures 2ch simultaneously so that switching of ch is not required Verification method: System verification test (It is verified that application of the system does not lead to change in the current value)
5	Generation of surge noise from a momentary event	Countermeasure (operation): Excluding extreme fluctuations in current value from the evaluation
6	Common-mode noise	Countermeasure: Application of a transformer and soft magnetic material Verification method: Combination test with the investigation equipment (noise level is evaluated under conditions assuming measurement is performed)
7	Drift in current value depending on the site environment	Countermeasure (operation): Measuring back-ground (BG) before moving into the irradiation area on the site, and considering it as the reference current value when there is no irradiation
8	Wait time until current value stabilizes	Countermeasure: Estimating the stable current value based on the attenuation curve, or considering the maximum fluctuation to be an error (*If the wait time is long) Verification method: Demonstration testing of the estimation method (possibility of being able to estimate based on the attenuation curve is verified)
9	Cable disconnection	A method that can determine cable disconnection is developed and verified

6.2.6 Status of improvement in the hole cover installation equipment

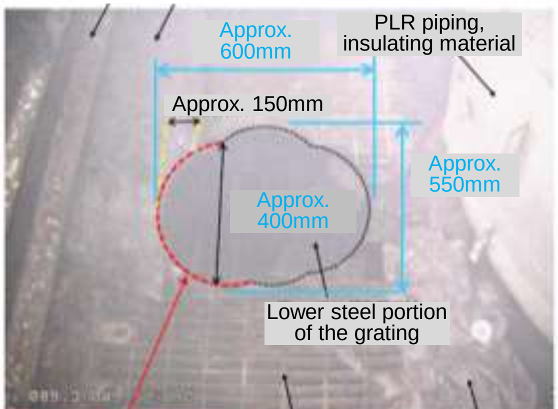
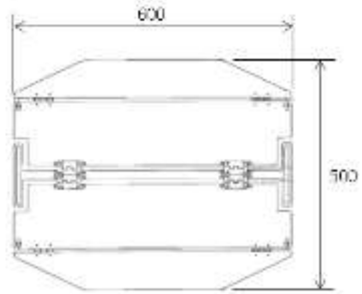
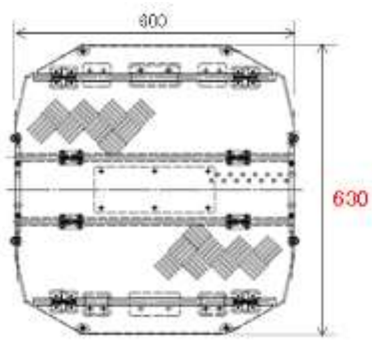
The following improvements in the hole cover installation equipment were made in response to the issues persisting after previous project and for further functional enhancement. The test results were verified that there is no problem in the applicability of the hole cover and the travel efficiency of the investigation equipment.

Table 23: Improvements in the hole cover installation equipment (1)

No.	Items	Status during previous project	Improvement details	Result of verification
1	Revised wire part	The wire had come off from the pulley, it had come loose, and the suspension balance was lost.  	・Changed the stainless wire rope (Φ2) to a cord with a Kevlar core (Φ2.2 (load capacity 300kg))	Lifting operation was repeated (about 10 times) and it was verified that the wire was not loose. 
2	Revised the pulley part		・Changed the pulley with a separate shaft and roller to one in which these are integrated.	Lifting operation was repeated (about 10 times) and it was verified that the pulley was not getting stuck anywhere. 

6.2.6 Status of improvement in the hole cover installation equipment

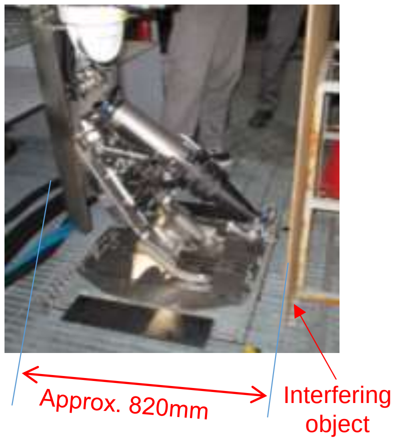
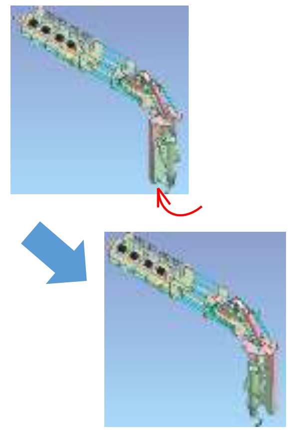
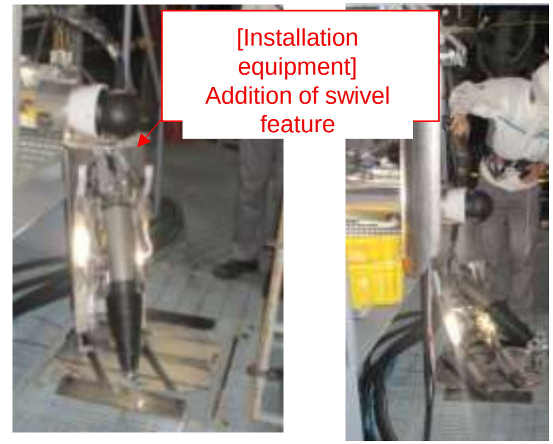
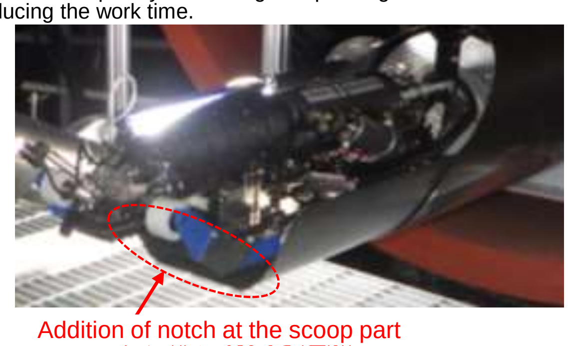
Table 24: Improvements in the hole cover installation equipment (2)

No.	Items	Status during previous project	Improvements	Verification results
3	Revised the strength, mass, material, and shape of the hole cover	• The handle plate of the hole cover got bent due to insufficient strength when the investigation equipment was traveling. • The equipment slipped while traveling. Hence the material of the surface of the cover needs to be reviewed. • Along with the increase in the size of the grating hole at the site (work performed on June 18, 2021 after previous project), the size of the hole cover needs to be increased.  	• The thickness of the hole cover was changed from 3t ⇒ 6t • The surface was fabricated using checkered steel plates, and the ease of traveling on the cover was verified. • The hole cover was enlarged.  	The investigation equipment was let to travel on the surface of the hole cover, and it was verified that there is no problem with respect to deformation, traveling efficiency and installation efficiency. No problem in installation efficiency using the hole cover installation equipment  Hole cover No problem of interference or in the traveling efficiency after the investigation equipment is positioned as well. 

6.2.7 Status of improvement in the installation equipment

The following improvements in the installation equipment were made in response to the issues persisting after previous project and for further functional enhancement. The verification result was confirmed by means of tests that there is no problem in the ease of installation and retrieval of the investigation equipment.

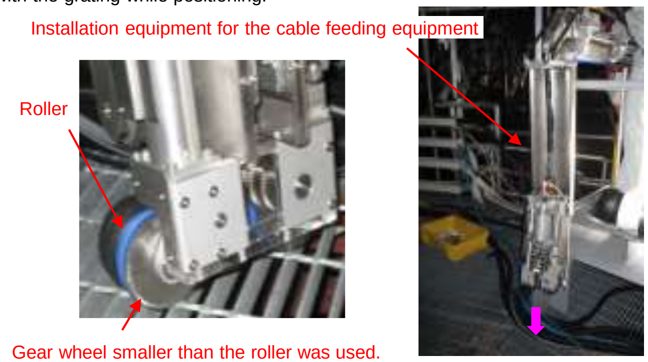
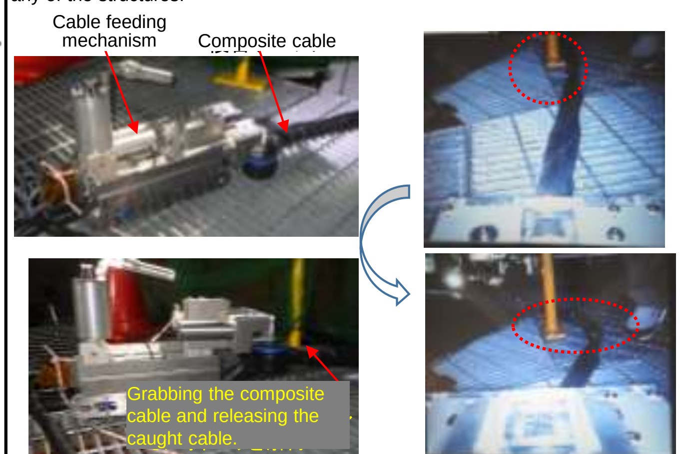
Figure 25: Improvements in the installation equipment for the investigation equipment

No.	Items	Status during previous project	Improvements	Verification results
1	Addition of swivel function	Since there were space constraints at the installation location, installation was difficult. 	A 90° swivel function was added by installing an “R guide” and “rack and pinion” 	·It was verified that the investigation equipment can be installed due to the addition of the swivel feature to the installation equipment. 
2	Addition of a notch in the scoop part	There was an incident in which the equipment slipped out of place during installation and retrieval.	A notch was added to the scoop part. 	The stability of the equipment during installation and retrieval was enhanced (prevention of slipping out of place) due to the notch at the scoop part at the tip of the installation equipment, and as a result the frequency of bending and pushing out was lowered thus reducing the work time. 

6.2.8 Status of improvements in the cable feeding equipment

The following improvements in the cable feeding equipment were made in response to the issues persisting after previous project and for further functional enhancement. The test results were verified avoidance of the interfering roller part at the time of installation, cable feeding and release functions, and that there is no interference at the time of lifting.

Table 26: Improvements in the cable feeding equipment

No.	Items	Status during previous project	Improvements	Verification results
1	Revised the gear wheel of the roller part	The gear wheel of the roller part was likely to interfere with the grating while installing the cable feeding equipment.  	Since the size of the roller is Φ90mm, the gear wheel was changed to a smaller size (Φ90 ⇒ 84mm) to eliminate the interference.	The cable feeding equipment was suspended from the installation equipment that was turned 90°, and it was verified that the roller part does not interfere with the grating while positioning. 
2	Increase in the elevating length of the roller part in the cable feeding equipment	If the cable got caught in the B1 investigation equipment left behind, the cable feeding equipment could not easily release it.  	The elevating length of the cable feeding mechanism was changed from 50mm ⇒ 80mm to enable release of the cable.	It was verified that by changing the elevating length of the cable feeding mechanism from 50mm ⇒ 80mm, the cable can be released if it gets caught in any of the structures. 

6.2.9 Status of study of seal box (including cable drum)

It was verified that there is no problem in operational performance, when the following seal boxes are designed and manufactured, and combined with each equipment.

In the future, carrying-in and installation will be verified by means of mock-up tests.

(1) Seal box for the cable feeding equipment (including cable drum) [250A] (Refer to Figure 44)

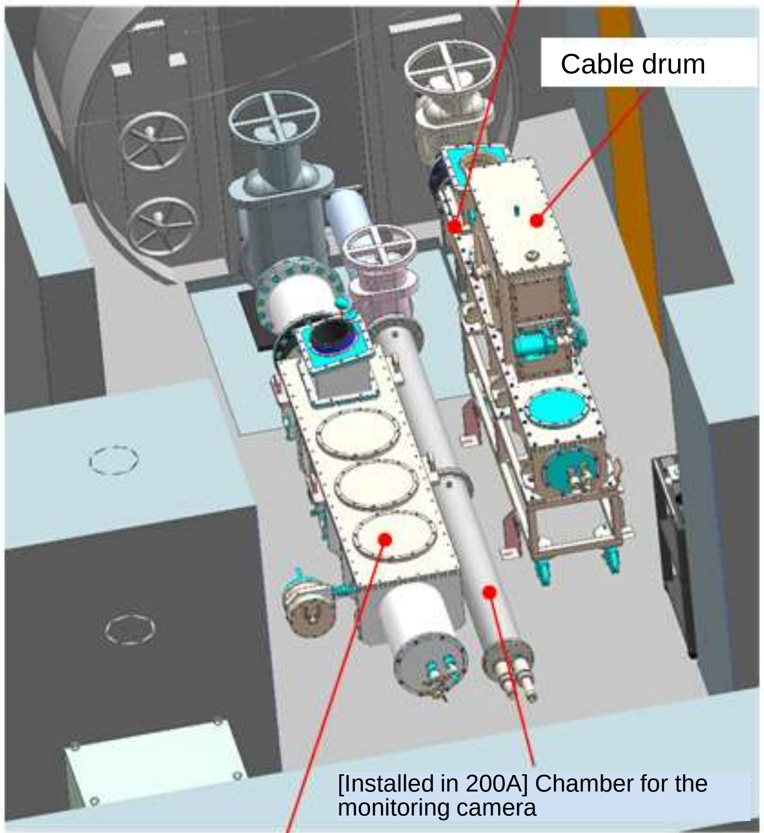
(2) Seal box for the hole cover installation equipment [350A] (Refer to Figure 45)

(3) Seal box for the investigation equipment (including cable drum) [350A: switched after installing (2)] (Refer to Figure 46)

250A: (Existing hole of 250mm in diameter opened in X-2 penetration)
350A: (Existing hole of 350mm in diameter opened in X-2 penetration)

6.2.9 Status of study of seal box (including cable drum)

(1) Seal box for the cable feeding equipment (including cable drum) [250A]
(2) Seal box for the hole cover installation equipment [350A]



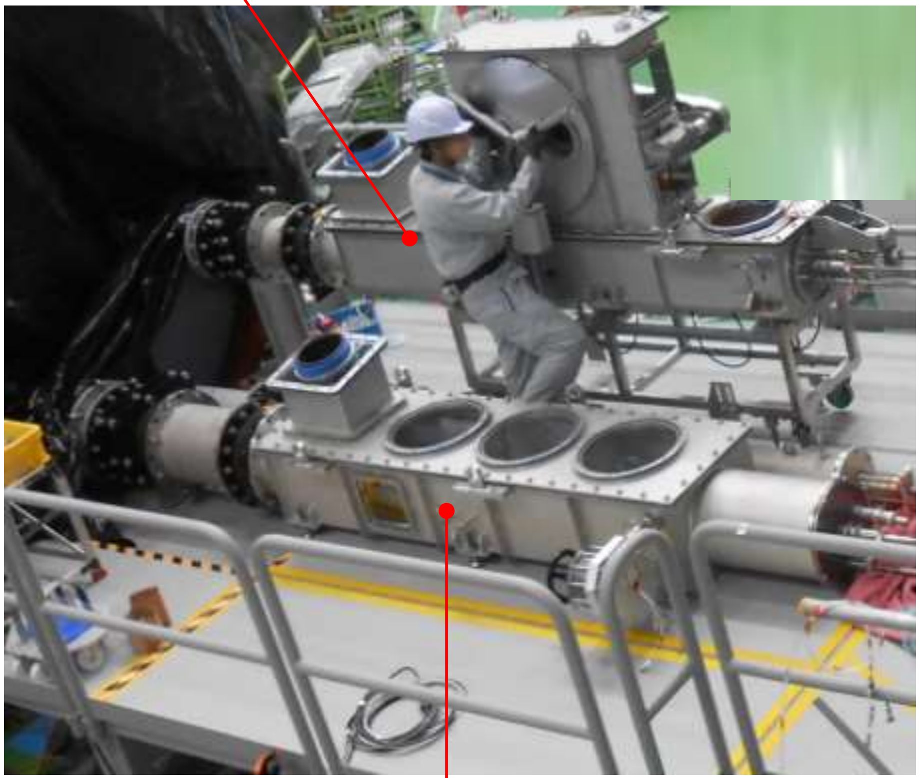


Figure 44: Installation status of the seal box for the cable feeding equipment and the seal box for the hole cover installation equipment

6.2.9 Status of study of seal box (including cable drum)

(3) Seal box for the investigation equipment (including cable drum) [350A: replaced after installing (2)]

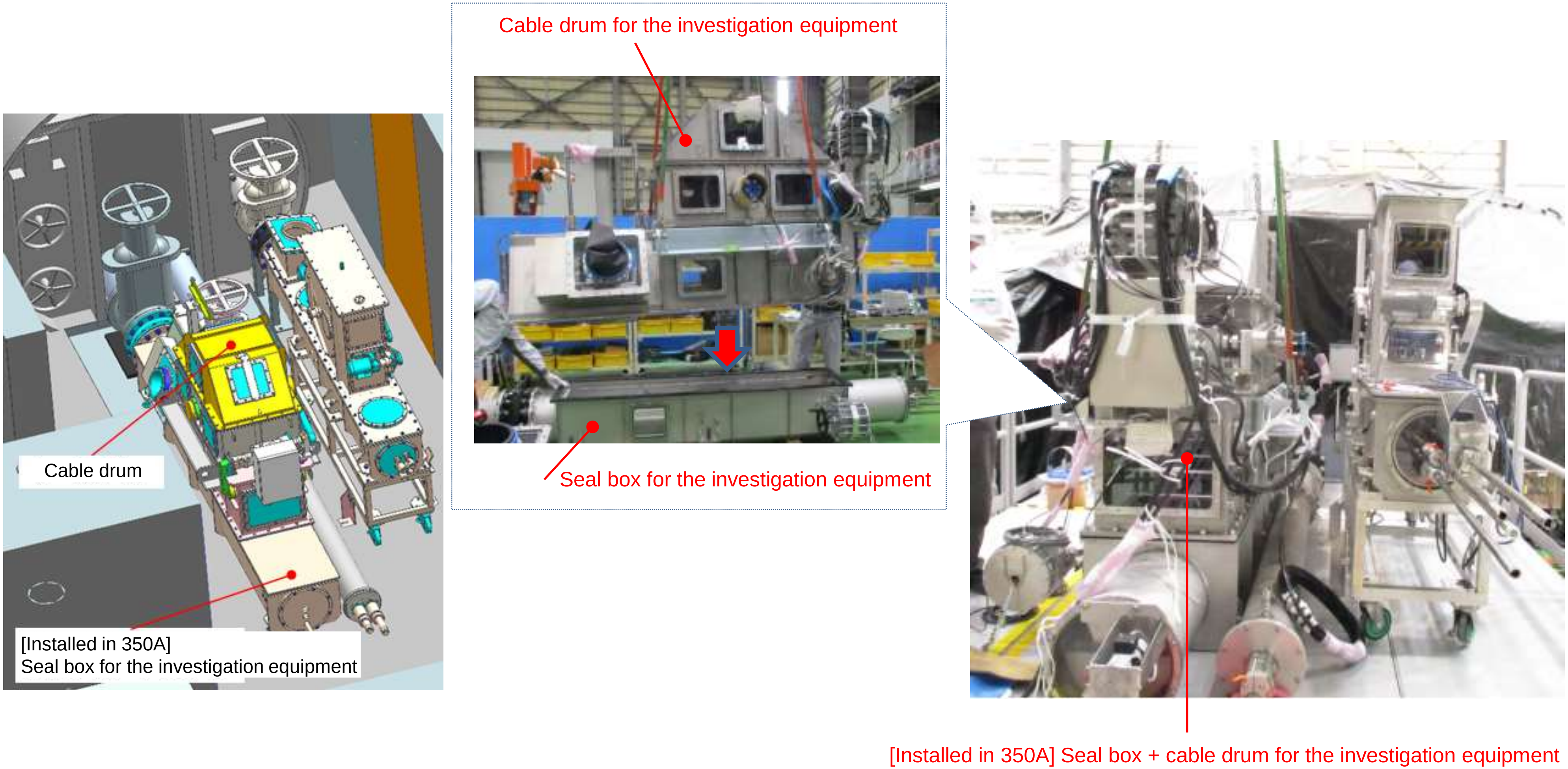


Figure 45: Installation status of the seal box for the investigation equipment

6.2.10 Status of study of the monitoring camera

(1) The status of the study of the monitoring camera is given below.

To enhance further functional improvement after the previous project, a bend part of the monitoring camera was added for improvement to enlarge the view range. As a result of the test, there was no problem in visibility.

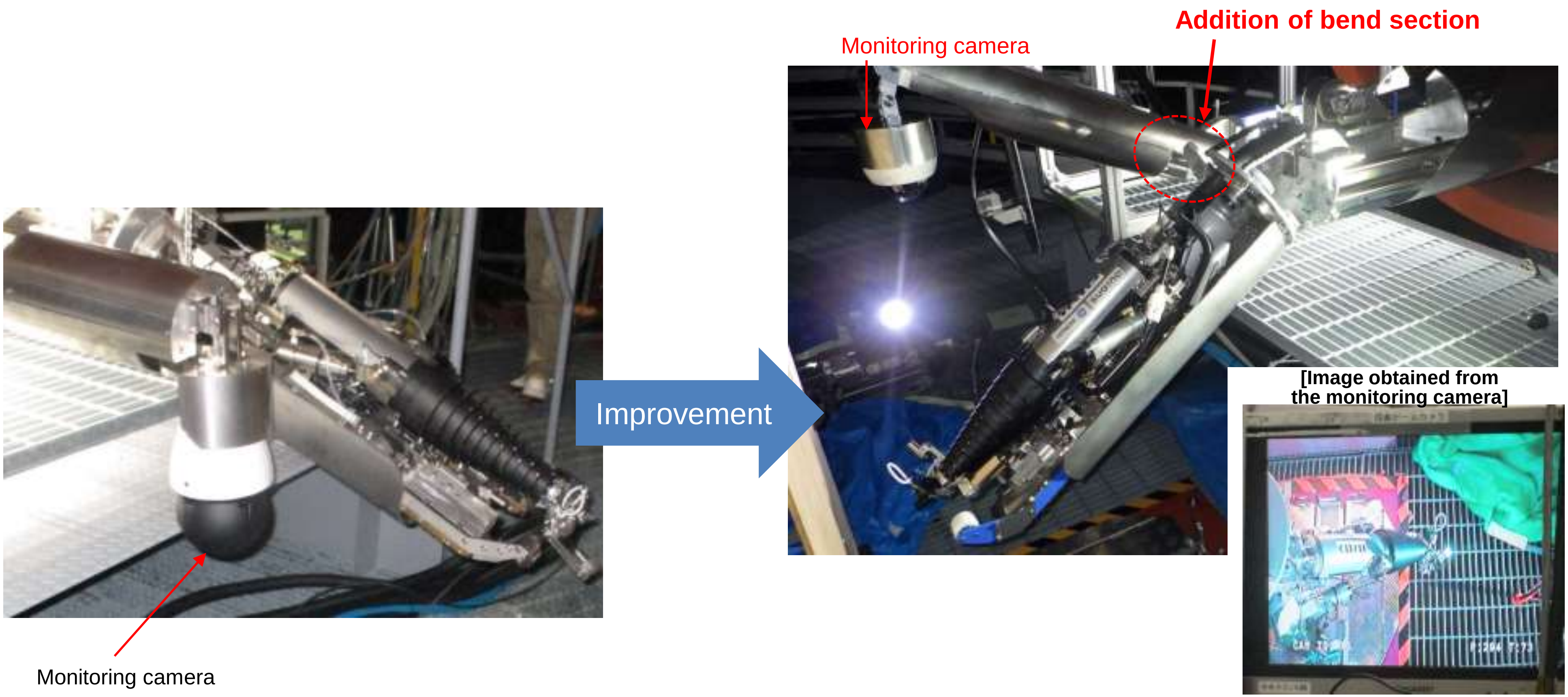
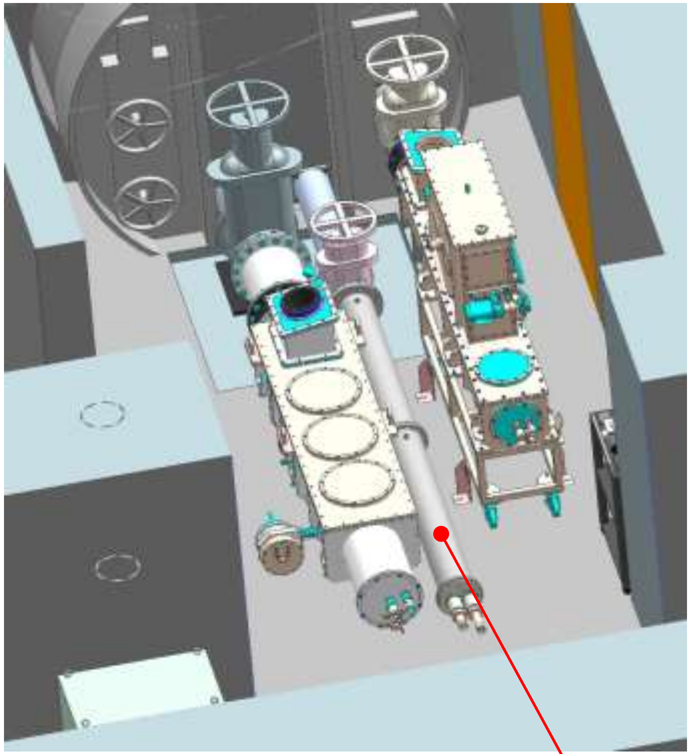


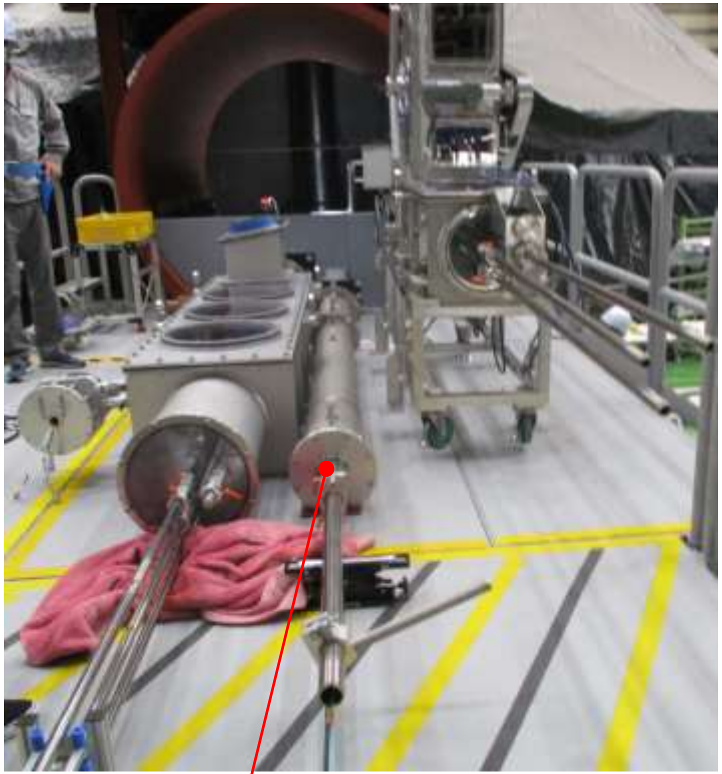
Figure 46: Status of study of the monitoring camera

6.2.10 Status of the monitoring camera

(2) The status of the monitoring camera chamber is given below.

The monitoring camera chamber was fabricated with dimensions such that it can be placed inside the air lock room. It was verified that there is no problem in operational performance when the monitoring camera is installed inside the chamber.



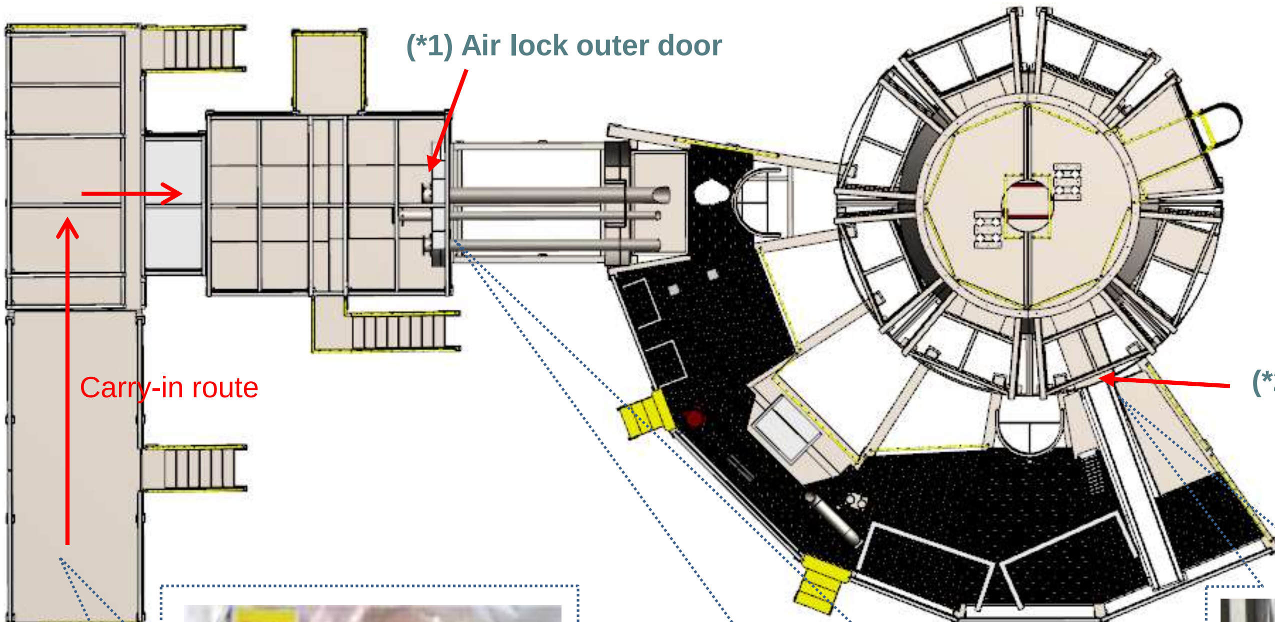


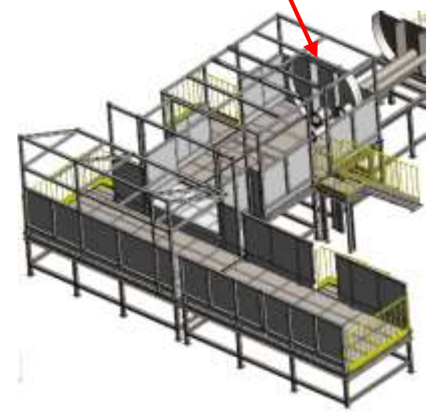
[Installation in 200A] Monitoring camera chamber

Figure 47: The status of the monitoring camera chamber

6.3 Mock-up test plan

According to the mock-up test plan, the mock-up test will be conducted at the test facility that was simulated actual environment (Mock-up tests are planned to be conducted in FY2022).






A photo of the carry-in route (at the site)


A photo of the vicinity of the air lock outer door (at the site)

A photo of the vicinity of the CRD opening (at the site)

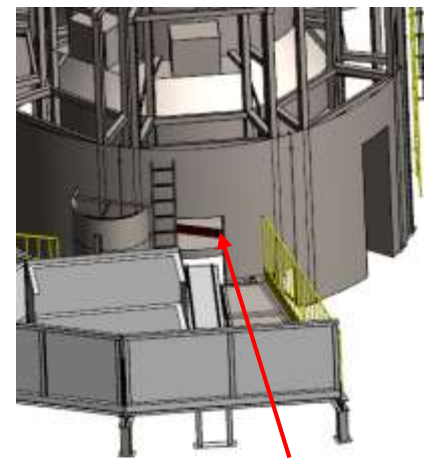


Figure 48: Status of study of the mock-up test facility

6.4 Issues

A list of work risks in this project is indicated below.

Table 28: List of work risks (1/6)

Work step		Anticipated risk	Occurrence frequency	Countermeasures
Major category	Sub-category			
Installation of monitoring camera inside PCV	① Passing the bend type dome camera through the guide pipe (200A) ② Installing the camera at an arbitrary position so that it can monitor work in the following steps.	The camera gets damaged due to interference with structures in the surrounding area while the camera is in operation	Medium	Selecting a camera with protective cover so that the lens does not get damaged directly.
Installation of cable feeding equipment inside the PCV	① Passing the installation equipment through the guide pipe (250A) ② Pushing through the installation equipment till it crosses the handrail ③ Bending the installation equipment ④ Rotating the cable drum and suspending the cable feeding equipment ⑤ Positioning the cable feeding equipment	The hand rail interferes with the installation equipment when the installation equipment is being pushed through	**High**	・Operating from the most suitable monitoring camera position ・Clearly specifying the operating range by marking the operating pole
		The cable drum motor does not move and hence the cable feeding equipment cannot be suspended.	Low	Enabling the cable drum to be operated manually
		The gear wheel part of the cable feeding equipment gets damaged during positioning.	Medium	Circumventing the interference by using a gear wheel part with a diameter smaller than the grabbing part
Covering the opening for the ROV	① Passing the hole cover installation equipment through the guide pipe (350A) ② Pushing through the hole cover installation equipment up to the opening ③ Suspending the hole cover ④ Inserting the hole cover pin into the groove on the grating ⑤ Releasing the grip and installing the hole cover ⑥ Pulling in and retrieving the hole cover installation equipment	When the hole cover installation equipment is being pushed through, it gets pushed too much and interferes with the structures.	Medium	Marking the operating pole so that the equipment does not get pushed too much
		While installing the hole cover, it gets misaligned.	Medium	・Determining the location to be monitored using the bend type dome camera and the cable feeding equipment camera, so that there is no misalignment ・Even then if there is misalignment, grabbing the hole cover, retrieving it and installing again
Installation of investigation equipment inside PCV	① Passing the installation equipment through the guide pipe (350A) ② Pushing through the installation equipment till it crosses the handrail ③ Bending the installation equipment ④ Rotating the cable drum and suspending the investigation equipment ⑤ When the front crawler part touches the ground, rotating the investigation equipment towards the left and suspending it ⑥ Positioning the investigation equipment	The hand rail interferes with the installation equipment when the installation equipment is being pushed through.	Medium	・Re-examining the shape of the installation equipment scoop to secure larger clearance ・Monitoring with bend type dome camera and cable feeding equipment camera to make sure there is no interference
		The structures interfere with the installation equipment when the installation equipment is being pushed through.	**High**	Marking the operating pole so that the equipment does not get pushed too much
		The cable drum motor does not move and hence the investigation equipment cannot be suspended.	Low	Enabling the cable drum to be operated manually
		The structures interfere with the camera at the tip of the investigation equipment when the investigation equipment is being suspended.	**High**	・Adding a swivel mechanism to the scoop part of the installation equipment to avoid interference with the structures ・Clearly specifying the suspension area to make sure there is no interference

6.4 Issues

A list of work risks in this project is indicated below.

Table 29: List of work risks (2/6)

B2 investigation: Conducted in March 2017

Work step		Anticipated risk	Occurrence frequency	Countermeasures
Major category	Sub-category			
Traveling from X-2 penetration to B1 investigation equipment left behind	① Letting the cable feeding equipment travel, and moving it to the position from where the investigation equipment can be comprehensively monitored ② Letting the investigation equipment travel up to right in front of the B1 investigation equipment left behind, while rotating the cable drum ③ If the cable is about to get caught, adjusting the position of the cable as needed using the cable feeding equipment	The equipment gets damaged due to interference with structures in the surrounding area while the investigation equipment is traveling.	Medium	・Planning the layout of the camera in such a way that it can monitor the interfering objects without any omissions ・Letting the equipment travel while checking for interferences by means of the bend-type dome camera, cable feeding equipment camera, and the investigation equipment camera
		The equipment slips on the grating and is unable to travel and rotate.	Medium	Enhancing the performance of the crawler
		The cable drum motor does not move and hence the cable feeding equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The cable feeding equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the cable feeding equipment
		The cable drum motor does not move and hence the investigation equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The investigation equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the investigation equipment
		The cable gets caught in the handrail, etc. and hence the investigation equipment cannot travel.	Medium	Releasing the caught cable using the cable feeding equipment
		The structures, etc. on the travel route cannot be verified inside the PCV environment (darkness, steam).	Low	Using a camera that has been used for investigation inside PCV in the past (B2 investigation)
		The cable feeding equipment gets overturned while crossing over the composite cable.	Low	Winding the cable drum, retrieving the cable feeding equipment and installing once again
Extension of rod from right in front of the B1 investigation equipment left behind	① Rotating the investigation equipment while looking at the position of the laser pointer, and making fine adjustments to the extension position ② Raising the rod up to the specified hoisting angle ③ Extending the rod ④ Acquiring information on the area in front of the pedestal CRD opening by operating the camera *: Visibility up to inside the pedestal CRD opening is verified during the mock-up tests. ⑤ Retracting the rod	The rod interferes with the structures while it is extended.	Medium	・Verifying that there are no interference objects at the extension position by means of a laser pointer, before extending the rod ・Extending while verifying that there are no interfering objects in the surroundings by inching ahead
		Due to breakage of the internal tube air does not get supplied and hence the rod cannot be extended.	Low	・Passing a Kevlar cord through the internal tube so it does not break ・Retrieving the investigation equipment, if it breaks
		The extended rod cannot be retracted due to breakage of the internal tube and problem with the electrical system.	Low	Winding the cable drum so that the rod can be retracted mechanically

6.4 Issues

A list of work risks in this project is indicated below.

Table 30: List of work risks (3/6)

Work step		Anticipated risk	Occurrence frequency	Countermeasures
Major category	Sub-category			
Crossing over the B1 equipment left behind (onward route)	① Moving the cable feeding equipment to the back of the investigation equipment so that it can be comprehensively monitored while crossing over the B1 investigation equipment left behind ② Investigation equipment crossing over the B1 investigation equipment left behind	While crossing over, the investigation equipment loses balance and gets overturned.	Low	Winding the cable drum and retrieving the investigation equipment
		While crossing over, it interferes with the surrounding structures (150A piping, etc.)	Medium	Performing comprehensive monitoring by means of the cable feeding equipment camera, and checking the front by means of the investigation equipment camera.
Traveling from B1 investigation equipment left behind up to the CRD opening	① Letting the investigation equipment travel up to the front of the CRD opening by rotating the cable drum ② If the cable is about to get caught, adjusting the position of the cable as needed using the cable feeding equipment	The equipment gets damaged due to interference with structures in the surrounding area while the investigation equipment is traveling.	**High**	・ Planning the layout of the camera in such as way that it can monitor the interfering objects without any omissions ・ Letting the equipment travel while checking for interferences by means of the cable feeding equipment camera, and the investigation equipment camera
		The equipment slips on the grating and is unable to travel and rotate.	Medium	Enhancing the performance of the crawler
		The cable drum motor does not move and hence the cable feeding equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The cable feeding equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the cable feeding equipment
		The cable drum motor does not move and hence the investigation equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The investigation equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the investigation equipment
		The cable gets caught in the handrail, etc. and hence the investigation equipment cannot travel.	**High**	Releasing the caught cable using the cable feeding equipment
		The structures, etc. on the travel route cannot be verified inside the PCV environment (darkness, steam).	Low	Using a camera that has been used for investigation inside PCV in the past (B2 investigation)

6.4 Issues

A list of work risks in this project is indicated below.

Table 31: List of work risks (4/6)

Work step		Anticipated risk	Occurrence frequency	Countermeasures
Major category	Sub-category			
Extending the rod to investigate inside the pedestal	① Rotating the investigation equipment while looking at the position of the laser pointer, and making fine adjustments to the extension position ② Raising the rod up to the specified hoisting angle ③ Extending the rod ④ Acquiring information from inside the pedestal by operating he camera ⑤ Retracting the rod	The rod interferes with the structures while it is extended.	Medium	・Verifying that there are no interference objects at the extension position by means of a laser pointer, before extending the rod ・Extending while verifying that there are no interfering objects in the surroundings by inching ahead
		Due to breakage of the internal tube air does not get supplied and hence the rod cannot be extended.	Low	・Passing a Kevlar cord through the internal tube so it does not break ・Retrieving the investigation equipment, if it breaks
		The extended rod cannot be retracted due to breakage of the internal tube and problem with the electrical system.	Low	Winding the cable drum so that the rod can be retracted mechanically
		The image sensor of the camera gets damaged due to the high radiation environment.	Low	Selecting a radiation resistant camera that has been used in similar environments (B2 investigation inside PCV)
		Gets overturned due to the vibrations of the earthquake.	Low	Verifying by means of mock-up tests whether or not there is a possibility of getting overturned
Backing up to B1 investigation equipment left behind	① Backing up the investigation equipment from the investigation location ② Letting the investigation equipment travel up to the B1 investigation equipment left behind while supporting the cable by means of the cable feeding equipment	The equipment gets damaged due to interference with structures in the surrounding area while the investigation equipment is traveling.	**High**	・ Planning the layout of the camera in such a way that it can monitor the interfering objects without any omissions ・ Letting the equipment travel while checking for interferences by means of the investigation equipment camera
		The equipment slips on the grating and is unable to travel and rotate.	Medium	Enhancing the performance of the crawler
		The cable drum motor does not move and hence the cable feeding equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The cable feeding equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the cable feeding equipment
		The cable drum motor does not move and hence the investigation equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The investigation equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the investigation equipment
		The cable gets caught in the handrail, etc. and hence the investigation equipment cannot travel.	**High**	Releasing the caught cable using the cable feeding equipment
		The structures, etc. on the travel route cannot be verified inside the PCV environment (darkness, steam).	Low	Using a camera that has been used for investigation inside PCV in the past (B2 investigation)

6.4 Issues

A list of work risks in this project is indicated below.

Table 32: List of work risks (5/6)

Work step: Major category	Work step: Sub-category	Anticipated risk	Occurrence frequency	Countermeasures
Crossing over the B1 equipment left behind (return route)	① Moving the cable feeding equipment to the back of the investigation equipment so that it can be comprehensively monitored while crossing over the B1 investigation equipment left behind ② Crossing over the B1 investigation equipment left behind by backing up the investigation equipment	While crossing over, the investigation equipment loses balance and gets overturned.	Low	Winding the cable drum and retrieving the investigation equipment
		While crossing over, it interferes with the surrounding structures (150A piping, etc.)	Medium	Performing comprehensive monitoring by means of the cable feeding equipment camera, and checking the back by means of the investigation equipment camera.
Traveling from the B1 investigation equipment left behind up to the X-2 penetration	① Letting the cable feeding equipment travel, and moving it to a position where the investigation equipment can be comprehensively monitored ② Backing up the investigation equipment up to right in front of the X-2 penetration while rotating the cable drum ③ If the cable is about to get caught, adjusting the position of the cable as needed using the cable feeding equipment	The equipment gets damaged due to interference with structures in the surrounding area while the investigation equipment is traveling.	High	・ Planning the layout of the camera in such a way that it can monitor the interfering objects without any omissions ・ Letting the equipment travel while checking for interferences by means of the investigation equipment camera
		The equipment slips on the grating and is unable to travel and rotate.	Medium	Enhancing the performance of the crawler
		The cable drum motor does not move and hence the cable feeding equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The cable feeding equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the cable feeding equipment
		The cable drum motor does not move and hence the investigation equipment cannot travel.	Low	Enabling the cable drum to be operated manually
		The investigation equipment cannot travel due to issues in the electrical system.	Low	Winding the cable drum and retrieving the investigation equipment
		The cable gets caught in the handrail, etc. and hence the investigation equipment cannot travel.	High	Releasing the caught cable using the cable feeding equipment
		The cable feeding equipment gets overturned while crossing over the composite cable.	Low	Winding the cable drum, retrieving the cable feeding equipment and installing once again
		The structures, etc. on the travel route cannot be verified inside the PCV environment (darkness, steam).	Low	Using a camera that has been used for investigation inside PCV in the past (B2 investigation)

6.4 Issues

A list of work risks in this project is indicated below.

Table 33: List of work risks (6/6)

Work step		Anticipated risk	Occurrence frequency	Countermeasures
Major category	Sub-category			
Retrieval of the investigation equipment	① Winding up the cable when the investigation equipment comes up to the retrieval position ② When the investigation equipment is placed in the scoop part of the installation equipment, bending the installation equipment to bring it to a horizontal position ③ Pulling in and retrieving the investigation equipment	The cable drum motor does not move and hence the investigation equipment cannot be wound up.	Low	Enabling the cable drum to be operated manually
Retrieving the hole cover	① Passing the hole cover installation equipment through the guide pipe (350A) ② Pushing through the hole cover installation equipment up to the hole cover position ③ Suspending the wire to a height such that the handle can be grabbed ④ Grabbing the handle ⑤ Winding up the wire, and placing the hole cover on the installation equipment ⑥ Pulling in and retrieving the hole cover installation equipment	When the hole cover installation equipment is being pushed through, it gets pushed too much and interferes with the structures.	**High**	Marking the operating pole so that the equipment does not get pushed too much
		Wire gets overwound and breaks.	Medium	Marking the position indicating over-winding
Cable feeding equipment retrieval	① Winding up the cable when the cable feeding equipment comes up to the retrieval position ② When the cable feeding equipment is placed in the scoop part of the installation equipment, bending the installation equipment to bring it to a horizontal position ③ Pulling in and retrieving the cable feeding equipment	The cable drum motor does not move and hence the cable feeding equipment cannot be wound up.	Low	Enabling the cable drum to be operated manually
Retrieval of the monitoring camera inside PCV	① Pulling in and retrieving the bend-type camera	The camera gets damaged due to interference with structures in the surrounding area while the camera is in operation	Medium	Selecting a camera with protective cover so that the lens does not get damaged directly.

6.5 Level of the goal achievement

● Level of the goal achievement

As the results of the elemental tests and equipment manufacturing, the specifications were verified to satisfy its requirements.

- There is a prospect of capturing visual datas of inside the pedestal, where is dark, by using the camera and extending the extension rod mounted on the investigation equipment when it can reach the pedestal CRD opening after installing inside the PCV through the X-2 penetration and travelling over the first floor grating.

6.6 Future plans

The investigation instruments (point cloud data sensor and radiation sensor) will be mounted to verify the movement. Also, the risk identification and countermeasures will be implemented by conducting comprehensive tests. Further, the equipment will be continuously improved towards perfection by conducting in-plant verification (unit tests) and mock-up tests using mock-up test facilities in preparation for the on-site demonstration. Development items and future plans are indicated below.

Figure 34 : Development items and future plans

No.	Items	Classification	Details	Accomplishments	Future plans
1	Detailed designing, manufacturing and unit tests of the access and investigation equipment	Equipment for investigating inside the pedestal	Main body	① Traveling up to the pedestal CRD opening ② Insertion and retrieval from the access route (350A) ③ Traveling across the B1 investigation equipment left behind and embedded cables ④ 5m extension rod with air drive	Functional verification through in-plant verification and mock-up tests
			Composite cable	① Thinning of cables to Φ40	
			Point cloud data sensor	① Can be used in actual equipment environment (darkness, fog, water droplets, high radiation) ② Dimensions and weight such that equipment can be mounted on the tip of the extension rod	Mounting on the implementation equipment
			Radiation sensor	① Minimum 1Gy/h can be measured ② Dimensions and weight such that equipment can be mounted on the tip of the extension rod	Mounting on the implementation equipment
2		Ancillary equipment	Hole cover installation equipment	① Blocking of the hole for ROV ② Can be remotely installed and retrieved	Functional verification through in-plant verification and mock-up tests
3			Installation equipment	① Insertion and retrieval of equipment for investigating inside the pedestal into the PCV	
4			Cable feeding equipment	① Grabbing and feeding the composite cable for the equipment for investigating inside the pedestal ② Monitoring the work of the equipment for investigating inside the pedestal using the mounted camera	
5			Seal box (Including cable drum)	① Composite cable for the equipment for investigating inside the pedestal can be fed and wound up ② Ensuring air-tightness (boundary part)	
6			Monitoring camera	① Work of equipment for investigating inside the pedestal and ancillary equipment (hole cover, installation equipment, cable feeding equipment, etc.) can be monitored	
7	Mock-up test	Testing facility	Preparation of test facility	Designing of the mock-up test facility	Fabrication of the mock-up test facility
8	On-site demonstration plan	Plan	On-site demonstration plan	Commencing mock-up test planning	Study of on-site demonstration plan reflecting the results of the mock-up test

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