IRID

In-house project

Development of technology for detailed investigation inside the primary containment vessel (on-site demonstration for detailed investigation inside PCV through X-6 penetration)

Final report for FY2020

May, 2021

International Research Institute for Nuclear Decommissioning (IRID)

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5. Summary and future plan

1. Background and purpose of the project

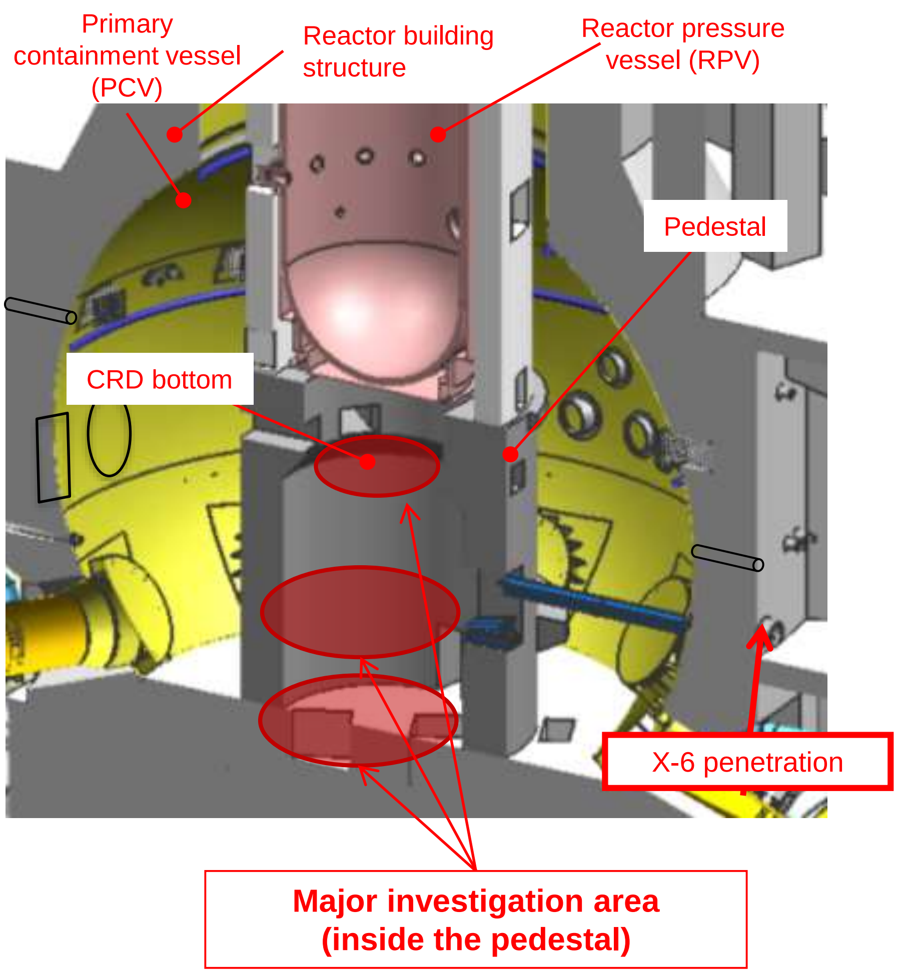
【Background】

As a result of investigation inside the primary containment vessel (PCV) of Unit 2 conducted in January 2018, pebble-and clay-like depositions were confirmed on the entire pedestal bottom.

Moreover, a part of the fuel assemblies had dropped on the bottom, and the depositions identified in the surrounding area were presumed to be fuel debris.

【Purpose】

The access and investigation equipment is intended to enter through the X-6 penetration that was used for a previous investigation inside the PCV after making a larger-diameter opening. A detailed investigation will be undertaken to verify the effectiveness of this technology. Additionally, fuel debris collection equipment will be installed to collect the depositions in the PCV, and the effectiveness of the developed technology will be confirmed.



【Overview of the PCV cross-section and the investigation points】

2. Overview of the project

FY2016-2017: Development of Technology for Investigation Inside the PCV

↓

FY2017-2018: Development of Technology for Detailed Investigation Inside the PCV

↓

FY2018-2019: Development of Technology for Detailed Investigation Inside the PCV (onsite demonstration for detailed investigation inside the PCV through X-6 penetration)

(FY2016–2019: Subsidy projects)

↓

FY2020-2023: Development of Technology for Detailed Investigation Inside the PCV (onsite demonstration for detailed investigation inside the PCV through X-6 penetration)

(FY2020–2023: IRID In-house project)

↓

- Development of Technology for Retrieving Fuel Debris and Reactor Internals
- Development of Sampling Technology for Retrieving Fuel Debris and Reactor Internals. Development of Technology for Increasing the Scale of Fuel Debris Retrieval in Stages

Project organization

International Research Institute for Nuclear Decommissioning (IRID)

- Development planning and technological management
- Technological process control: Progress of technology and equipment development
- Technology management for development phase

Tokyo Electoric Power Company (TEPCO) Holdings, Inc.

- Schedule management for site verification
- Management of the field demonstration phase
- Administration work, including communication with government

Mitsubishi Heavy Industries, Ltd.

→Access and investigation apparatus and other operation training
→Conducting field demonstrations (detailed investigation inside a PCV)

- Access and investigation apparatus
  1. Mock-up test considering the site condition
  2. Operation training
- Equipment related to establishing the access route
  1. Operation training
- Other ancillary facilities
  1. Design and manufacturing
- Small-amount fuel debris collection equipment
  1. Operation training
- Conducting field demonstrations

Toshiba Energy Systems and Solutions Corporation

→Operation training for X-6 penetration hatch opening equipment
→Site verification (X-6 penetration hatch opening)

- Overoll plan of X-6 penetration hatch opening
- Preparation for X-6 penetration hatch opening
- Conducting field demonstrations

TEPCO Holdings, Inc.

→Operation training for access and investigation apparatus
→Site verification (access and investigation apparatus operation)

- Access and investigation apparatus
  1. Mock-up test considering the site condition
  2. Operation training
- Small-amount fuel debris collection equipment
- Operation training
- Conducting field demonstrations

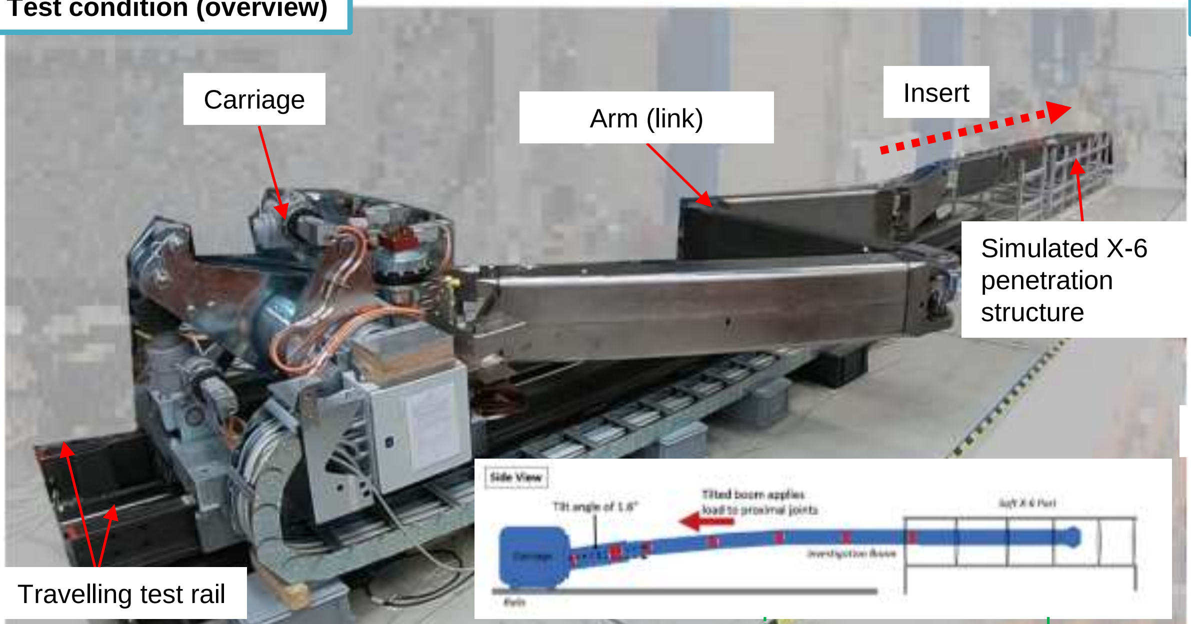
4. Implementation items and results

4.1 Access and investigation equipment

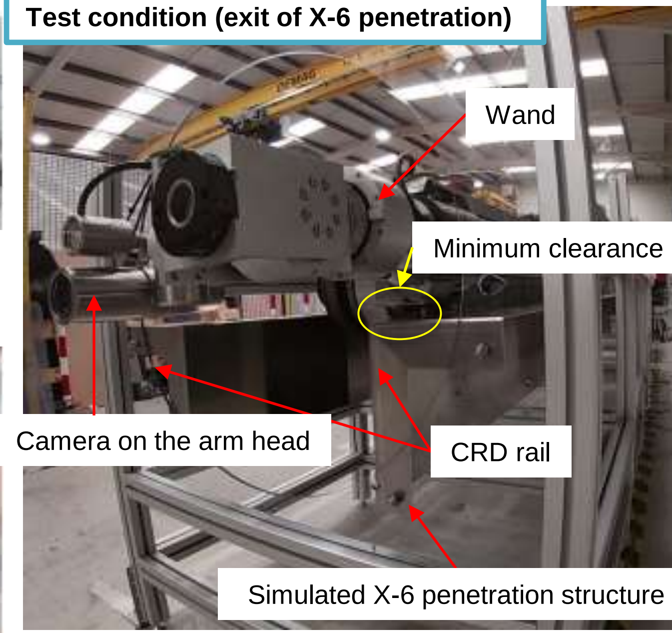
(1) Mock-up test considering the site condition

【Mock-up for the arm (test for passing through the X-6 penetration) 】

Test condition (overview)



Test condition (exit of X-6 penetration)



Swinging motions can be reduced by balanced motion of the two parts.

- The test result confirmed that the arm can pass through the X-6 penetration without interference.
- Interference risks can be reduced by appropriate motion control to prevent moving the link part backward under its own weight and moving forward by a driving motor of the link part. Consequently, swinging motions of the arm head in a horizontal direction were controlled (both amplitudes are approximately 20mm).
- The minimum clearance in the test is 10mm. The clearance will be increased by adjusting the height of the insert position.

4.1 Access and investigation equipment

(1) Mock-up test considering the site condition

【Installation test】

There are concerns over interference and other issues because of the narrowness of the spaces in the enclosure. Therefore, the mechanical interference was checked after the arm and Dexter were installed in the cell, and electrical connections including the camera connection were also checked.

Installing equipment in the enclosure

The test results confirmed that the arm and the maintenance manipulator can be moved without mechanical interference, and electric functions (control and image signals) are at satisfactory levels.

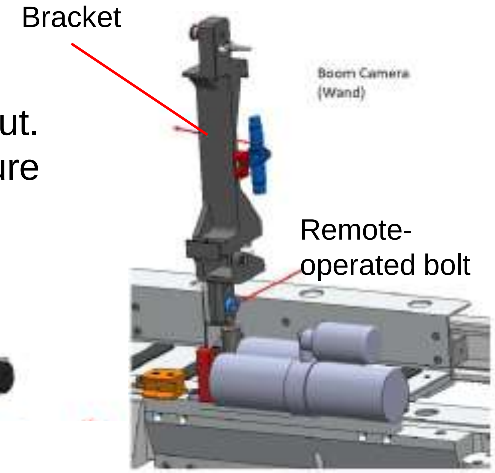
4.1 Access and investigation equipment
(1) Mock-up test considering the site condition

【A mock-up test for the maintenance manipulator (Dexter)】

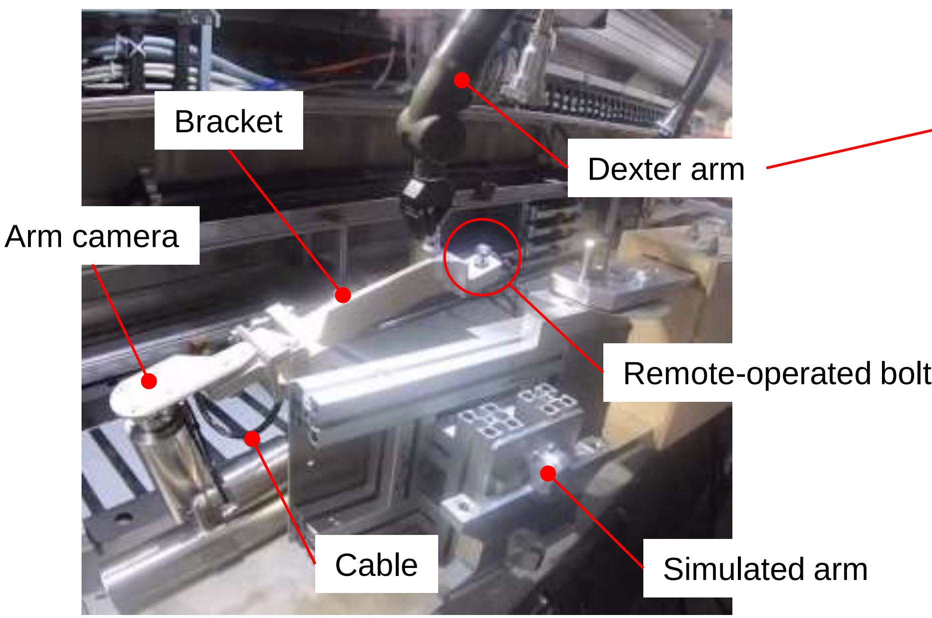
・A mock-up test for Dexter using a simulated arm in the enclosure was carried out.
・Feasibility of remote operation by Dexter was confirmed according to a procedure manual.

・Arm camera replacement

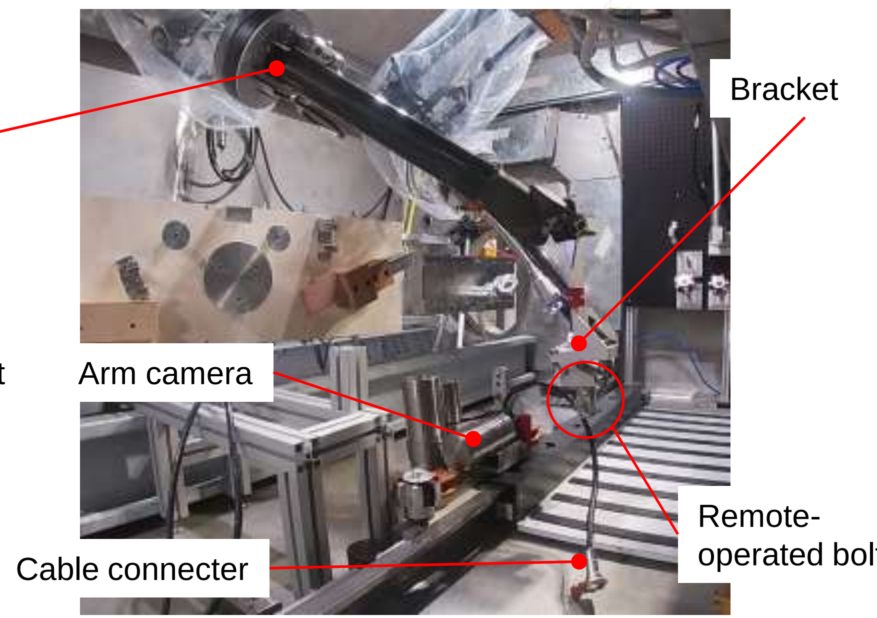
Removed and installed the arm camera, bracket, and cable connector using a remote-operated bolt.



Removal of the arm camera



Removal of the bracket



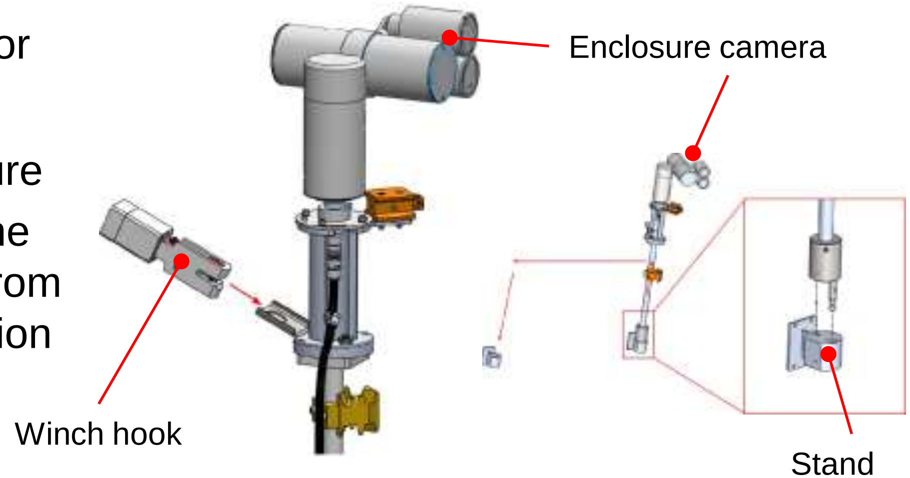
4.1 Access and investigation equipment

(1) Mock-up test considering the site condition

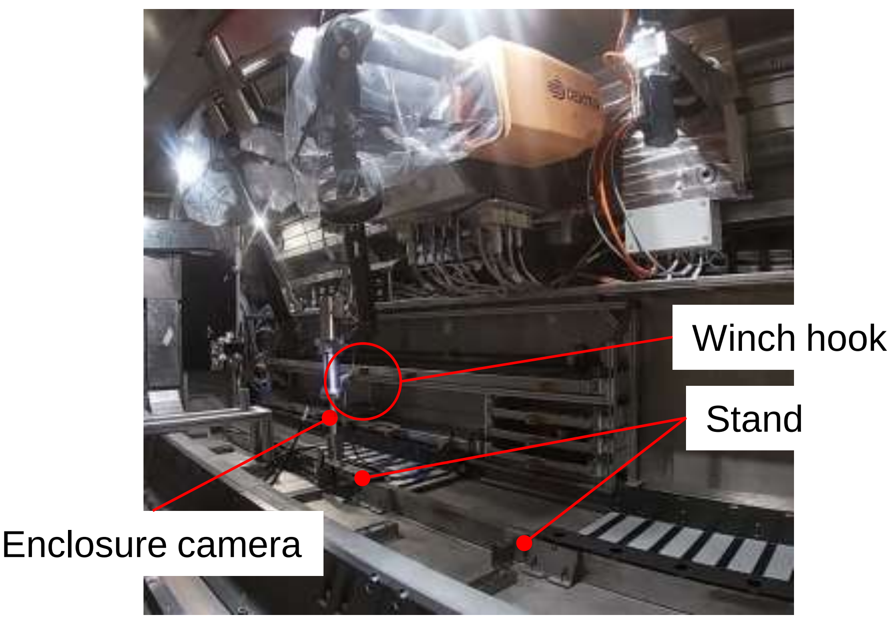
【A mock-up test for the maintenance manipulator (Dexter)】

・Change of the camera position in the enclosure

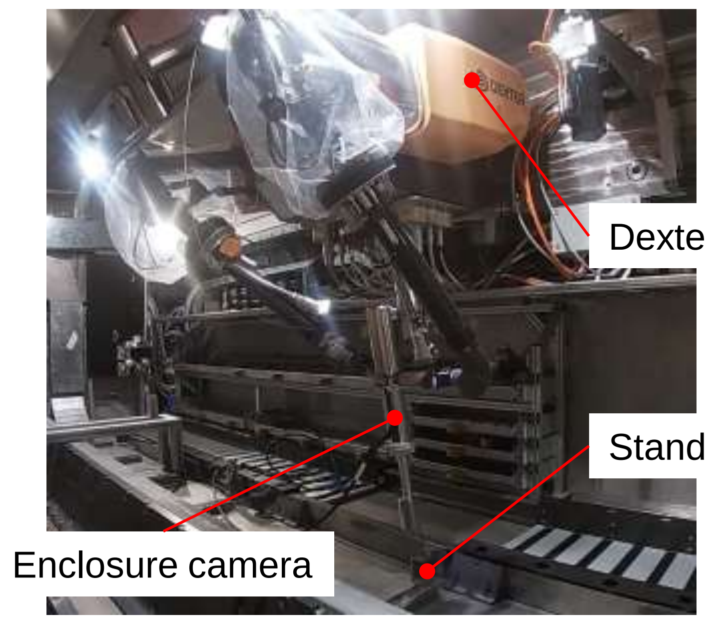
Removal and installation of a winch hook on the enclosure camera, withdrawal of the camera from the stand installed in the enclosure, and insertion of the camera into another stand.



Withdrawal of the enclosure camera



Insertion of the enclosure camera



4.1 Access and investigation equipment

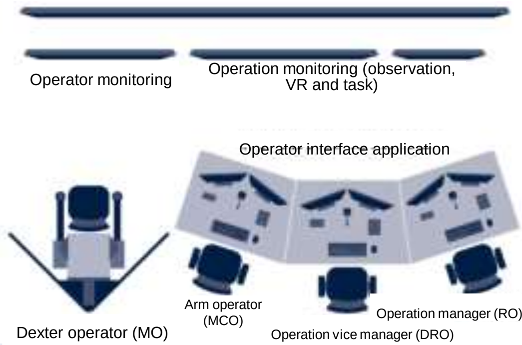
(2) Operation training

i. Team organization, ii. Operator selection

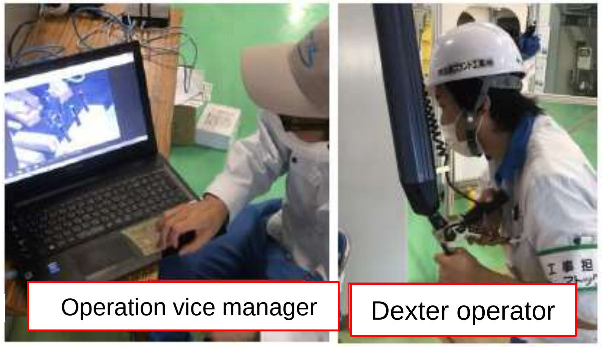
Operators of the arm-type access and investigation equipment have four roles. The two-group structure has been established for this investigation. The future plan is to select operators after confirming their competence through training in terms of knowledge, experience, and technical requirements.

Operators	Roles
Operation manager	･Responsible for the operator team ･Work plan development
Operation vice manager	･Substitute for an operation manager ･Operation of display, lighting and auxiliary equipment
Arm operator	Arm operation
Dexter operator	Dexter operation

Four roles of each operator



Example of operator allocation



Practical training (Technical training center)

iii. Training plan

The training plan is to have operators acquire techniques using actual equipment while gradually increasing the difficulty of training levels. Each training step and phase was studied.

Beginner training
Concepts of remote operation
Basic knowledge and operation are acquired to get used to remote operation.

→

Intermediate training
Operation of actual equipment (basic)
Detailed knowledge of practical equipment operation and software is acquired. Roles in a team are determined depending on the capability of candidates.

→

Advanced training
Operation of actual equipment (practical)
Practical equipment operation is performed according to work procedures that will actually be carried out by a team unit.

Training steps

Steps	Summary of training
Beginner training	･Remote operation method and operation precautions ･Basic operation of Dexter ･Basic operation of control and VR systems
Intermediate training	･Overview of the arm-type access and investigation equipment ･Work with the arm-type access and investigation equipment (theory and practice) ･Intensive training for an arm operator (learning of equipment operation) ･Skill evaluation (by testing)
Advanced training	Operation of the entire work procedure for investigation plan (including emergency operation)

Overview of each training step

4.2 Equipment related to establishing the access route

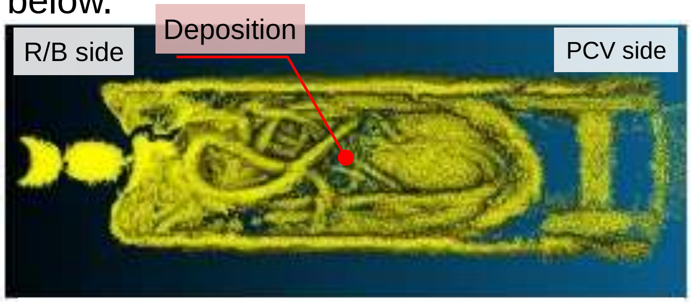
(1) Operation training

【Investigation of depositions accumulated in the X-6 penetration】

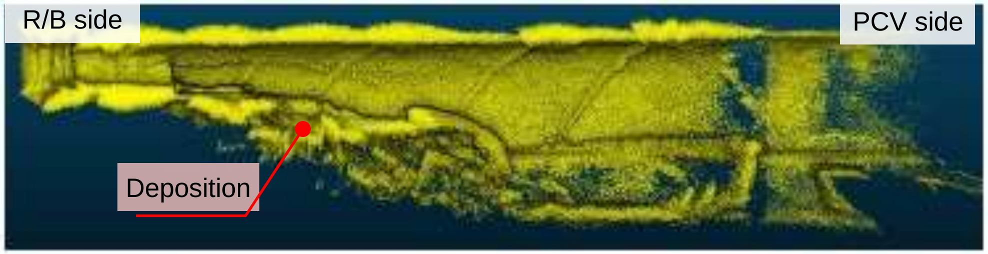
Tokyo Electric Power Company (TEPCO) Holdings Inc. investigated depositions accumulated in the X-6 penetration and acquired more detailed information on the distribution of the deposition in the penetration than existing image information.

The test results will be reflected in the future operational plan, its verification, and training.

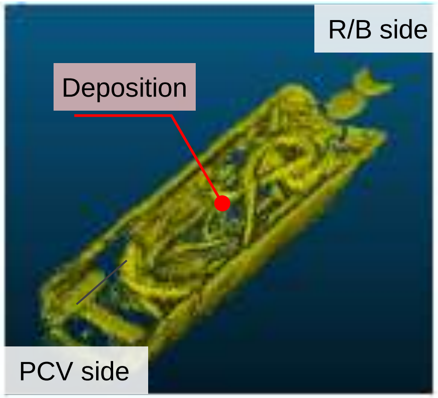
The image information of the distribution in the X-6 penetration provided by TEPCO Holdings is as shown below.



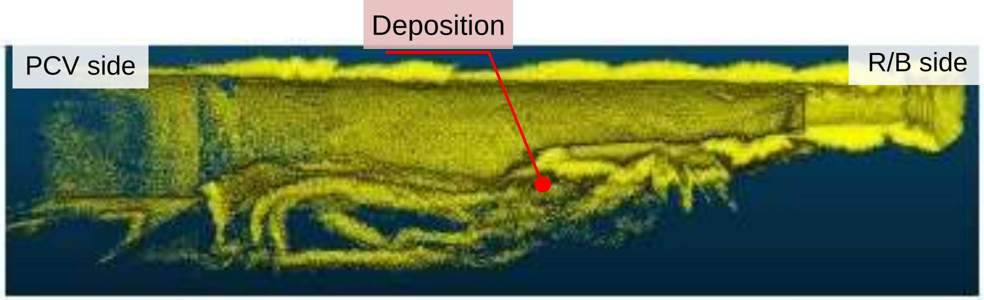
Horizontal section view (directly upward direction)



Vertical section view (right side view from R/B)



Horizontal section view (diagonally upward direction)



Vertical section view (left side view from R/B)

4.2 Equipment related to establishing the access route

(2) X-6 penetration hatch opening: The overall plan and preparation

【Overview】

➢ The X-6 penetration hatch is opened by remote operation to establish the access route through which the investigation equipment enters the PCV from the X-6 penetration, while ensuring that the isolation room*1) functions as the PCV boundary.

【Progress status in FY 2020】

➢ The site test was carried out to confirm operability of equipment. Additionally, detailed work steps based on training results were created and the site investigation was conducted.

(Specifications and structures of the isolation room>

【Common specifications】
○Pressure resistance: 6kPa(G)(1F=2 management value 5.5kPag or less)
○Main material: Carbon steel

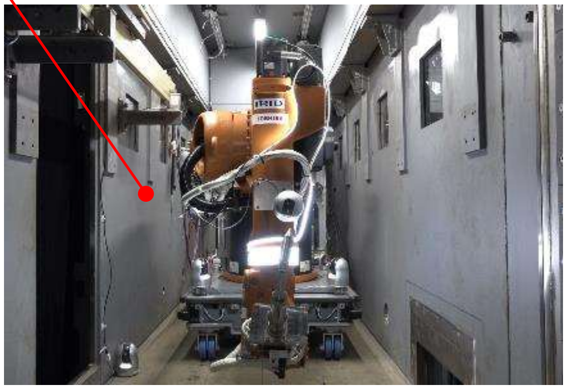
【Isolation room in the stage】
○Functions:
➢ Serves as a boundary covering the interior of the concrete stage in the area from the X-6 penetration sleeve to the hatch isolation room.
○ Specifications: Approx. 1ton/W1.2×L1.7×H1.8m

【Hatch isolation room】
○ Functions:
➢ Serves as a boundary while the hatch is being opened.
➢ Serves as a boundary/shielding by means of an air-tight door after the hatch has been opened.
○ Specifications: Approx. 5.5ton/W1.7×L5.3×H2.5m

【Hatch opening device】
○Functions:
➢ Opens the hatch of the X-6 penetration
○Specifications: Approx. 2.3ton/W1×L2×H1.6m

【Robot carry-in room】
○Functions:
➢ Serves as a boundary while the hatch is being opened /during carry-in and carry-out of equipment
○ Specifications: Approx. 8ton/W1.7×L5.3×H2.5m

Isolation room (full view from behind)



Hatch opening device (installed in the isolation room

*1) Isolation room: In-stage isolation room, hatch isolation room and robot carry-in room are collectively called “isolation room.”

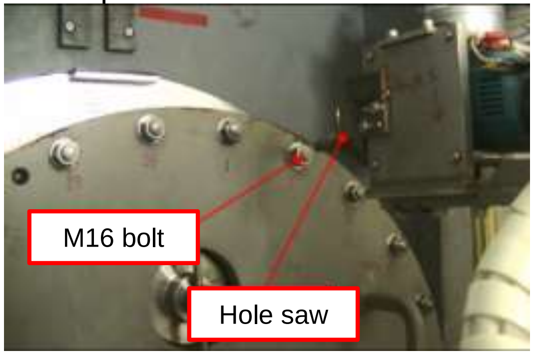
4.2 Equipment related to establishing the access route

(2) X-6 penetration hatch opening, entire planning and preparation

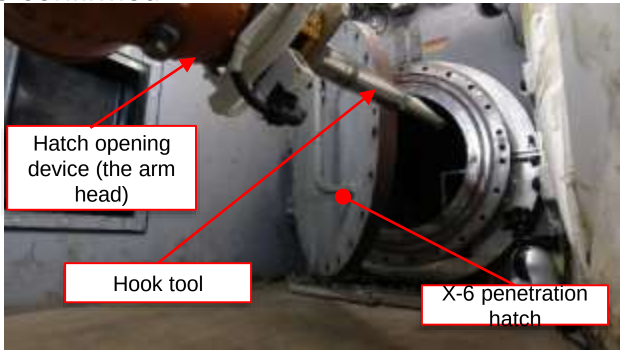
【The operability confirmation test】

- The operability test for the main steps was conducted to confirm the work procedure and allocation of the workers and the work hours.
- Work hours in each step to finish work within specified work hours at the site were confirmed.

In-stage isolation room installation work



Fastened bolt releasing work using a hole saw



Hatch opening by using a hook tool

【Site investigation】

- Site investigation of the inside of the reactor building and the west yard was undertaken to verify hatch opening at the site. The information obtained in this investigation will be utilized for the site verification.

Measuring the west yard

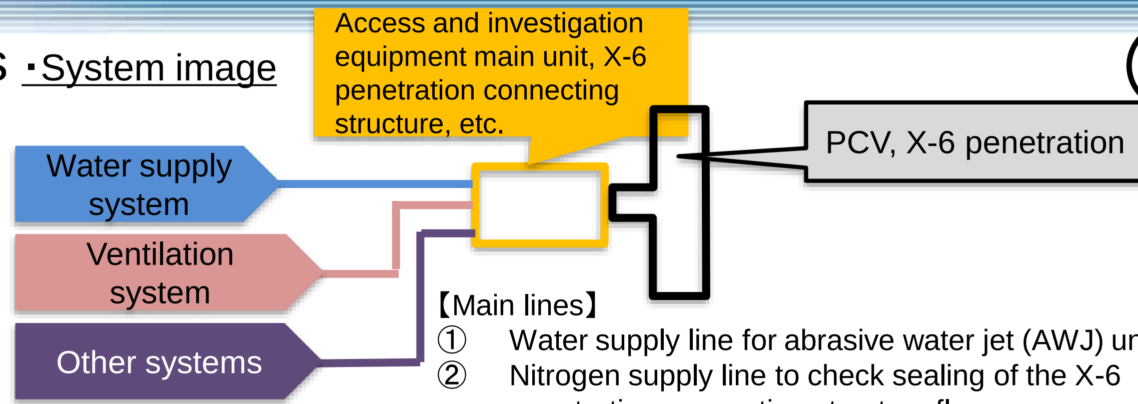
Detecting buried metal in the reactor building

4.3 Other ancillary facilities

(1) Design and manufacturing

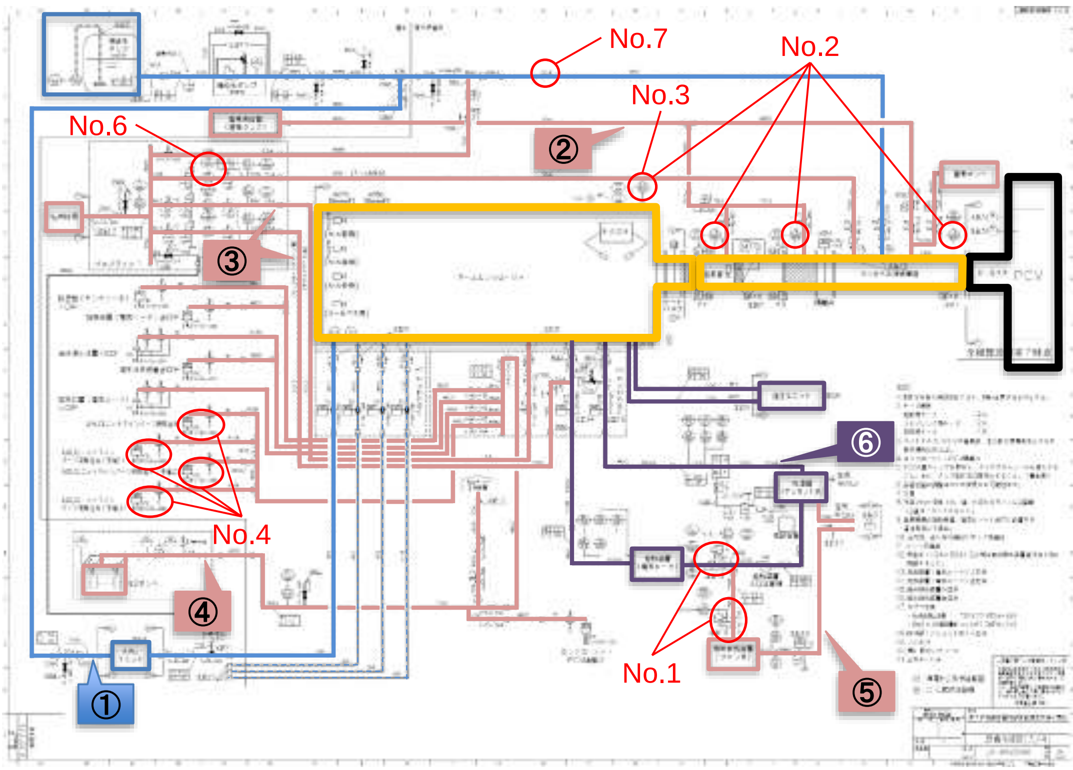
i . System plan

・System image



【Main lines】
- ① Water supply line for abrasive water jet (AWJ) unit
- ② Nitrogen supply line to check sealing of the X-6 penetration connection structure flange
- ③ Nitrogen purge line connecting to a maintenance manipulator in the enclosure
- ④ Nitrogen supply line for air actuating valve
- ⑤ Nitrogen (air) exhaust line
- ⑥ Dehumidifying circulation line of the enclosure

・Actual system plan



No	Revisions since FY 2020	Reasons for revision
1	The valve of a dehumidifying circulation line(V-VS-003,010) was replaced with an opening control valve.	Improvement of operation performance by adding a flow regulation function.
2	A pressure gauge (PT-001,002,003,004) was displayed in the operation room.	Improvement of monitoring for the access and investigation equipment main unit, the X-6 penetration connection structure, etc.
3	A pressure gauge (PT-001) function was added to activate an alarm when the pressure is high or low.	Improvement of enclosure protection function.
4	A valve of a water supply line for AWJ unit (V-WJ-002,004,006,008) was replaced with an air controlled valve.	Improvement of operation performance.
5	A strain measuring instrument of the X-6 penetration was removed.	Reflecting elimination of requirements from the connecting structure side.
6	Nitrogen flow measurement (FT/FI-020) for arm cleaning was added.	Improvement of management functions for amount of consumption of nitrogen.
7	A hose diameter in the exit side of supply water pump was changed (25A→20A).	Improvement of procurement efficiency.

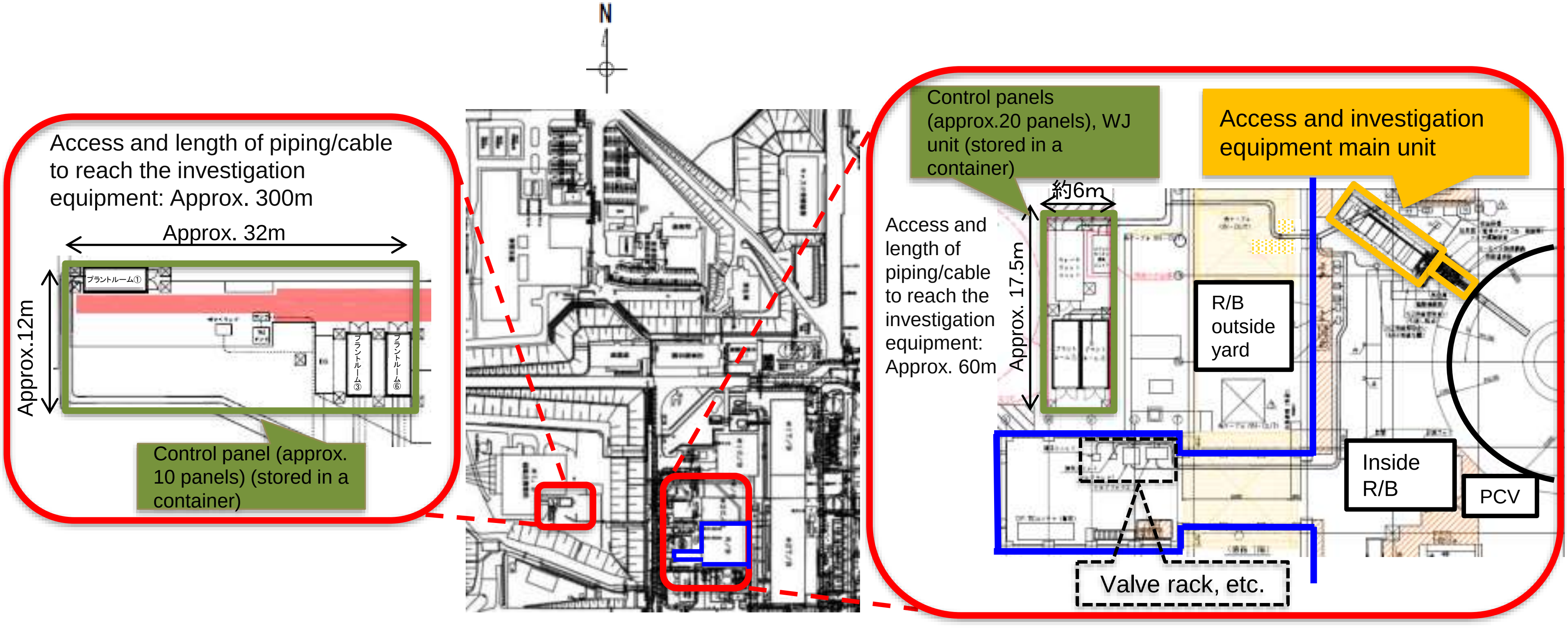
➡The system plan was partly revised and refined to improve the operation performance.

4.3 Other ancillary facilities

(1) Design and manufacturing ii . Site allocation plan

・The site investigation was carried out and the site allocation plan was reviewed considering the latest site environment conditions (radiation dose, distance constraints*, congestions with other constructions by TEPCO Holdings, Inc., etc.)

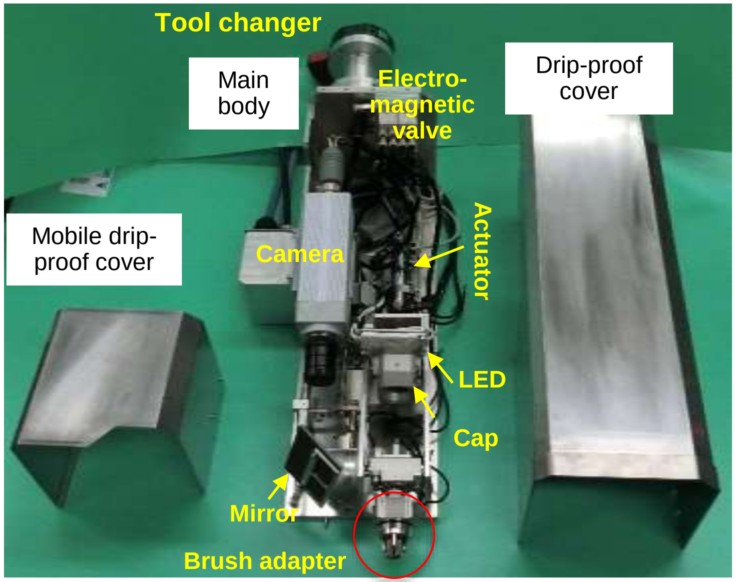
* There are constraints on access and distance to the investigation equipment main unit (including sensors), control panels and abrasive water jet (AWJ) unit from the viewpoint of voltage drop, noise, pressure loss of piping, etc.



R/B: Reactor building

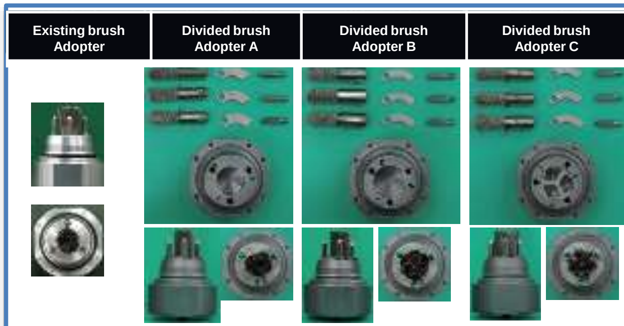
4.4 Equipment for collecting fuel debris 【Brushing method】

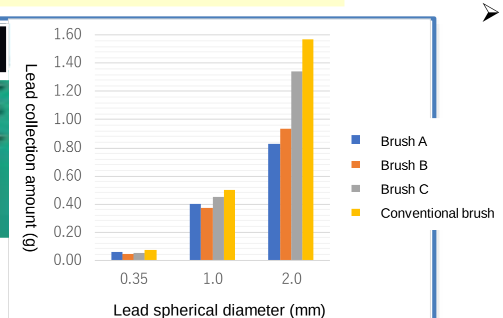
Some revisions were made **to improve handling property** by using a manipulator and to **reduce temperature inside equipment.**



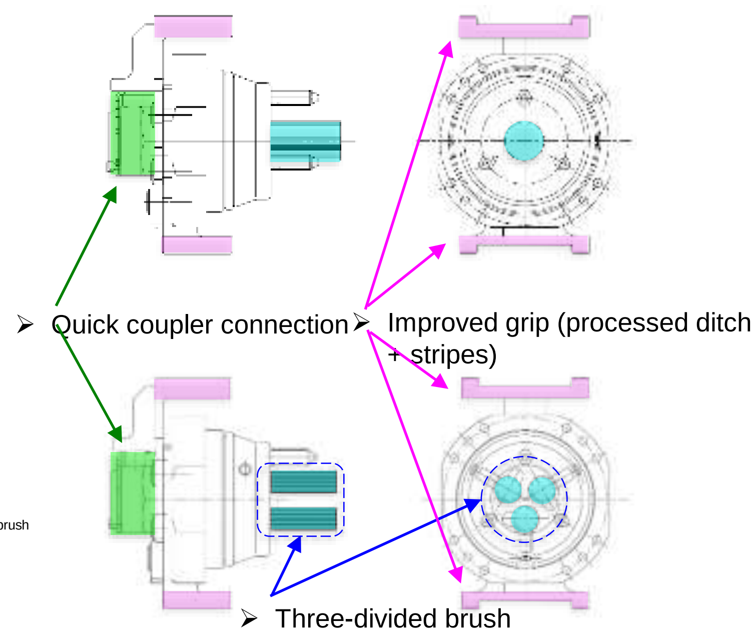
	Parts	Revised design
Brush method	Brush adopter	Improvement of handling capability by a manipulator Simplified operation of implementation/removal of brush adopter
		Three-divided-brush structure (simplified collecting work)
Common parts	Camera and light	Adopted LED module (temperature reduction in equipment)
	Drawing position for cables	Improvement of handling capability to avoid interferences when connecting cables, etc.

Dimensions: Length 542mm x Width 211mm x Height 204mm (including a gripper)
Mass: 7.6kg





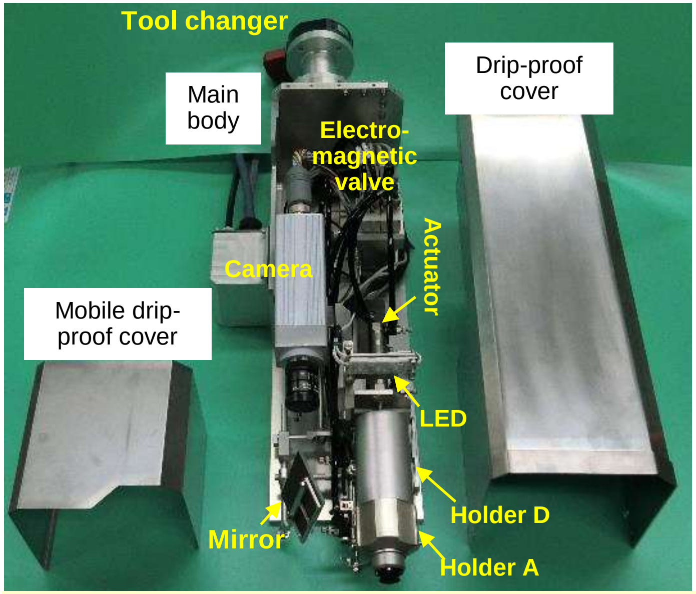
Divided brush performance test for collecting simulated fuel debris



Improved brush adapter structure (one-touch method)

4.4 Equipment for collecting fuel debris 【Sucking method】

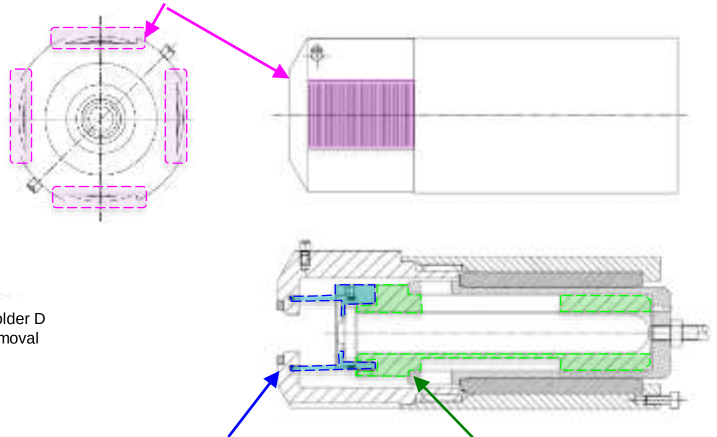
Some revisions were made **to improve handling property** by using a manipulator and to **reduce temperature inside equipment.**



Dimensions: Length 550mm x Width 211mm x Height 204mm (including a gripper)
Mass: 8.2 kg

	Parts	Revised design
Vacuum vessel	Holder A/D Spring guide	Improvement of handling capability by a manipulator
Common parts	Camera/light	Adopted LED module (temperature reduction in equipment)
	Drawing position for cables	Improvement of handling capability to avoid interferences when connecting cables, etc.

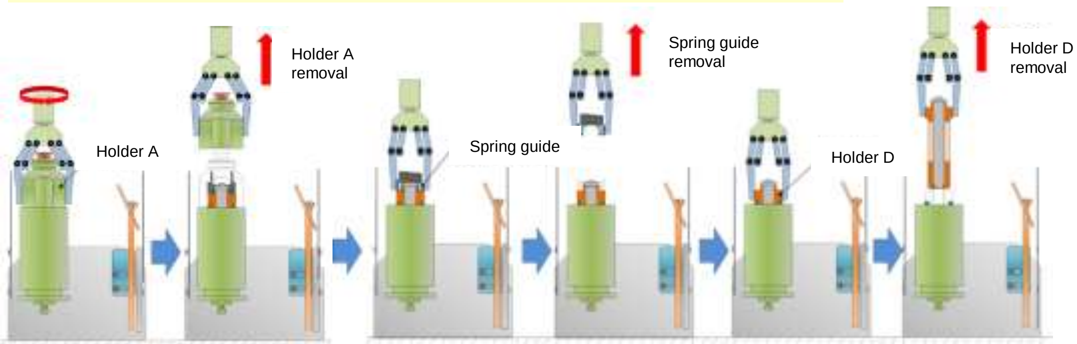
Holder A
- Improved grip (processed ditch + stripes)



Spring guide
- Unified spring and guide
- Improved grip (processed ditch)

Holder D
- Improved grip (processed ditch)

Improved holder structure



Flow of improved holder removal

4.4 Equipment for collecting fuel debris 【Temperature reduction in equipment】

【Purpose】Study of **adoption of low heat light** because of a concern that internal temperature may exceed the operating temperature limits.

【Conditions】Environmental temperature in the PCV: 40℃ Temperature limits: Electro-magnetic valve (50℃), camera (55℃), actuator (60℃)

【Results】**LED module: BFL359MX24 will be adopted.**

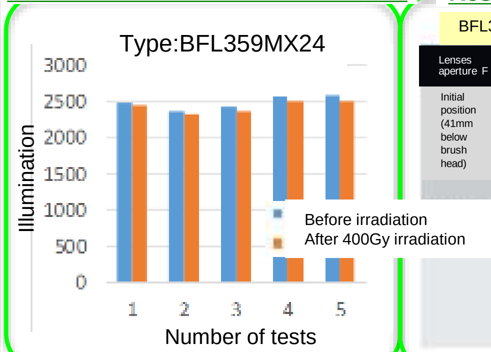
Low voltage LED module

Performance comparison results of low voltage LED modules

Candidate light	Temperature in equipment	Radiation resistance *1)	Camera image	Voltage decrease (calculated value)	Evaluation
Current light (10W)	x	--	--	--	x
LED module BFL366DW12x2(1.0Wx2)	○ Less than temperature used in equipment	○ (underway) Small change in illumination before/after irradiation(rate of change:-1.5-1.4%)	○ Clear image Camera diaphragm:F5.6	5.6V](140m, 0.16A, 0.13sq)	○
LED module BFL359MX24x1 (1.6W)	○ Less than temperature used in equipment	○ (underway) Small change in illumination before/after irradiation (rate of change:-2.9-1.5%)	○ Clear image Camera diaphragm:F4	2.3V (140m, 0.066A, 0.14sq) Small voltage drop	◎
LED module OZLM1D65x2(1.4Wx2)	○ Less than temperature used in equipment	○ (underway) illumination before/after irradiation (rate of change:-2.5-2.3%)	△ Darker than others Clear image Camera diaphragm:F5.6	8.3V (140m, 0.24A, 0.14sq)	△

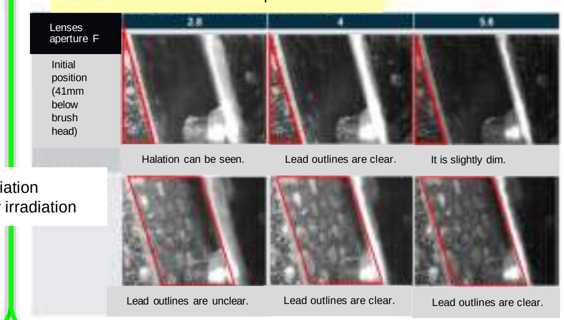
*1) LED module power off, gamma ray irradiation (dose rate: More than100Gyh, accumulated dose rate: 80Gy) The LED module will be power-on, gamma ray irradiation test (dose rate: More than 10Gyh, accumulated dose: 20Gy) will be conducted.

Results of radiation-resistance test



Results of test for adjusting camera lenses

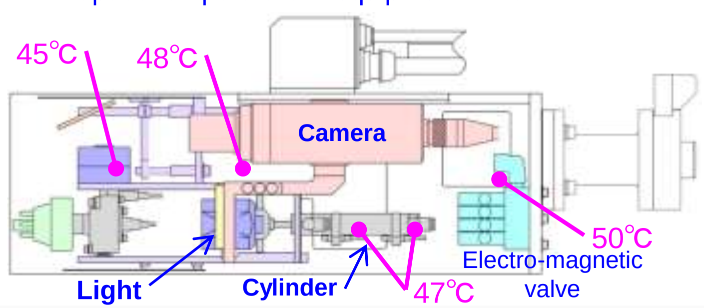
BFL359M24x1 Unit: Lens aperture F4



Result of temperature test in equipment

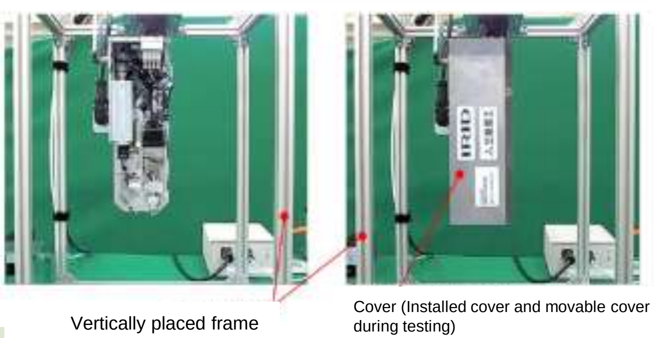
LED module light: BFL359MX24×1

*Space temperature in equipment at 40℃



Temperature limits

Device	Operating temperature limits
Camera	0℃～55℃
Electro-magnetic valve	-10℃～50℃
Cylinder	0℃～60℃



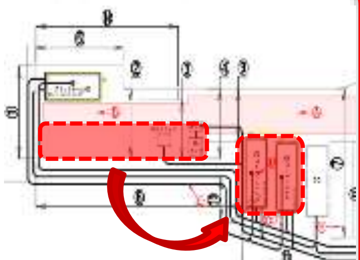
Test conditions

4.5 Conducting field demonstrations

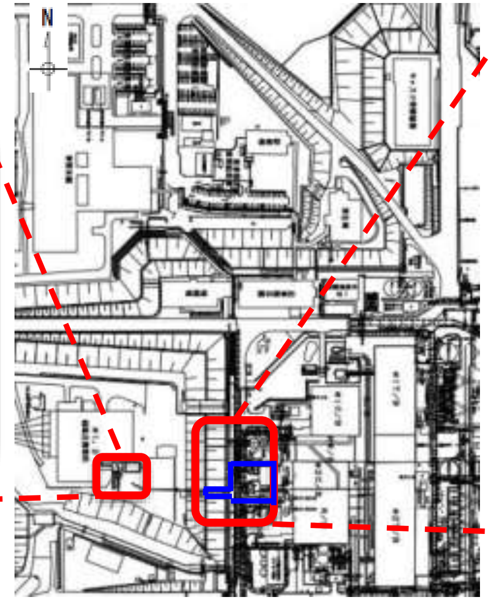
(1) Site investigation

The site investigation confirmed the feasibility of satisfying various conditions of the space required for implementation of the existing building and utilities, and traffic lines of construction vehicles (reflecting the site investigation results in a layout plan, ref. 4.3 (1) ii.).

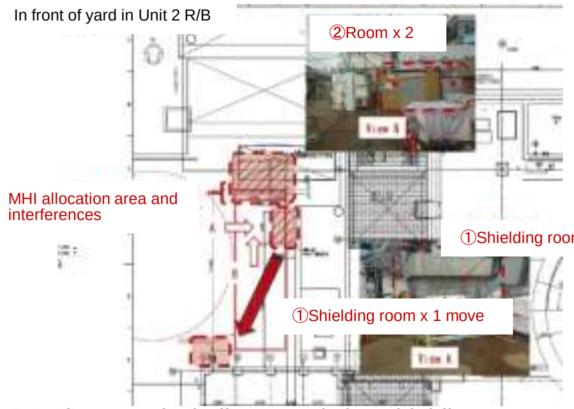
Plant room area A (ultra-high pressure open/close area)



Allocation of the plant room is changed to ensure enough space for connection of construction vehicles.



Plant room area B (Unit 2 R/B west yard)



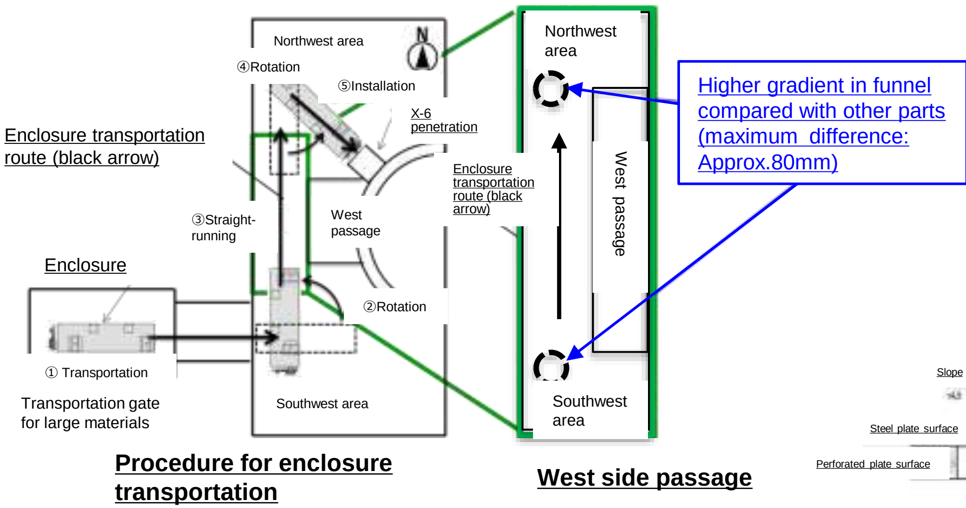
Interferences including an existing shielding room are planned to be removed in advance.

4.6 Others

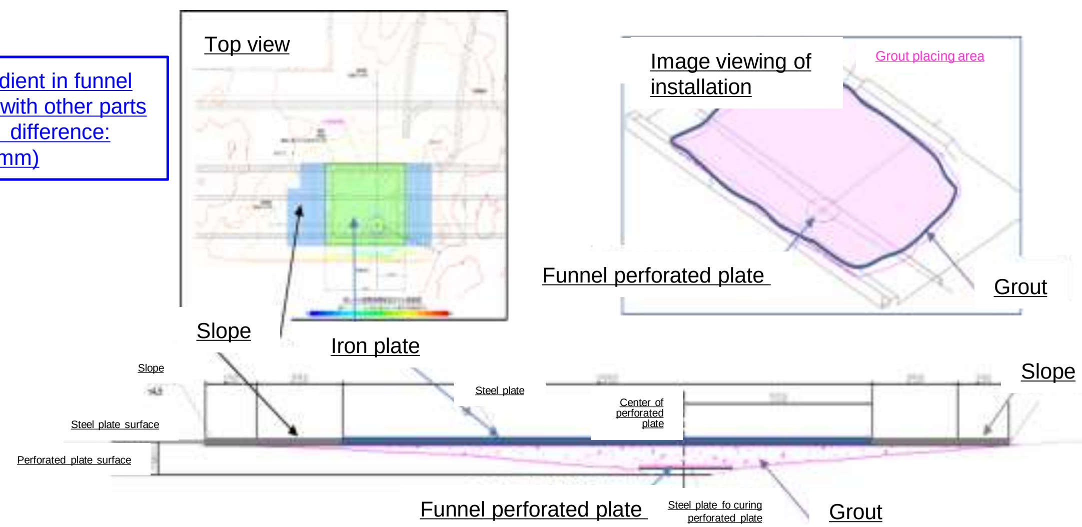
(1) Countermeasures for reliability improvement of transporting the access and investigation equipment

i. Funnel planarization

- When transporting the enclosure, it is necessary to planarize depressed parts of the floor funnel at two parts of the transportation route (northwest and southwest of the reactor building (R/B)) for the stable transportation in the R/B.
- As a result of comparing the planarizing methods, a planarizing method of filling in depressed parts with grout was adopted (Reason for selection; Durability of grout is high and there is no radiation exposure during implementing grout).



Floor funnel on the transportation route



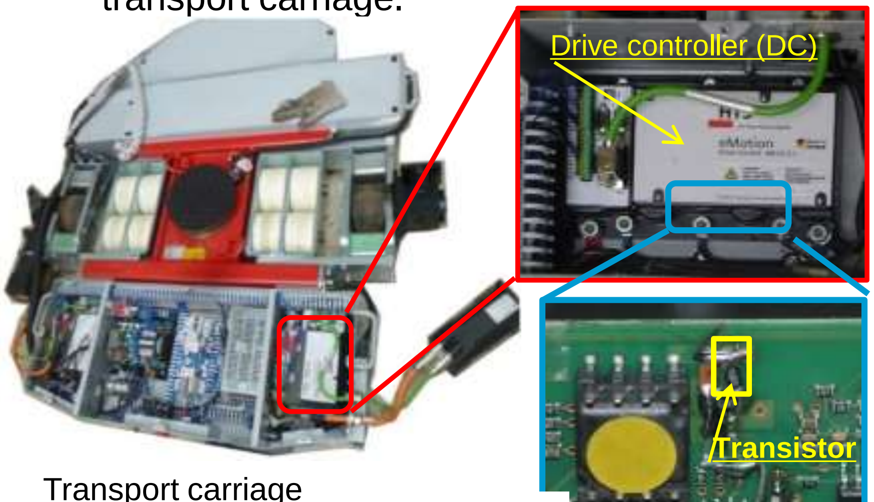
Planarizing method using grout

4.6 Others

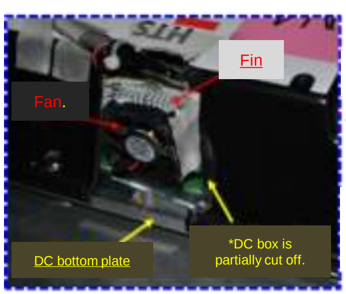
(1) Countermeasures for reliability improvement of transporting the access and investigation equipment

ii. Study on reliability improvement of the transport carriage

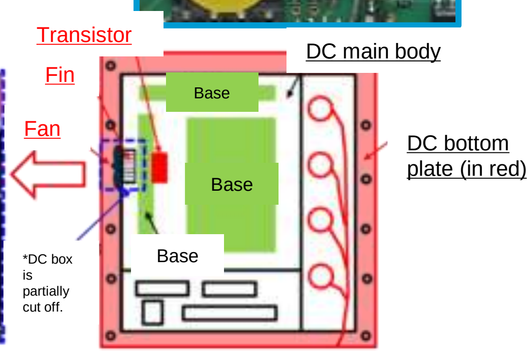
- As a result of a test that was carried out to determine the cause of transport carriage accidents, it was confirmed that a high temperature environment would increase the possibility of failure due to the transistor on the drive controller (DC) substrate.
- As a countermeasure against high temperatures, a fin fan was installed on the transistor substrate to confirm the effectiveness of temperature rise suppression, and the fan was also installed for the transport carriage.



Transport carriage



Appearance of fin fan installation



DC figure of fin fan installation (top view)

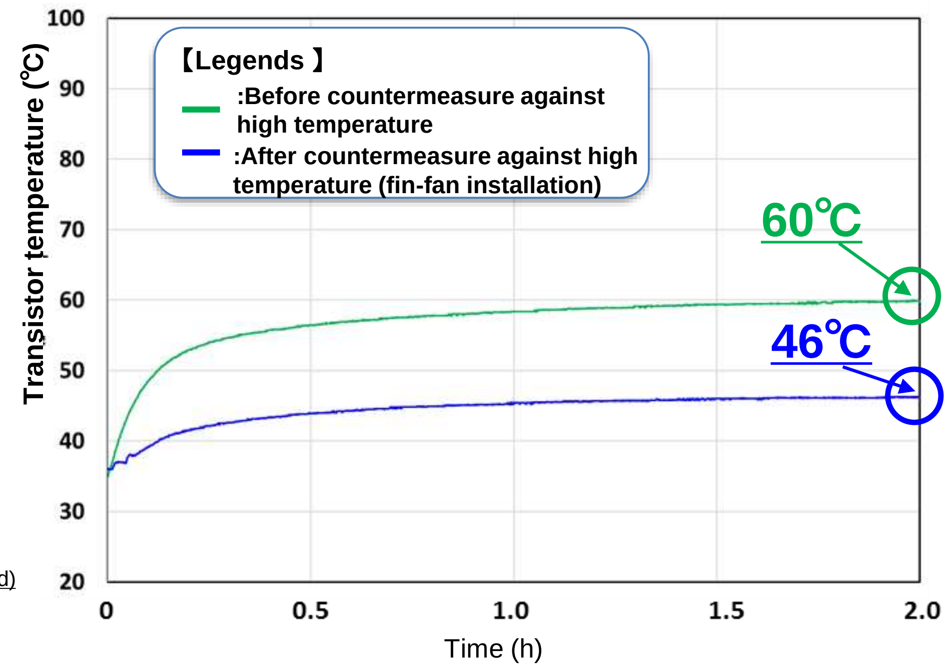


Fig. Temperature changes of the transistor before/after countermeasure against high temperatures (2-hour operation, outside temperature:: 35℃)

4.6 Others

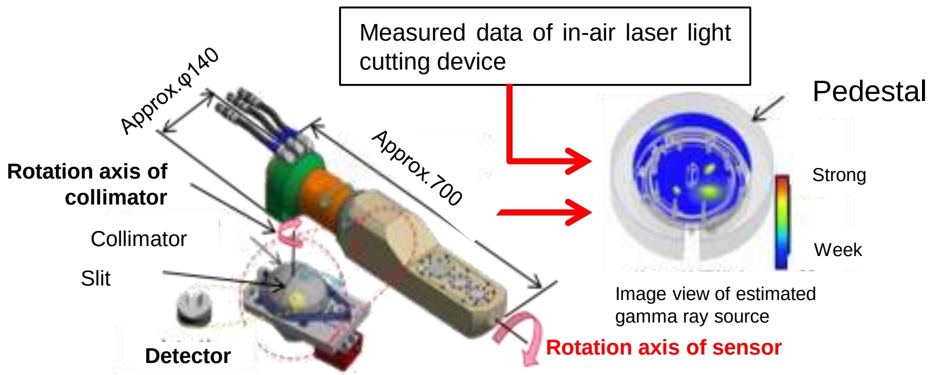
(2) Study on calibration of gamma sensor and assembly of maintenance gamma sensor

i . Study on calibration of gamma sensor

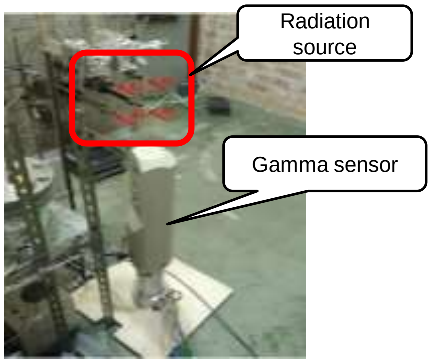
- To ensure a dynamic range of approximately 1Gy/h – 1000Gy/h (assuming isotropic radiation source), output voltage was calibrated to be an appropriate value for spatial dose rate, and its nearly linear shape was confirmed.

  * Silicon diode with temperature dependency was used as a detector.
- Irradiation test was carried out after calibration. The test result confirmed that the direction of the gamma sensor to detect radiation dose was appropriate.

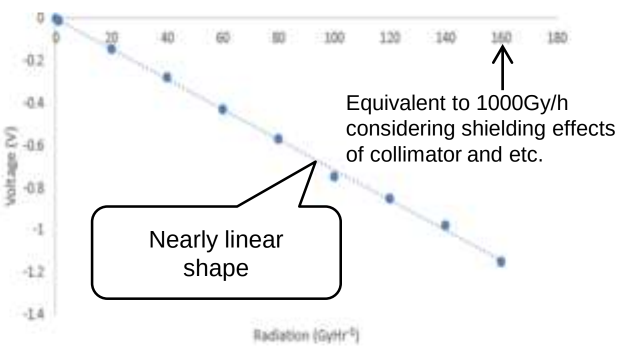
  * A gamma sensor is designed to measure the distribution of gamma source in the PCV, and to contribute to estimating the location and distribution of fuel debris in combination with measured data of the in-air laser light cutting device.



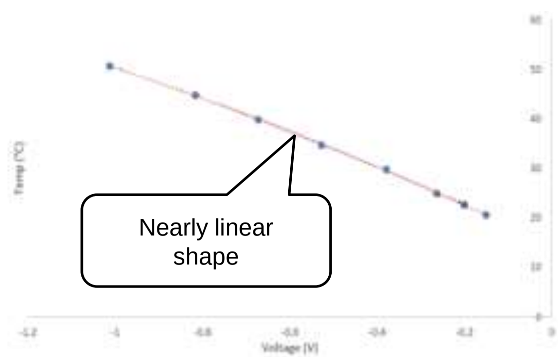
Overview of gamma sensor and image figure of estimating gamma radiation source



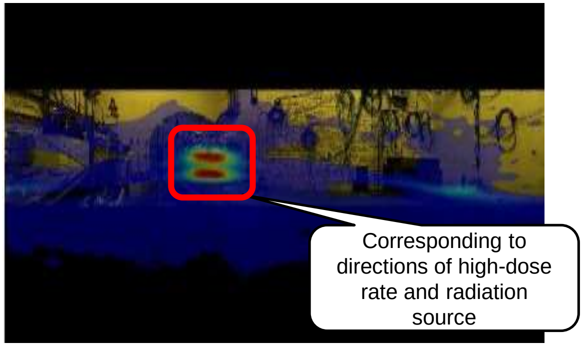
Test environment for measuring the distribution of radiation dose



Relationship with spatial dose rate and output voltage



Relationship with output voltage and temperatures of detector



Overlapping image of measurement result and panoramic image

4.6 Others

(2) Study on calibration of gamma sensor and assembly of maintenance gamma sensor

ii . Assembly of maintenance gamma sensor

- Manufacturing of maintenance gamma sensor, basic performance inspection and calibration were carried out.

* A maintenance gamma sensor is used when maintenance of the gamma sensor is required

Maintenance gamma sensor

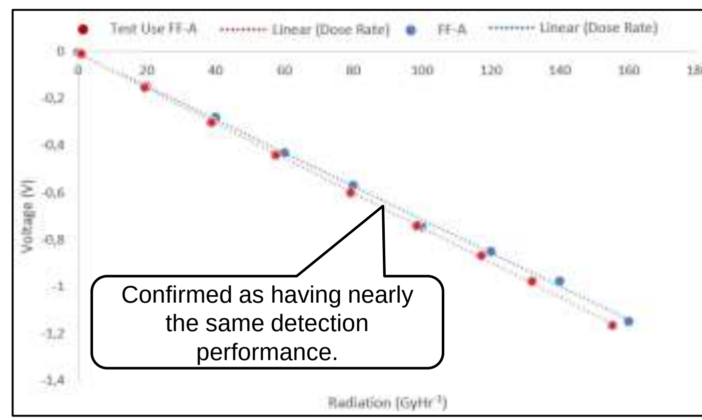
Oven and detector

Radiation Sources

Ambient Temperature Thermocouple (near)

Appearance of calibration facility

Appearance of basic performance inspection



Relationship between output voltage of detector and spatial dose rate

Maintenance gamma sensor: Test Use FF-A (red)

Gamma sensor: FF-A (blue)

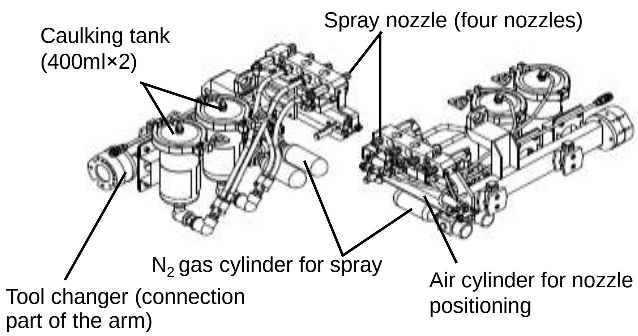
4.6 Others

(3) Design, manufacturing and verification of caulking coating tool

➢ Design and manufacturing of *caulking coating

Items	Specifications
External dimensions	H266mm×W293mm×L493mm
Weight	12.9kg
Driving method	Nitrogen gas supply (0.5MPa)
Coating method	Spray
Caulking materials	Styrene-butandiene rubber (SBR) Xylene (solvent)
Coating performance	Coating area: φ600mm Pressure resistance in coating area: 11kPa

*A tool designed to spray caulking materials to seal an isolation valve when a sheet leak occurs at the isolation valve sealing part.

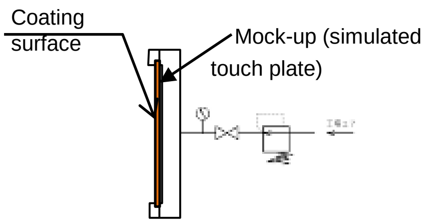


➢ Performance verification by a single function test

Items	Test results
① Coating test	A coating test of a mock-up (simulated touch plate) was carried out. ⇒Possible to coat more than the area of φ600mm by remote operation.
② Pressure resistance, air-tightness and leakage tests in the coating area	Caulking coating parts of a mock-up was pressurized up to 11kPaG (maximum value of differential pressure in the PCV and the enclosure) to confirm pressure resistance and air-tightness, and measure leakage amount ⇒No deformation was confirmed by visual observation. ⇒Leakage rate was confirmed to be less than 0.05vol%/h.

Coating test facility

After coating caulking material



Pressure resistance and leakage test

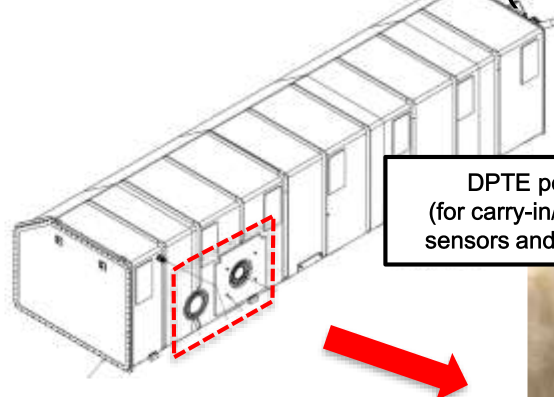
4.6 Others

(4) Design, manufacturing and verification of the DPTE container (1/2)

➢ Overview of the DPTE container

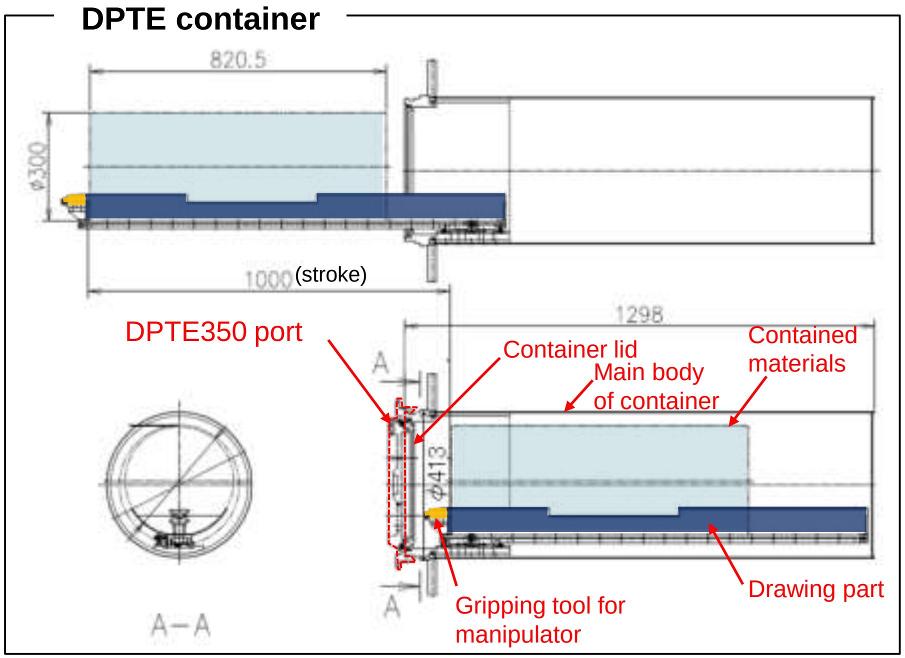
✓ It is a cylindrical type container installed on the DPTE port located at the side of the enclosure to carry in/out investigation sensors and tools, and to carry out fuel debris.

✓ The DPTE container is designed to fit onto a port via a double door interface. Materials can be transported while maintaining airtightness inside the enclosure and atmosphere in the reactor building to prevent spreading contamination.



➢ Design of the DPTE container (for carry-in/out of sensors and tools)

Items	Specifications
External dimensions	φ413mm×L1298mm×t1.5mm
Weight	Approx. 95kg
Materials	Container/lid: SUS304 Sealing part: Silicon rubber Drawing part: SUS304 (main structure part)
Containing part	Containing part: Less than φ300mm×L1100mm Containing weight: Less than 50kg
Pressure resistance and leakage	Pressure resistance:-5〜10kPaG、 Leakage amount: Less than 4×10^{-2}Pa・m^3／s
Major use	Carry-in/out of investigation sensor and tools



4.6 Others

(4) Design, manufacturing and verification of the DPTE container (2/2)

➢ Prototype and in-factory test of the DPTE container (carry-in/out of sensors and tools)

Items	Test results
①Appearance /welding inspections	Visual observation confirmed that there are no signs of significant damage, scratches or dirt. Non-destructive inspection (PT testing) for the welding part was carried out. The test result confirmed that there is no harmful defect.
②Operation check	Drawing and pressing force in the drawing part were measured. ⇒The test result confirmed that it can be operated at less than the specification value (10kg) of the maintenance manipulator.
③Pressure resistance/ leakage tests	(a)Applied and reduced pressure up to -5～10kPaG (design specification pressure of the enclosure) in the container. ⇒Visual observation confirmed that there is no deformation.
	(b)Leakage amount of a sealing part of the container main body was measured when 10kPaG pressure is applied. ⇒Test results confirmed that the design specifications (less than 4×10^{-2}Pa･m^3/s) were satisfied.
	(c)Leakage amount of a sealing part of the connection with the container and port (interface) was measured when10kPaG pressure is applied. ⇒Test results confirmed that the design specifications (less than 4×10^{-2}Pa･m^3/s) were satisfied.

Appearance inspection

Operation check (drawing part)

Pressure resistance and leakage test

4.6 Others

(5) Improvement of deposition removal equipment

➢ Performance validation of cable removal

When a performance test was carried out in FY 2019, a cable was caught in between the partition for testing and the CRD rail and remained on the CRD rail.

In FY 2020, performance validation of deposition removal was re-confirmed after reflecting the latest information of the deposition and reviewing a mock-up facility.

The test results confirmed that the range of cable removal was extended (a cable remaining at the upper half of a route that the arm-type access equipment will pass through was almost totally removed.

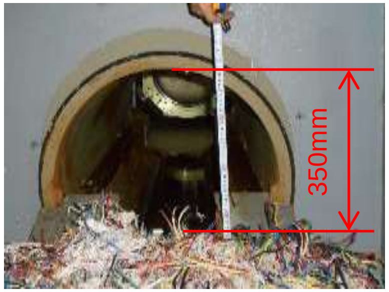
Items			Mock-up in FY2020	Mock-up in FY2019
Mock-up	CRD rail Space between left and right		One side: 600mm	One side: 200mm
	Grating scaffold on the CRD rail		Mock-up	No mock-up
Simulated deposition (*)	Remaining cables	Number of cables	11 cables	←
		Length	Approx. 8m	Approx.13m
	Deposition		Approx. 15L	Approx. 38L

*Latest information

Mock-up (FY2020)

Mock-up (FY2019)

Confirmation results (FY2019)



Confirmation results (FY2020)

5. Summary and future plan

(1) Summary of achievements in FY 2020

a. Access and investigation equipment:

i) The X-6 penetration pass-through test of the investigation arm test was carried out. The test results confirmed that the arm can pass through a narrow area and that controllability was improved.

ii) A mock-up test of a maintenance manipulator was carried out. The test results verified that the camera for the investigation arm can be replaced and the position of camera in the enclosure can also be changed by remote operation.

b. Isolation room and hatch opening equipment:

An operability test was carried out for the site operation. Additionally, detailed work steps were created based on training results and the site investigation was conducted.

c. The design of fuel debris collection equipment was improved and modified, and the site allocation plan was reviewed based on the site investigation results.

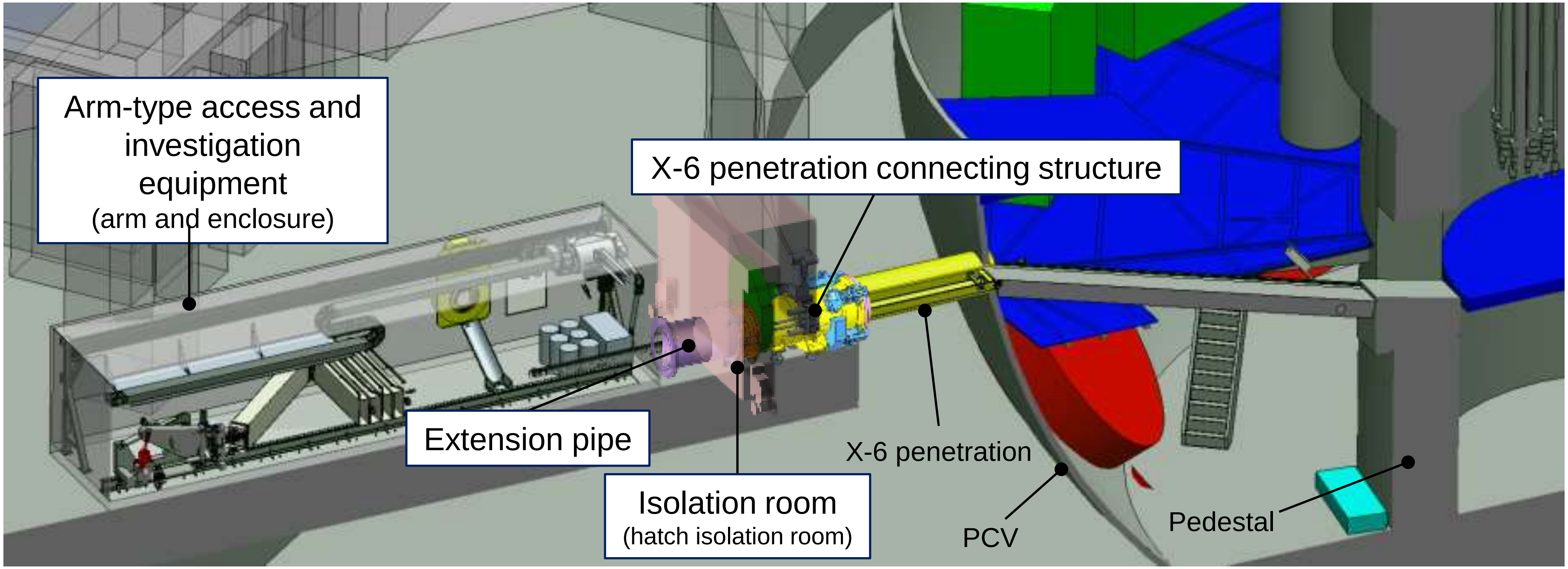
(2) Plans for FY 2021

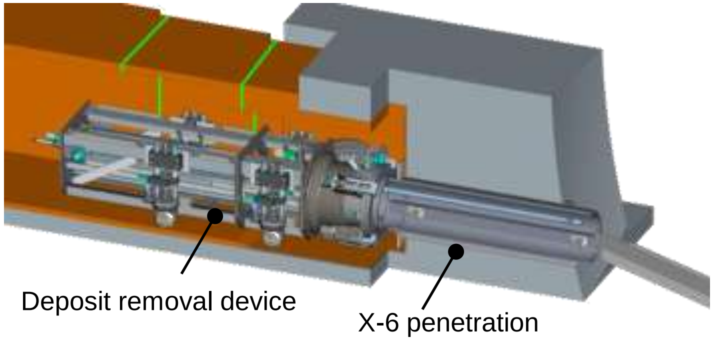
a. Testing of the access and investigation equipment will be continued in factories (UK/Japan), after which mock-up tests will start.

b. A field demonstration for other related equipment for establishment of the access route will start accordingly after training.

Appendix

Developed technology



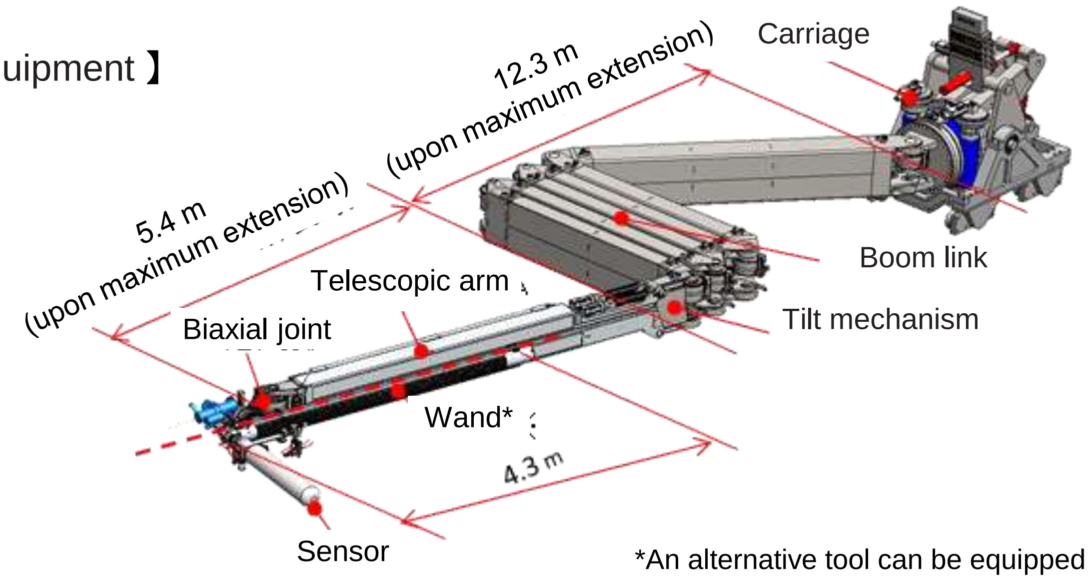


Equipment and structures	Main purpose
Arm-type access and investigation equipment	Acquisition of data on the inside of PCV (equipped with sensors), removal of obstacles (equipped with tools)
X-6 penetration connecting structure	Construction of PCV boundary and provision of access for arm (equipped with isolation valve)
Extension pipe	Shielding and provision of access for arm
Isolation room	Shielding and construction of PCV boundary while X-6 penetration lid is open (before X-6 penetration connecting structure is attached)
Deposit removal device	Removal of deposit, etc. from inside the X-6 penetration

Access and investigation equipment

【 Specifications and structure of arm-type equipment 】

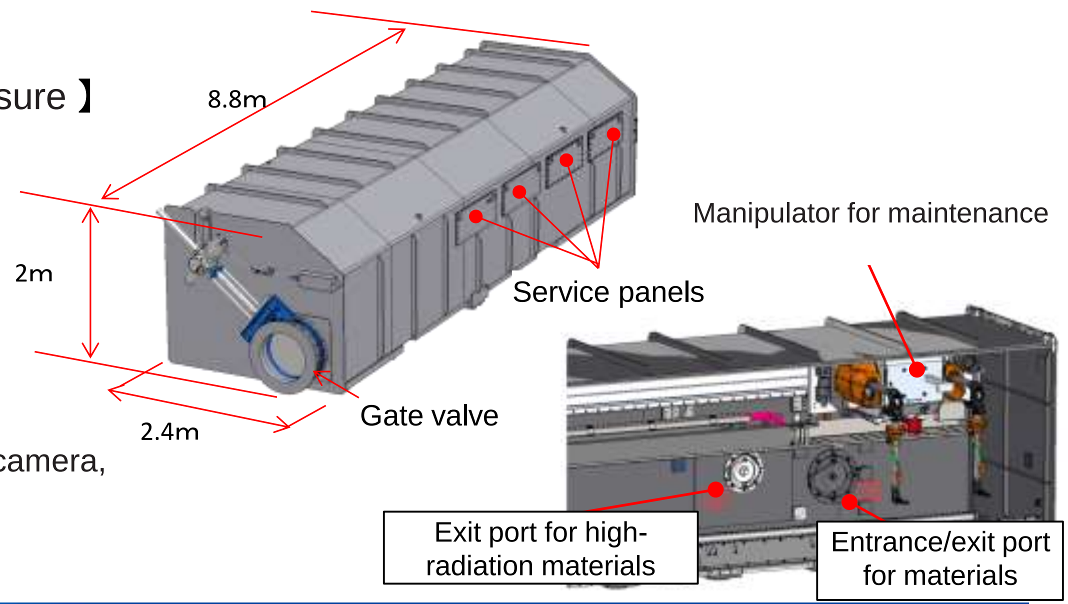
- ✓ Mountable sensor: 10 kg or less
- ✓ Mounted tools: Cutting and gripping tool
  water jet cutting tool
- ✓ Arm length: Approximately 18 m (except wand)
- ✓ Pressing force: 400 N
- ✓ Positioning accuracy: ±100 mm
- ✓ Accumulated dose: 1 MGy
- ✓ Accessories: Camera and light



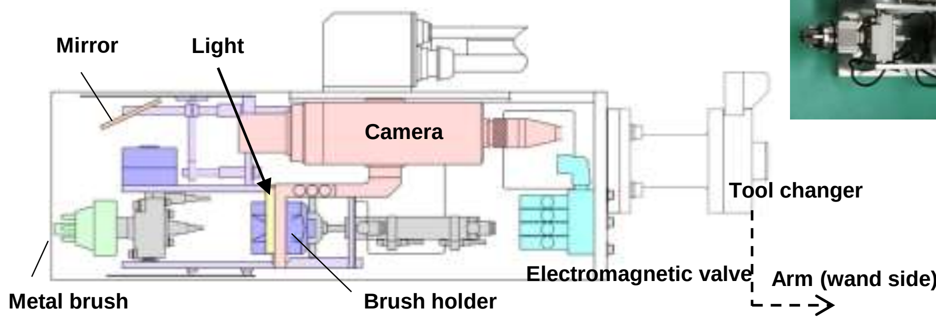
*An alternative tool can be equipped.

【 Specifications and structure of the arm enclosure 】

- ✓ Thickness of outer panel:
  10 mm for top and side panels
  25 mm for bottom panel
- ✓ Weight: approximately 30 tons
- ✓ Main material: Stainless steel
- ✓ Designed to withstand pressure: −5 to +10 kPaG
- ✓ Leakage rate: 0.05 vol%/h
- ✓ Accessories:
  Dual-arm manipulator for maintenance, gate valve, camera, light, etc.



Equipment for fuel debris trial retrieval

Method	Overview
Ultrafine metal-brush method Collecting of powdery deposition in the air (approximately Φ2mm)	**The deposition in the PCV is collected by using a metal brush on the tip.** **Mass** 7.6 kg **Dimension** Length 542mm×Width 211mm×Height 204mm  
Vacuum tube method Collecting powdery deposition together with water (less than Φ2mm)	**Collecting of deposition by sucking into vacuum tube.** **Mass** 8.2kg **Dimension** Length 550mm×Width 211mm×Height 204mm