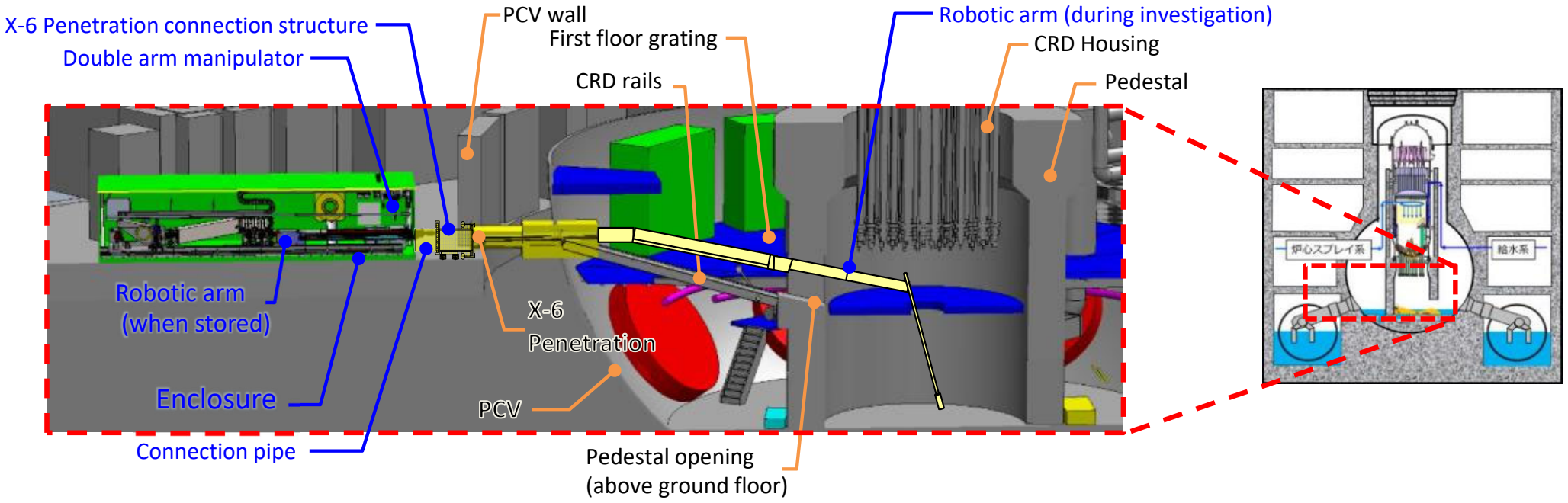
Unit 2 PCV Internal Investigation/ Preparation Status of Fuel Debris Trial Retrieval

January 25, 2024

International Research Institute for Nuclear Decommissioning
Tokyo Electric Power Company Holdings, Inc.

1. PCV internal investigation and trial retrieval plan overview

- In order to guarantee work safety and prevent the spread of contamination, the following equipment will be installed at the penetration to the Unit 2 primary containment vessel (hereinafter referred to as, "X-6 penetration") that will be used for the PCV internal investigation and also as a preparatory stage of trial retrieval.
  - A work room (isolation chamber) isolates the PCV when opening the X-6 penetration hatch
  - The X-6 Penetration connection structure isolates the inside of the PCV from the outside
  - The connection pipe shields radiation
  - A metal box that contains the robotic arm (enclosure)
- After installation of the aforementioned equipment, the robotic arm shall be fed into the PCV through the X-6 penetration to remove obstacles inside the PCV while also conducting internal investigations and moving forward with the trial retrieval of fuel debris.



Unit 2 internal investigation/trial retrieval plan overview

2. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment (Performance Tests)

- Tests are being performed on a mockup of the X-6 penetration at the Naraha mockup facility.
- Since we have confirmed that the bottom of the pedestal can be accessed without coming in contact with any of the surrounding structures during manual operation, and that obstacles can be cut away/removed, the fourth and final step of remote automatic operation tests to access the bottom of the pedestal and pass through the X-6 penetration are being implemented.
- When actually retrieving fuel debris, it will be necessary to repeatedly pass the robotic arm through very narrow spaces. Therefore, we continue to improve and optimize the control program in order to improve precision in preparation for using this technology in the field, and also the linkage between hardware and software, so as to reduce the risk of coming in contact with other structures. We are also simultaneously performing other tests.
- Furthermore, in addition to robotic arm testing, we are also developing this technology while confirming applicability to the actual worksite by looking at procedures that simulate actual work tasks, operator operability, and equipment reliability.

Performance tests

Covered in this report

Test category	Test details	Naraha
Robotic arm-related tests	Ability to pass through the X-6 penetration	Underway
	Removing obstacles at the exit for the X-6 penetration using the AWJ	Completed (work efficiency being examined)
	Function tests (deflection management, etc.)	Completed
	Ability to access the inside of the PCV ・Accessing the top of the pedestal ・Accessing the bottom of the pedestal	Underway
	Removing obstacles inside of the PCV ・Cutting obstacles inside the PCV after passing through the X-6 penetration	Completed (work efficiency being examined)
Double arm manipulator-related tests	Connecting sensor tools to the arms	Completed
	Connecting/removing the external cables to/from the arms	Completed
	Bringing in and removing sensor tools	Completed
	Removing the fixed arm jig	Completed
	Replacing arm cameras/lighting	Completed
	Changing the position of the enclosure camera	Completed
	Forced withdrawal of the arm	To be performed going forward
Combined tests (robotic arm + double arm manipulator	Performing tests on the series of tasks that will be needed for the investigation by combining both the arm and the double arm manipulator ・Investigation of the top of the pedestal ・Investigation of the bottom of the pedestal	To be performed going forward

3-1. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment (Pedestal Access Tests)

- In order to ascertain arm functions/applicability, we are currently conducting the fourth and final step of testing that focuses on “passing the robotic arm through platform openings (narrow spaces) and accessing the bottom of the pedestal”, which is important and technically difficult.

<Testing steps>

*Teach & repeat file (a file that determines the movements of each axis of the robotic arm)

Step 1

・Accessing the bottom of the pedestal with the arm (worker-assisted)
・T&RF* creation [Completed]

Step 2

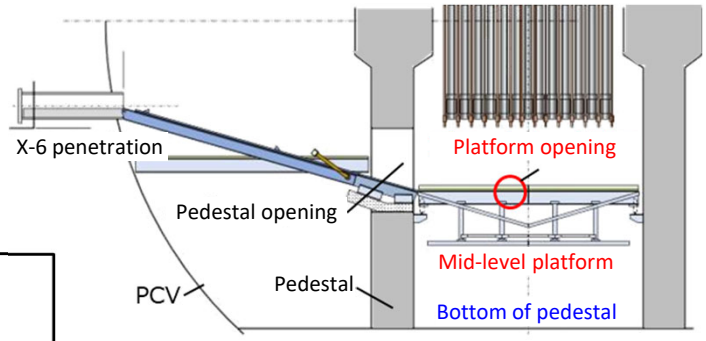
Attaching a laser scanner to the arm in order to acquire data on the position/shape of obstacles around the arm (point cloud data) [Completed]

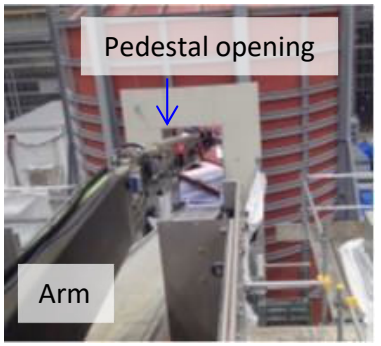
Step 3

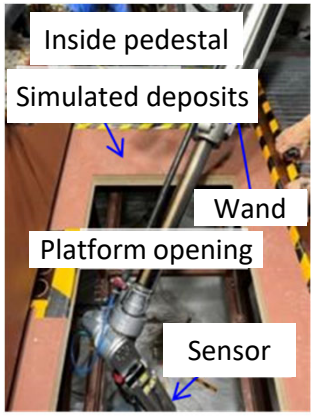
Reflecting point cloud data in the arm’s VR system [Completed]

Step 4

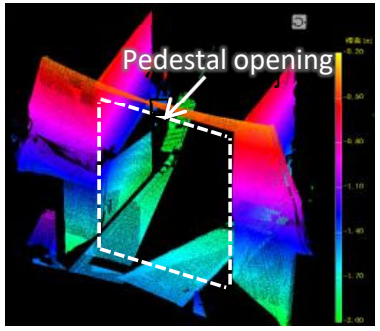
Accessing the bottom of the pedestal using the T&RF*, VR and cameras
- Ascertain VR accuracy
- Confirm camera visibility [Underway]





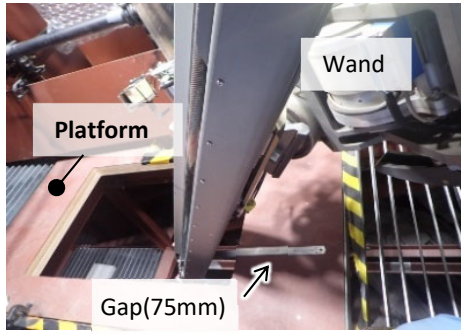


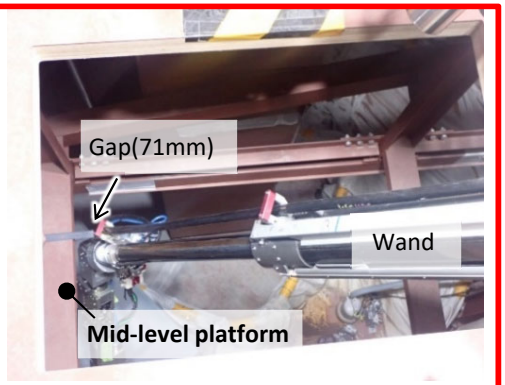
Step 1. Accessing the Bottom of the Pedestal with the Arm (Worker-assisted)



Laser scanner data

Step 2, 3. Acquiring Point Cloud Data

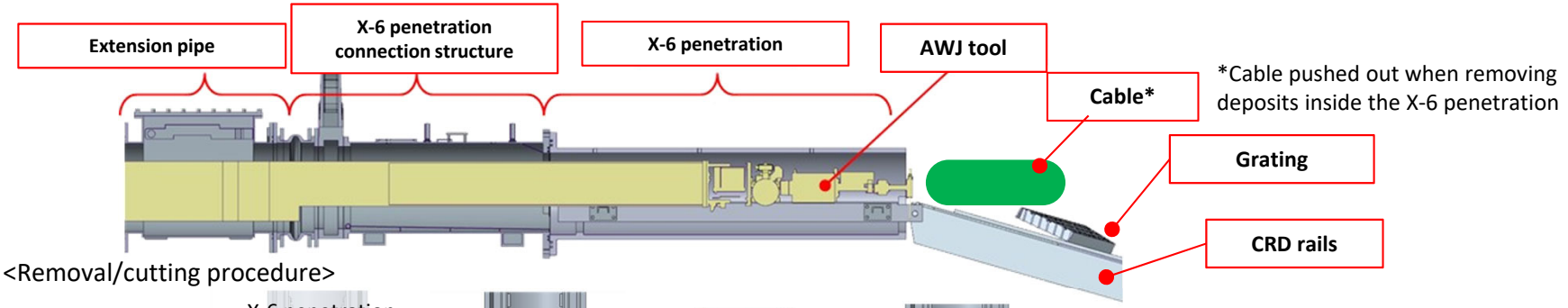




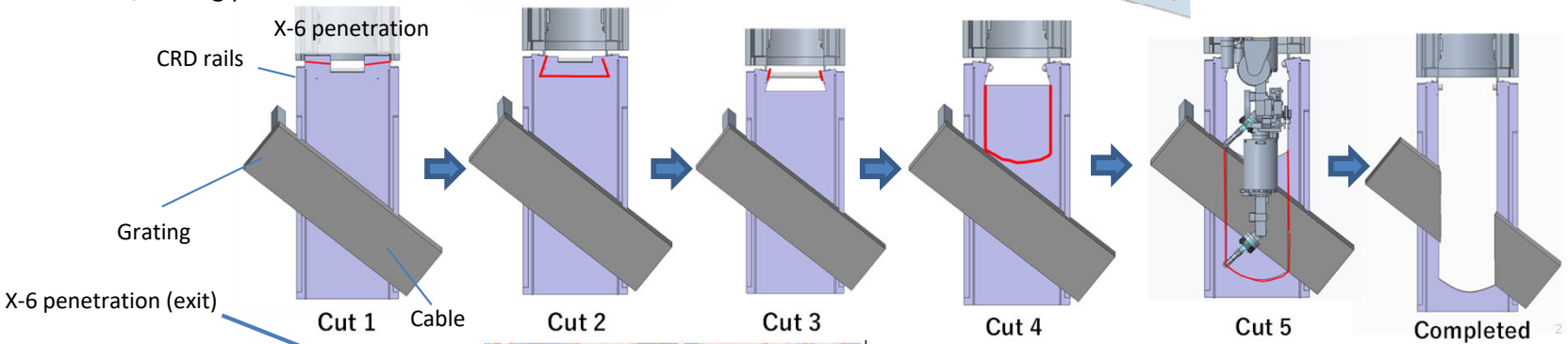
Step 4. Reflecting Point Cloud Data, Remote Access Status

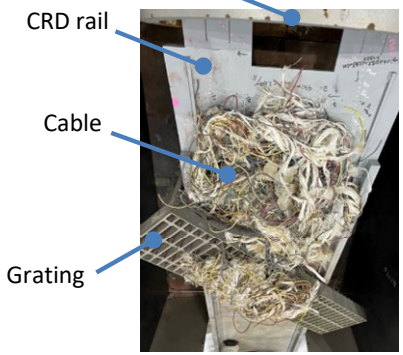
[Reference] Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment
[Tests on Removing Obstacles from the Exit of the X-6 Penetration Using the AWJ]

- Cutting away/removing the CRD rails/hoist, grating, cables, and electrical wire conduit that are obstacles to passing the arm through the penetration.
  - ➢ We have confirmed that obstacles at the exit for the X-6 penetration can be removed with the AWJ and that the arm can pass through after removal.
  - ➢ We've also confirmed that it takes time to adjust the angle and position of the AWJ nozzle in conjunction with the position of deposits and the cables above the CRD rails, thereby confirming through these tests that it will take time to construct an access route after the robotic arm has been inserted. Therefore, we continue to deliberate work efficiency (how to shorten work times).

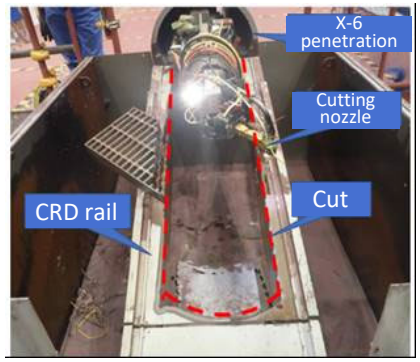


<Removal/cutting procedure>

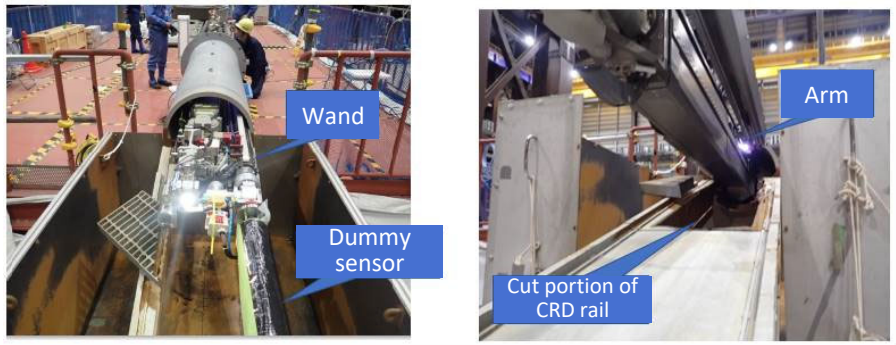




Prior to cutting



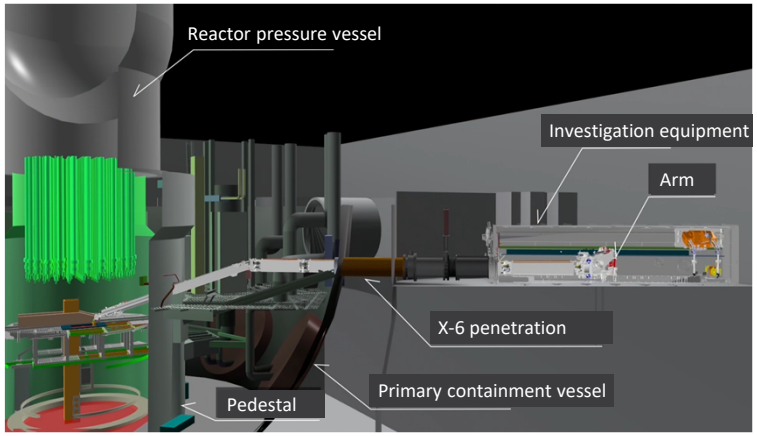
Cutting completed

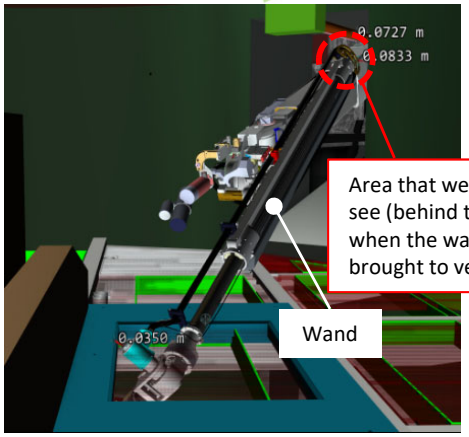


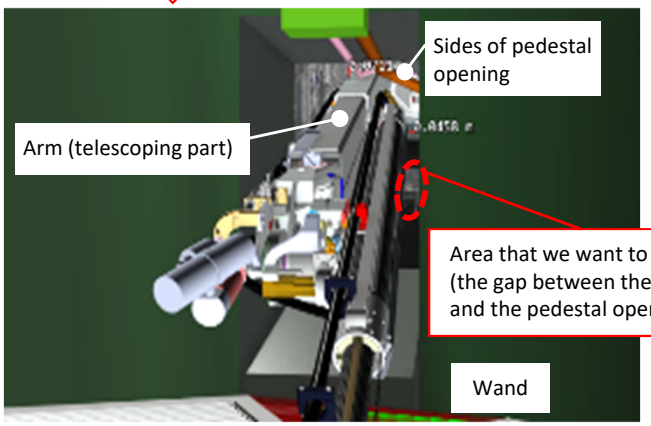
Confirming the ability of the arm to pass through the opening after cutting away obstacles

[Reference] Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment [Confirming Camera Visibility]

- Two more cameras and three more lights have been additionally installed in order to avoid obstacles behind and on the sides of the wand. Tests on accessing the bottom of the pedestal have confirmed that these cameras are effective (increased visibility).







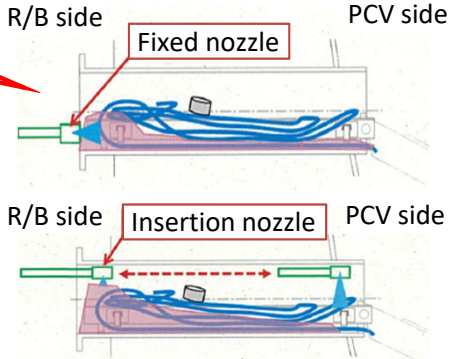
4-1. Deposit removal status

- During the removal of deposits from inside the X-6 penetration, deposit removal equipment will be set up inside an isolation chamber that serves as a boundary with PCV so that we can safely and carefully continue to remove deposits while preventing the gases inside the PCV from leaking out and impacting the surrounding environment.
- As with all tasks performed to date, we shall take dust measurements during this task using dust monitors and continually monitor dust concentrations in order to confirm that gases inside the PCV are not leaking out and impact on the surrounding environment.

Red outline indicates current progress;
X-6 penetration deposit removal
(low pressure water) are underway

Installation of
deposit removal equipment
(low pressure water)

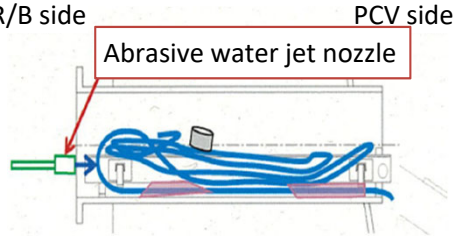
Spray jig installation
※Connected to X-53 penetration



Deposit removal equipment
(low pressure water)
※Remotely operated
Deposits are pushed with the dozer rod after which low pressure water is sprayed to remove the deposits

Removal of
deposit removal equipment
(low pressure water)

Installation of
deposit removal equipment
(high pressure water,
abrasive water jet)



Deposit removal equipment
(high pressure water,
abrasive water jet)

※ Remotely operated
Deposits are pushed with the dozer rod after which high pressure water/abrasive water jet is sprayed to remove the deposits

Removal of deposit removal equipment
(high pressure water,
abrasive water jet)

On to next step
Installation of X-6
penetration connection
structure

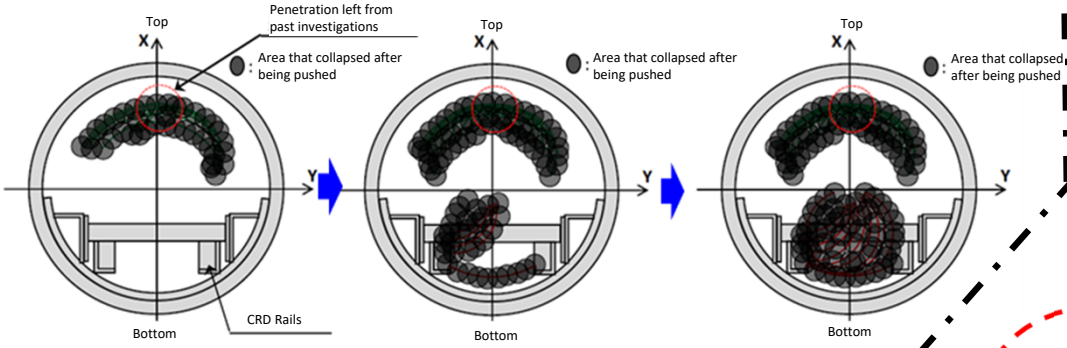
※Photos were taken using the mockup

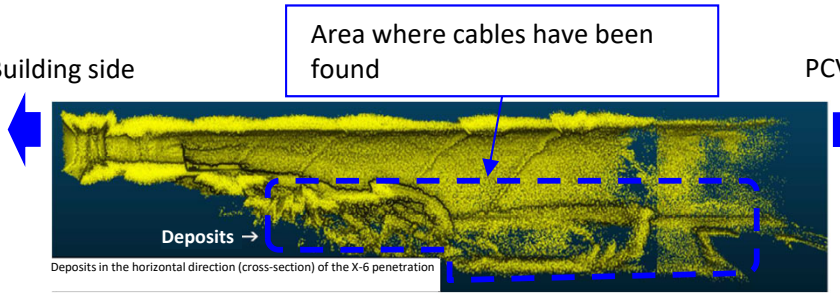
(Deposit removal from inside the X-6 penetration (low pressure water): Deposit collapsing work)

- We have started removing deposits from inside the X-6 penetration and are using a dozer rod to push and collapse deposits.
- The deposits around the penetration made during past investigations were pushed, and the deposits at the top part are pushed with the dozer rod without resistance. Deposits at the bottom part are being pushed with dozer rod as well although they are resistant compared to the upper part.

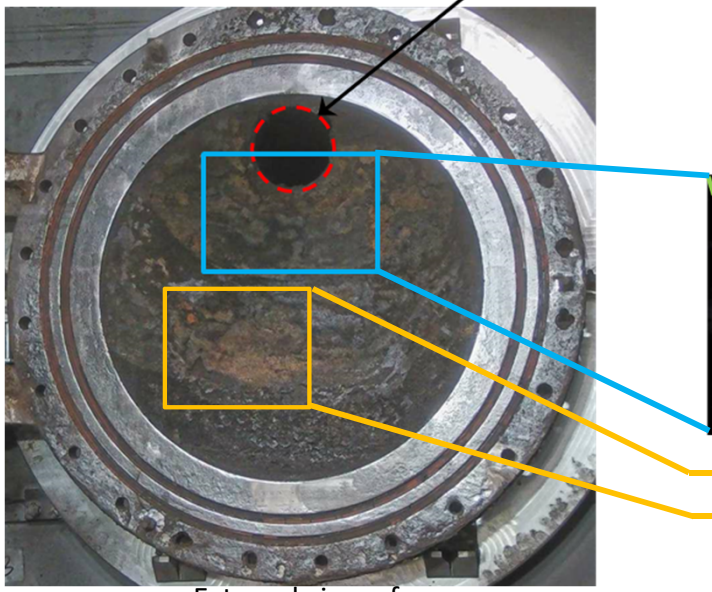
＜Deposit collapsing steps＞

The deposits around the penetration made during past investigations are being pushed, and the plan is to push the deposits while moving the dozer rod from top to bottom.

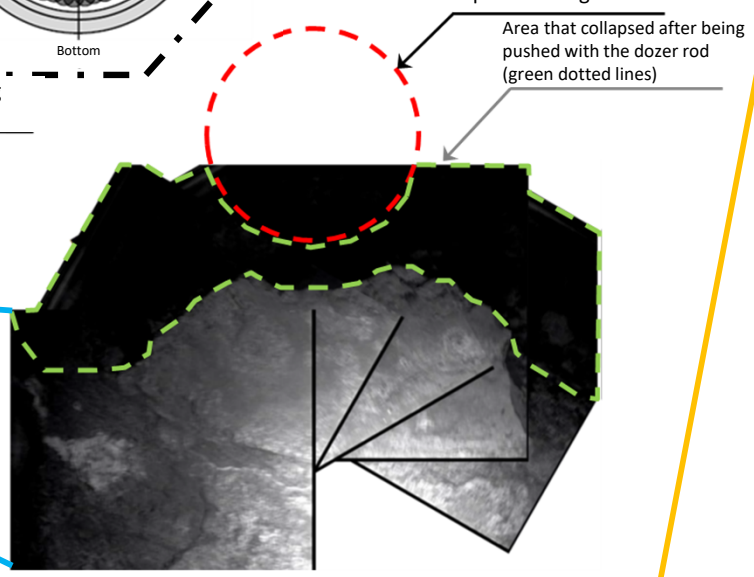




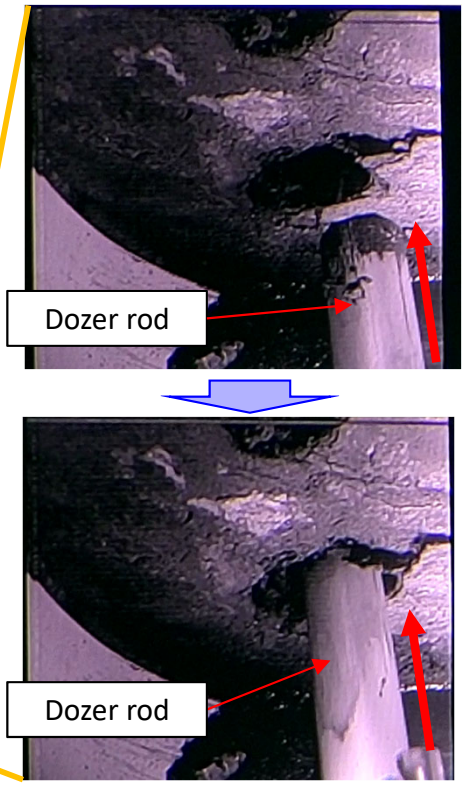
Results from 3D scan taken in October 2020



External view of X-6 penetration

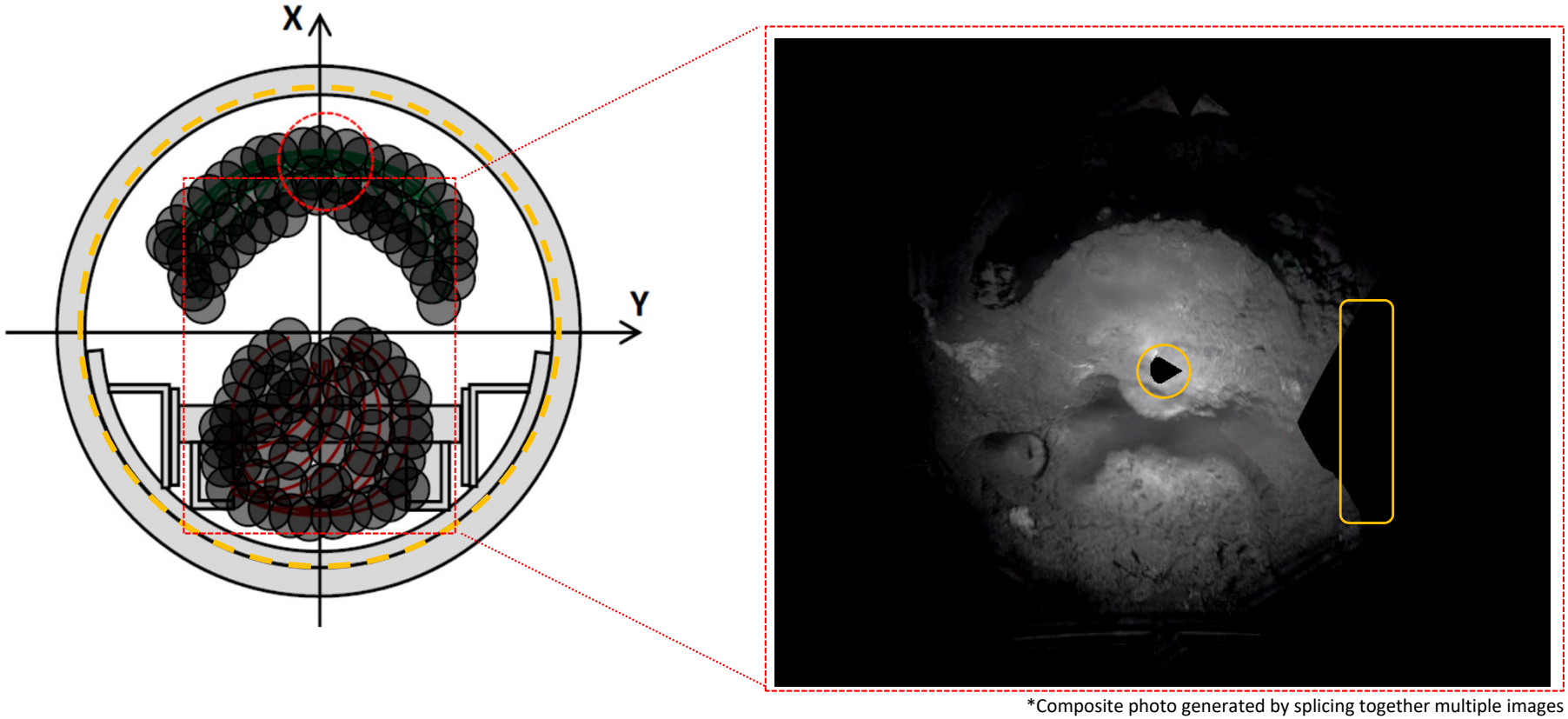


Collapsed deposit near the penetration made during past investigations (as of work on January 10)



Collapsed deposit (as of work on January 11)

- Resistant deposits at the bottom part of the penetration are also being pushed without issue.
- Deposits in the area of the deposit collapsing step were able to be collapsed with the dozer rod without issue just like the prior tests performed on the mockup.
- In regards to property of the deposit, the dozer rod met some resistance when penetrating deposits at the center and the bottom of the X-6 penetration, but they were able to push through without issue.



*Composite photo generated by splicing together multiple images

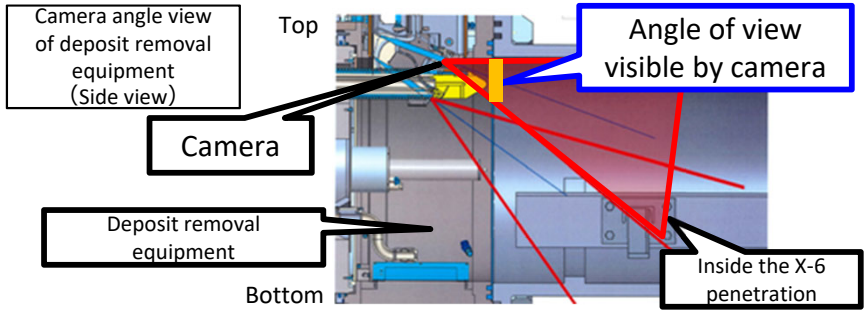
Collapsed deposit
(as of work on January 12)

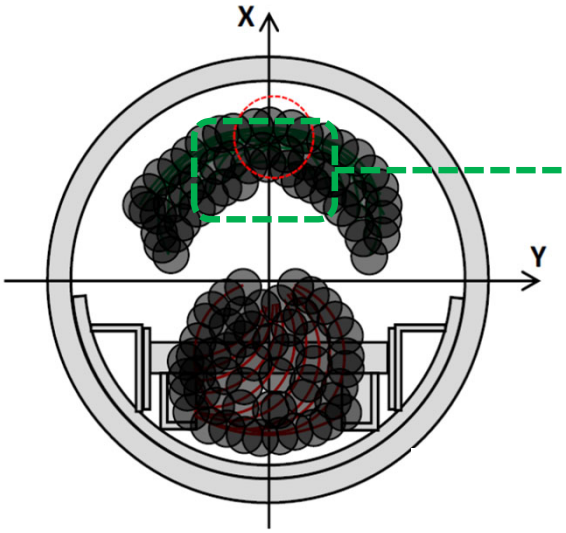
: Shows area without photo as well as the center point of collage construction

4-3. Field Work Progress

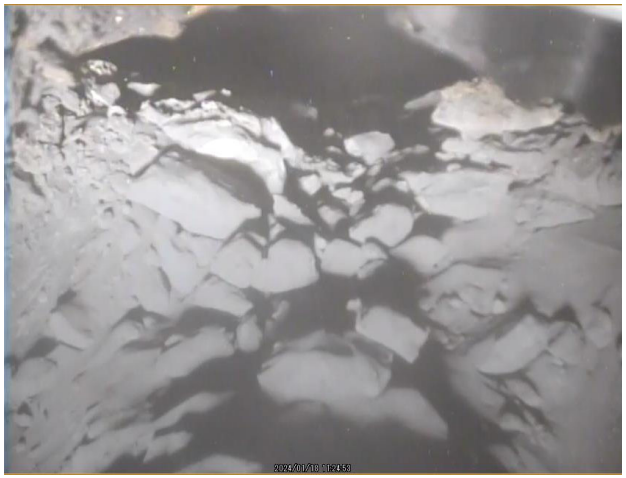
(Deposit removal using low pressure water (top part of the X-6 penetration)

- After completing collapsing deposits using the dozer rod, we sprayed low pressure water to remove the deposits.
- Although it took more time to remove deposits compared with the results of mockup performed earlier, deposits are gradually being removed, revealing cables. Also, mud-like deposits are remaining at the bottom of the penetration.

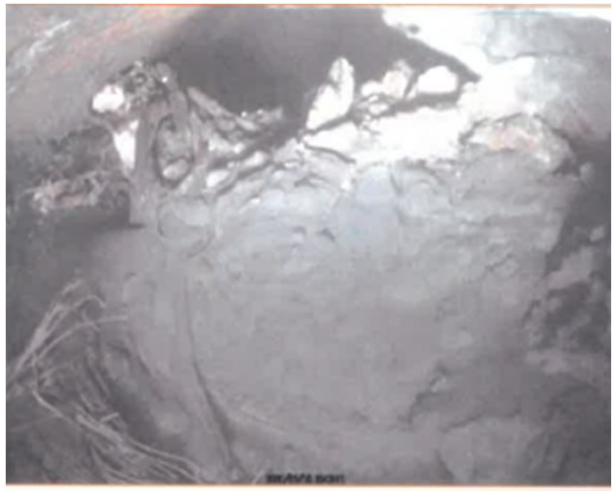




Before spraying low-pressure water
Before the work on January 17



After the work on January 18

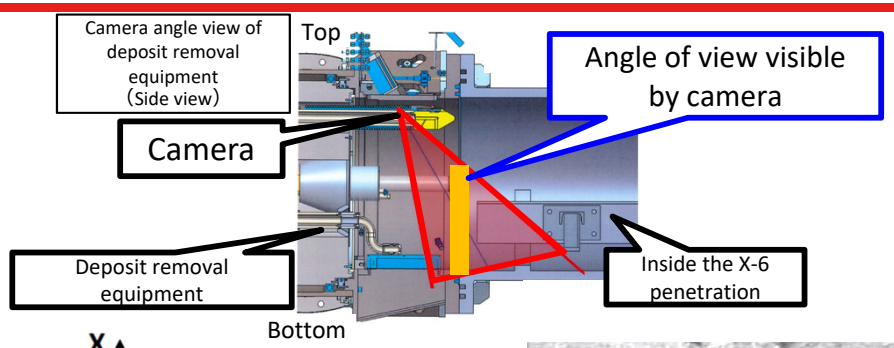


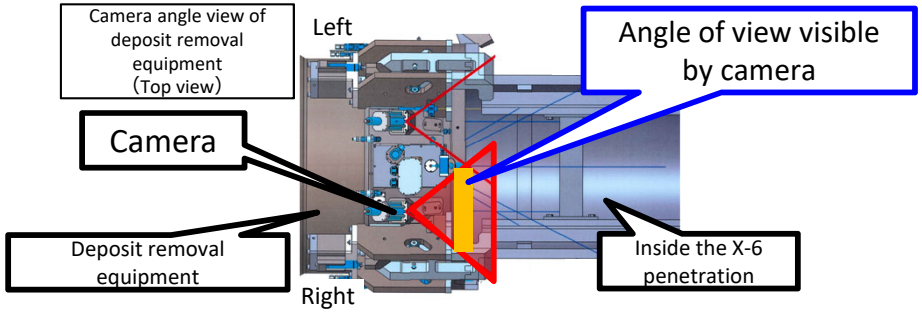
After the work on January 19

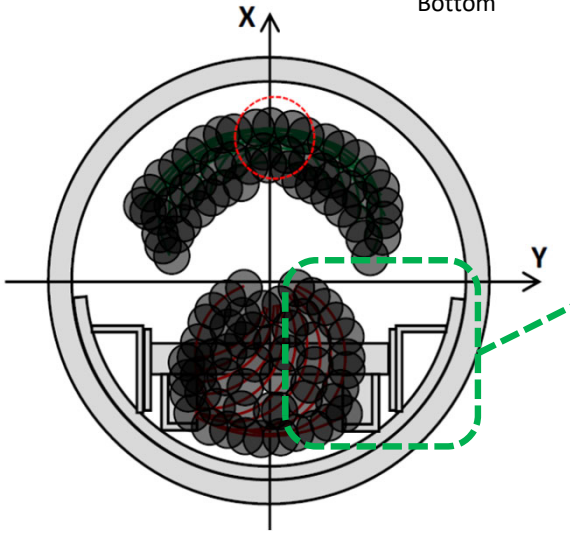
After the work on January 20

After the work on January 22

[Reference] Deposit removal using low-pressure water (bottom right of the X-6 penetration)





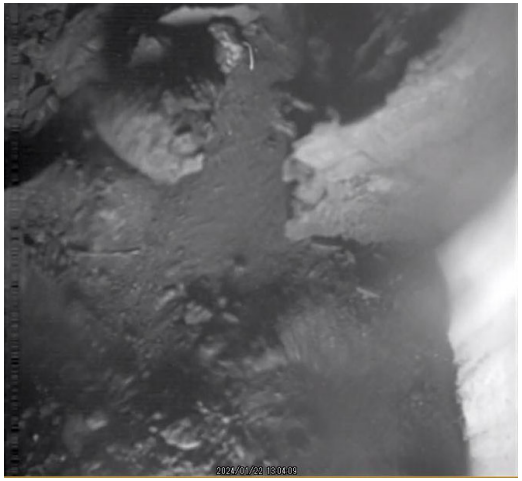


Before spraying low-pressure water
Before the work on January 17

Before the work on January 18

Before the work on January 19

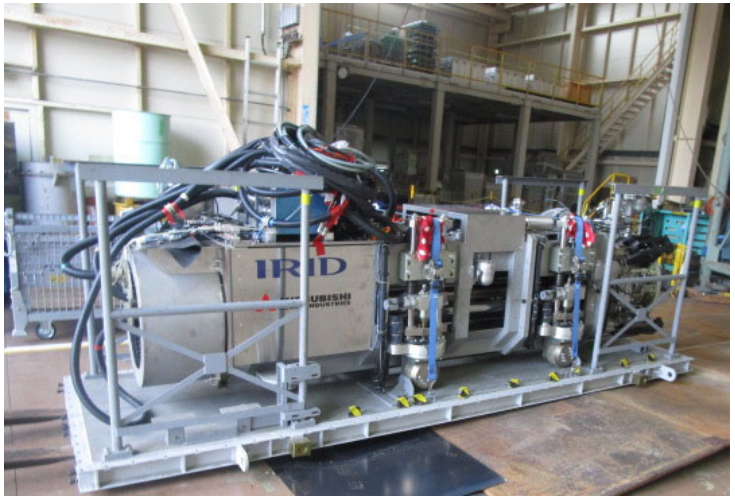
Before the work on January 20



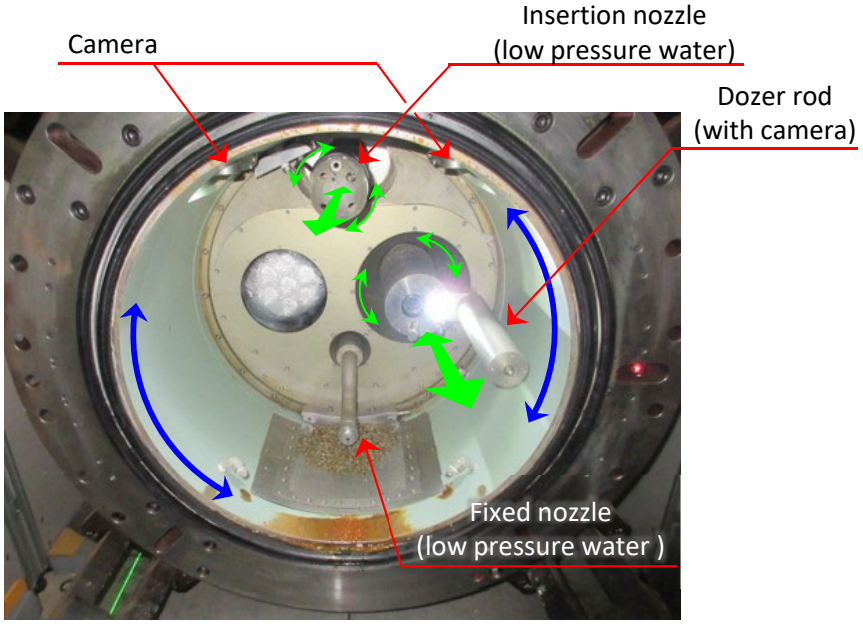
Before the work on January 22

[Reference] Deposit removal equipment
(low pressure water/high pressure water and abrasive water jet)

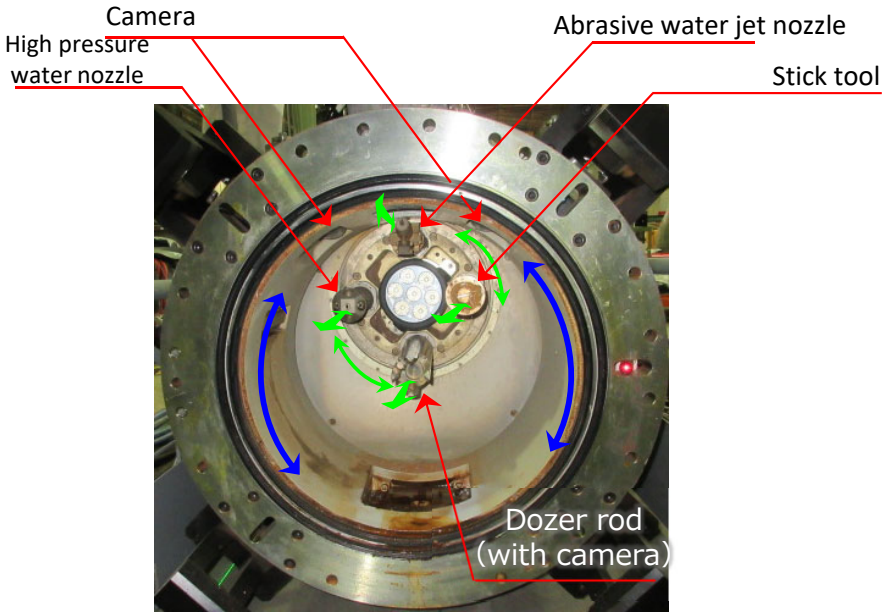
Exterior view of the deposit removal equipment
(low pressure water)



Exterior view of the deposit removal equipment
(high pressure water/abrasive water jet)



Cross-sectional view of the deposit removal equipment
(low pressure water) connection to X-6 penetration



Cross-sectional view of the deposit removal equipment
(high pressure water/abrasive water jet) connection
to X-6 penetration

5. Schedule

- Although it is taking time to remove the deposits compared to prior tests performed on the mockup, they are gradually being removed and we can see the cables. Starting in February, the remaining deposits and cables will be removed using the high pressure water and abrasive water jet.
- There are uncertainties of removing deposits with low pressure water and the future use of high pressure water/AWJ. In addition, we know through tests using the mockup that it will take time to construct an access route for the robotic arm. Furthermore, we must conduct additional tests to confirm the reliability of the robotic arm that will be used for the first time inside the primary containment vessel of a reactor that has suffered an accident. In light of these situations, to ascertain the attributes of fuel debris quickly and steadily, we will use the telescoping device that was successful during past internal investigations and can be inserted into the PCV without completely removing all of the deposits, to sample fuel debris. Thereafter, we will perform internal investigations and sample fuel debris with the robotic arm as we continue initiatives pertaining to trial retrieval.
- Prior to constructing an access route for the robotic arm, we will use the telescopic device to confirm conditions after the removal of deposits from inside the PCV thereby improving the certainty that robotic arm tasks can be performed.
- We plan to begin the trial retrieval of fuel debris by October 2024 at the latest.
- We will continue to steadily move forward and prioritize safety during the removal of deposits and the trial retrieval of fuel debris.

	FY2023	FY2024				FY2025
	Q4	Q1	Q2	Q3	Q4	
Deposit removal						
Telescopic device manufacturing/installation preparations						
Trial retrieval (fuel debris sampling using the telescopic device)						
Robotic arm testing, additional development as required by testing results						
Robotic arm installation preparations/robotic arm access route construction						
Use of robotic arm for internal investigations/fuel debris sampling						

[Reference] Field Work Progress

Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

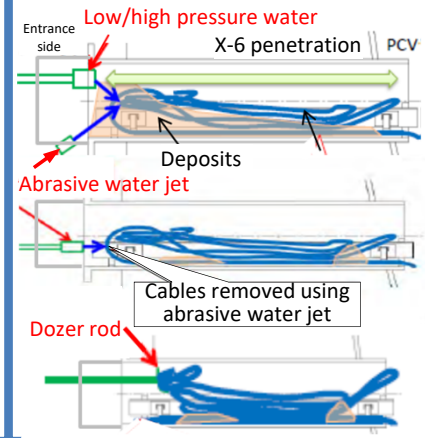
Approved

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

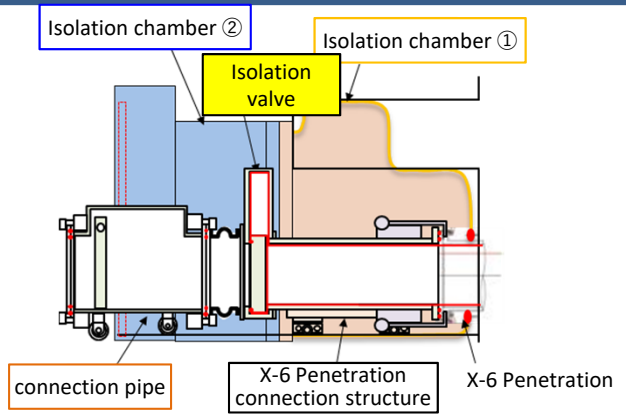
3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



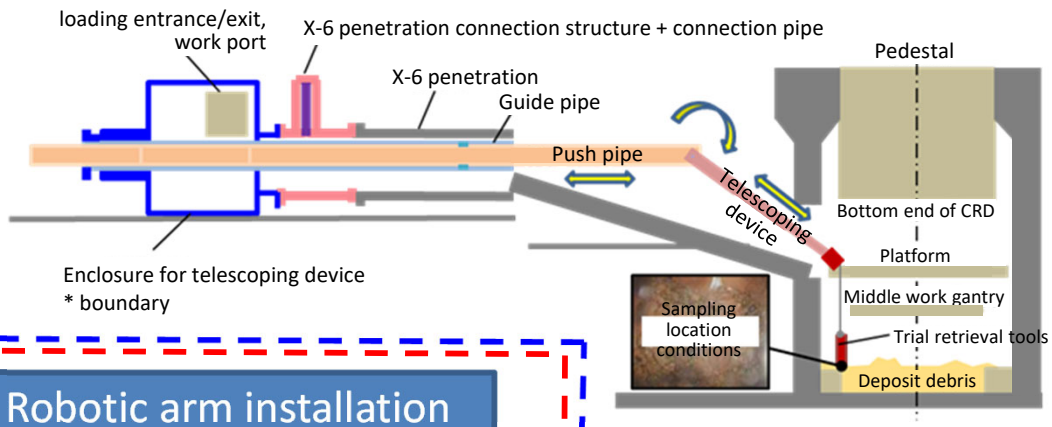
- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

4. Installation of X-6 penetration connection structure and connection pipe

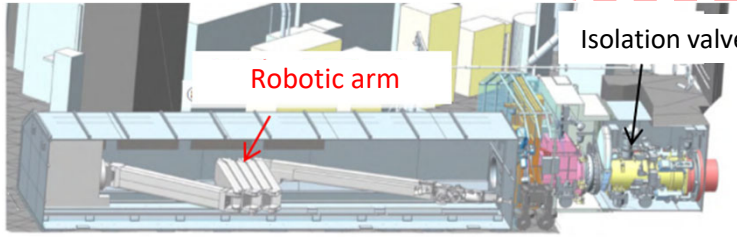


Approval application pending

5. Installation of telescopic device
6. Trial retrieval (debris sampling using telescopic device)

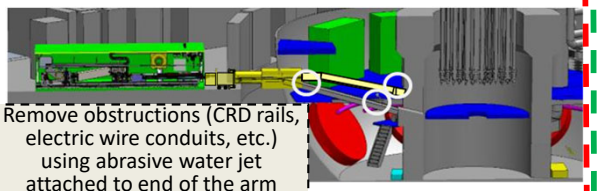


7. Robotic arm installation

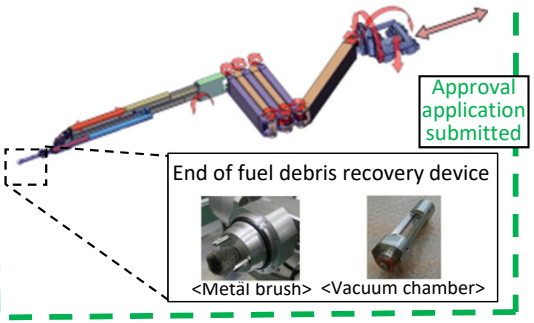


8. Internal investigation/debris sampling using robotic arm

① Internal investigation



② debris sampling using robotic arm



(Note)

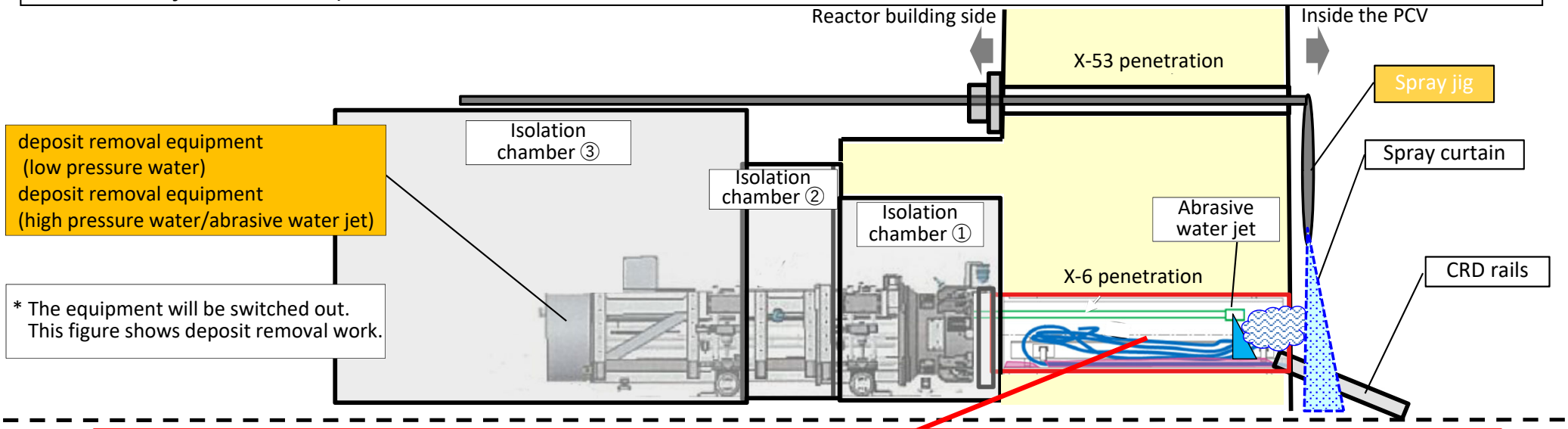
Isolation valve: Valve installed to separate the inside of the PCV from the outside

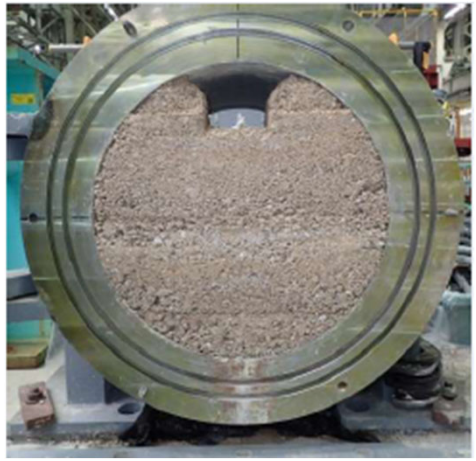
Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

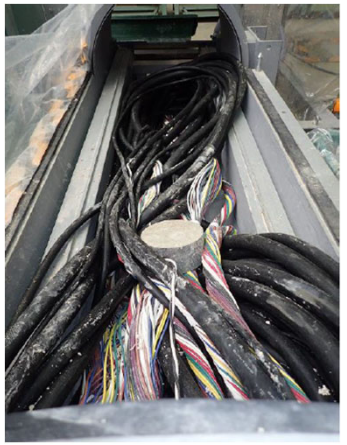
[Reference] Overview of Deposit Removal Work

In order to construct an access route for the trial retrieval of fuel debris, the following preparations will be made:

- Suppression of dust dispersion inside the PCV using a spray jig
- Removal of deposits inside the X-6 penetration using a deposit removal equipment (low pressure water/dozer rod)
- Removal of deposits inside the X-6 penetration using a deposit removal equipment (high pressure water/abrasive water jet/dozer rod)



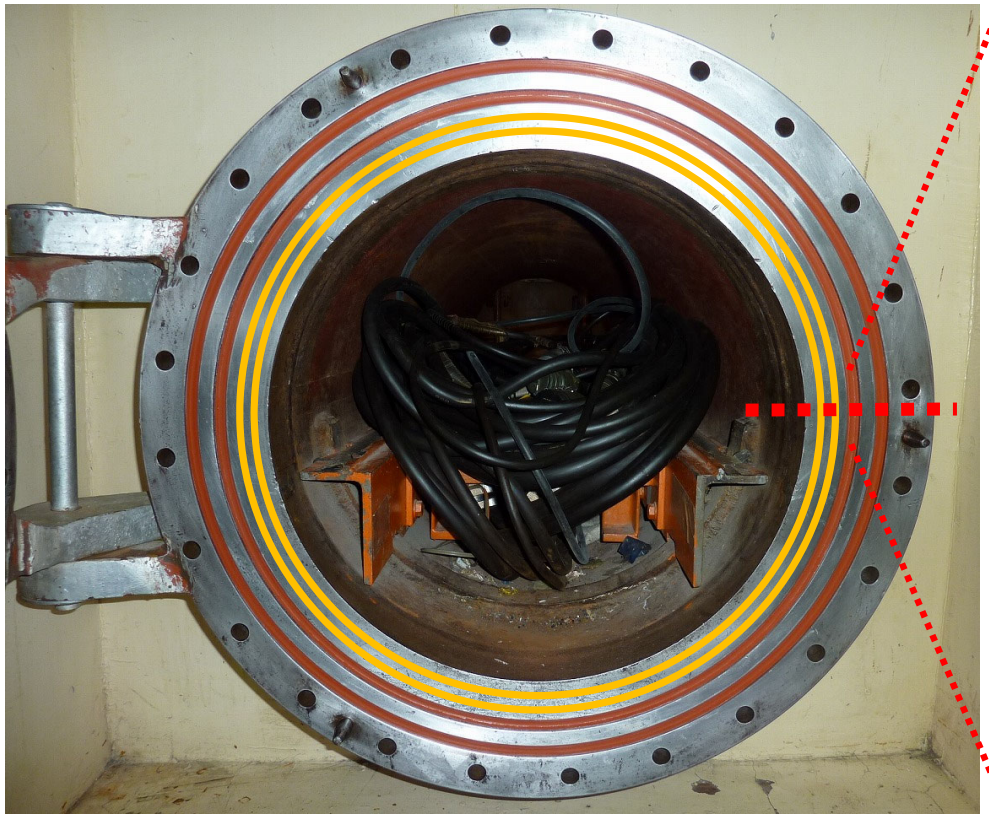




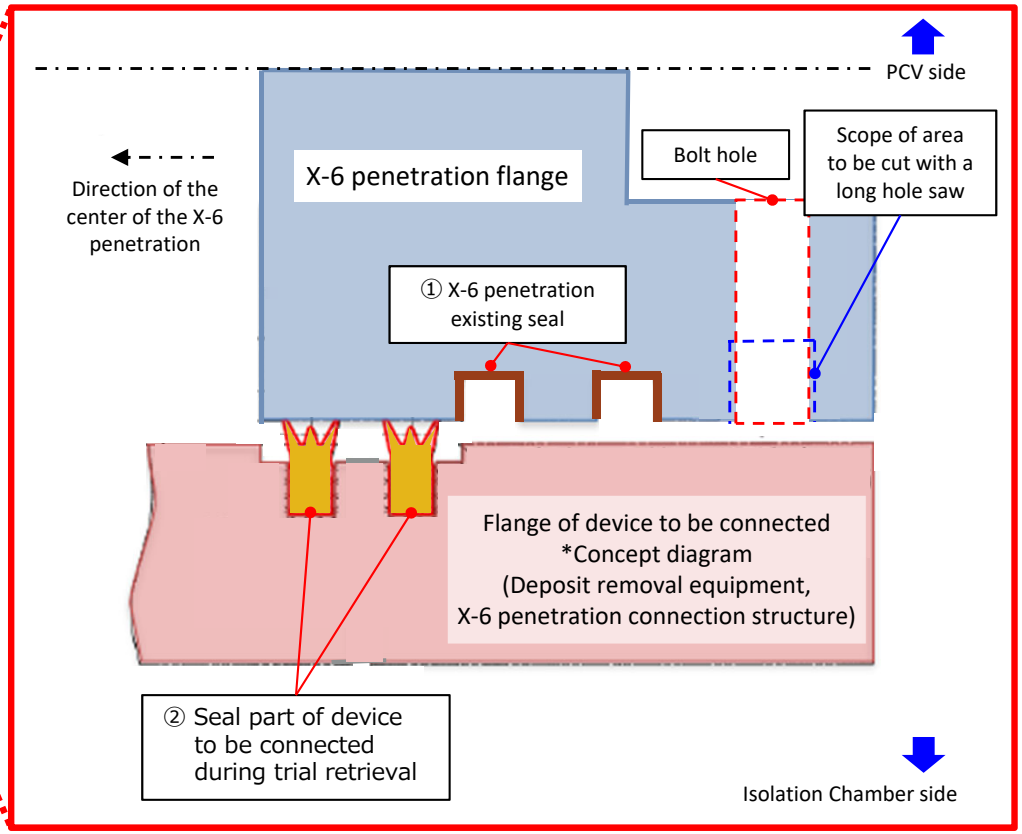
Conditions inside the X-6 penetration (mockup)

[Reference] Sealing of the Device Connected to the X-6 Penetration

- A deposit removal equipment and X-6 penetration connection structure will be connected to the hatch flange after it is opened



X-6 penetration hatch prior to the accident (open)

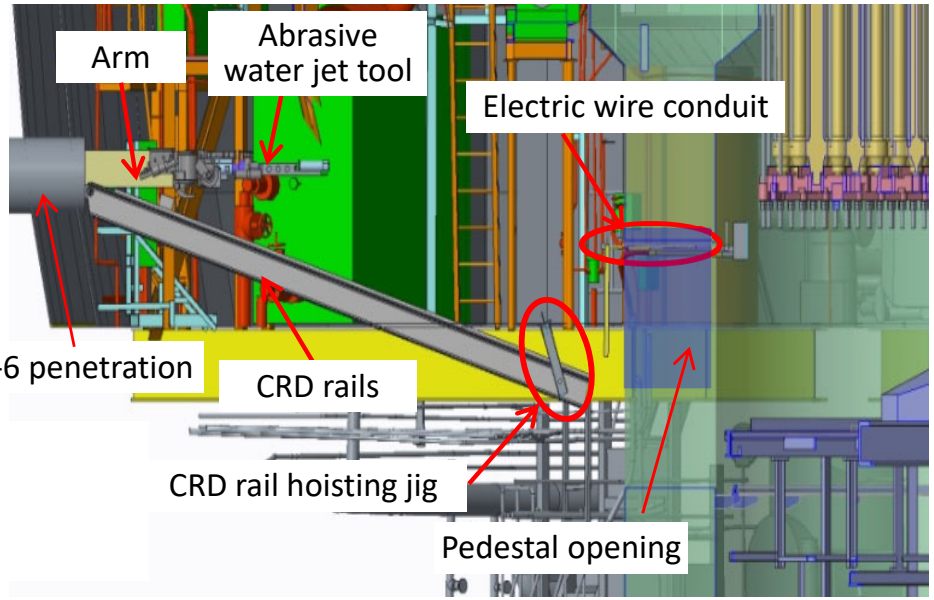


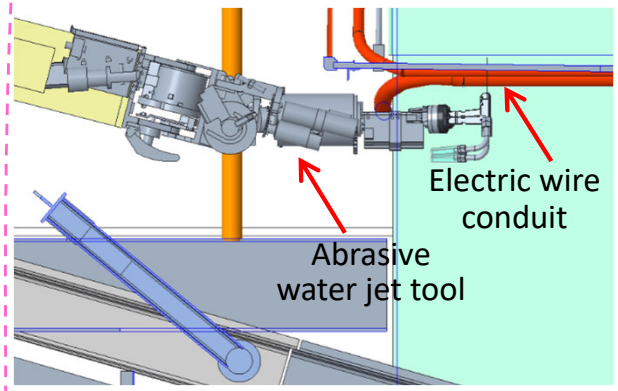
Location of seals when connecting devices to the X-6 penetration (as seen from above)

: ① X-6 penetration existing seal
: ② Seal of the devices connected to during trial retrieval
* Deposit removal equipment, X-6 penetration connection structure

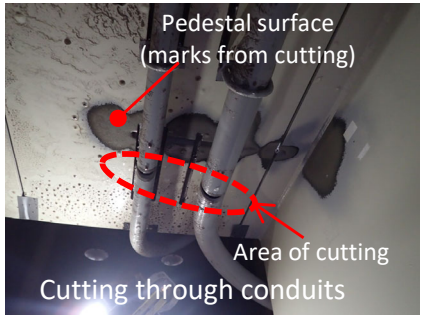
[Reference] Testing of Unit 2 Fuel Debris Trial Retrieval Equipment (Tests on Removing Obstructions inside the PCV)

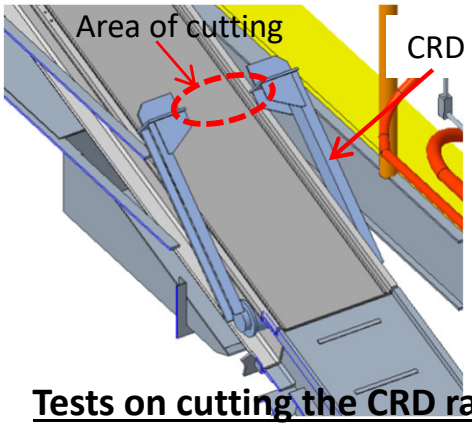
- The abrasive water jet tool was attached to the arm and tests on cutting away the CRD rail hoist jig and electrical wire conduits inside the opening of the pedestal, which are obstructions to passing the arm through, were performed.
- The work could be seen through the camera attached to the end of the arm, and we confirmed that the CRD rail hoist jig and electric wire conduits can be cut away as planned.
- Furthermore, we've also confirmed that it takes time to adjust the angle and position of the abrasive water jet nozzle as with cutting away the CRD rails, thereby confirming through these tests that it will take time to construct an access route after the robotic arm has been inserted. Therefore, we continue to deliberate work efficiency (how to shorten work times).



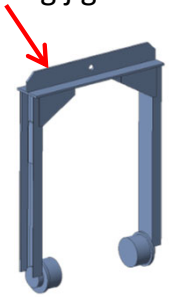


Tests on cutting away electric wire conduits

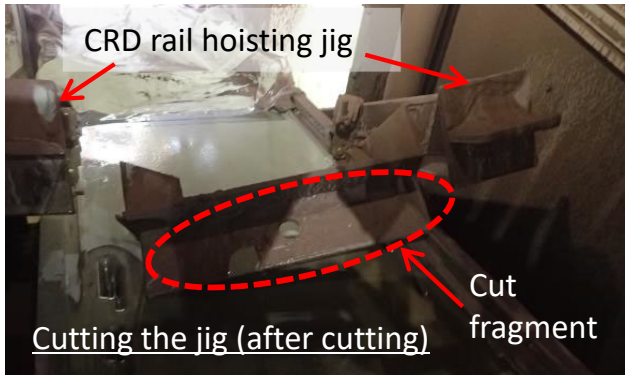




Tests on cutting the CRD rails



Structure prior to cutting



[Reference] Environmental Impact (1/2)

- The removal of deposits from inside the Unit 2 X-6 penetration has been ongoing since January 10, and we have not seen any radiological impact on the surrounding environment.
- During investigations, gases from inside the primary containment vessel have been prevented from leaking to the outside environment through the construction of a boundary.
- There have been no significant fluctuations in data from monitoring posts or dust monitors neither prior to or after work.
- Data from monitoring posts/dust monitors near site borders can be found on TEPCO's website
  Reference URL: https://www.tepco.co.jp/en/hd/decommission/data/monitoring/monitoring_post/index-e.html
  https://www.tepco.co.jp/en/hd/decommission/data/monitoring/dustmonitor/index-e.html

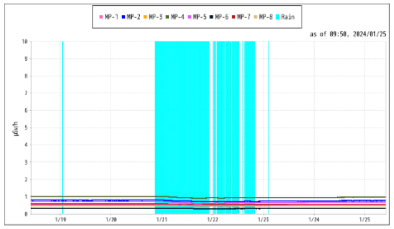
Radiation Dose measured at Monitoring Post of Fukushima Daiichi Nuclear Power Station

The following is the radiation doses of the air measured by the monitoring posts (MP1-8) at Fukushima Daiichi Nuclear Power Station.

Monitoring post (MP1 - MP8)

Monitoring points

Radiation dose



MP Unit : μSv/h Wind Velocity Unit : m/s
=Measurement value (2024/01/25 09:50)

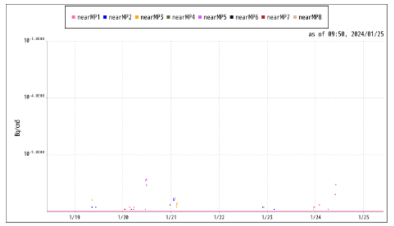
MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	Wind Direction	Wind Velocity	Rain
0.502	0.758	0.478	0.959	0.670	0.309	0.554	0.522	west-northwest	12.4	No

Radioactive Concentration measured at Dust Monitors near the Site Boundary of Fukushima Daiichi Nuclear Power Station

The following are radioactive concentrations in the air measured near the monitoring posts (MP1-8) at the site boundary of Fukushima Daiichi Nuclear Power Station.

Monitoring points

Radiation concentration



Radioactive Particles Monitor Unit : Bq/cm³ Wind Velocity Unit : m/s
=Measurement value (2024/01/25 09:50)

nearMP1	nearMP2	nearMP3	nearMP4	nearMP5	nearMP6	nearMP7	nearMP8	Wind Direction	Wind Velocity
1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	northwest	4.4

[Reference] Environmental Impact (2/2)

- The removal of deposits from inside the Unit 2 X-6 penetration has been ongoing since January 10, and during investigations plant parameters are continuously monitored. We have seen no significant fluctuations in primary containment vessel temperature neither prior to or after work, and there's been no change in the status of cold shutdown state.
- Primary containment vessel temperature data can be found on TEPCO's website.
  Reference URL: https://www.tepco.co.jp/en/hd/decommission/data/plant_data/unit2/pcv_index-e.html

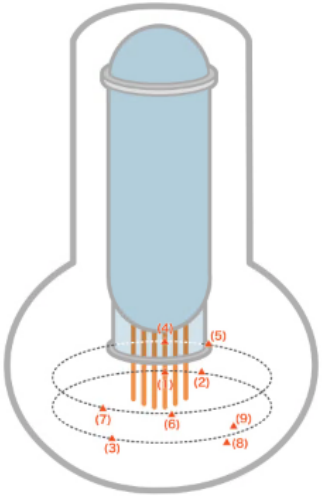
[Reference] Screen image of our website

Temperatures measured inside the Unit 2
Primary Containment Vessel at Fukushima
Daiichi Nuclear Power Station

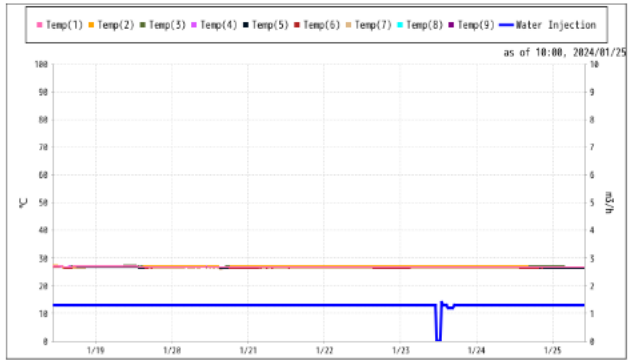
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

Monitoring points

Unit 2 reactor containment vessel



Temperature



Temperature Unit:℃、Water Injection Unit : m^3/h
▫Measurement value (2024/01/25 10:00)

Temp(1)	Temp(2)	Temp(3)	Temp(4)	Temp(5)	Temp(6)	Temp(7)	Temp(8)	Temp(9)	Water Injection
26.6	26.8	26.8	26.7	26.5	26.4	26.3	-	-	1.3