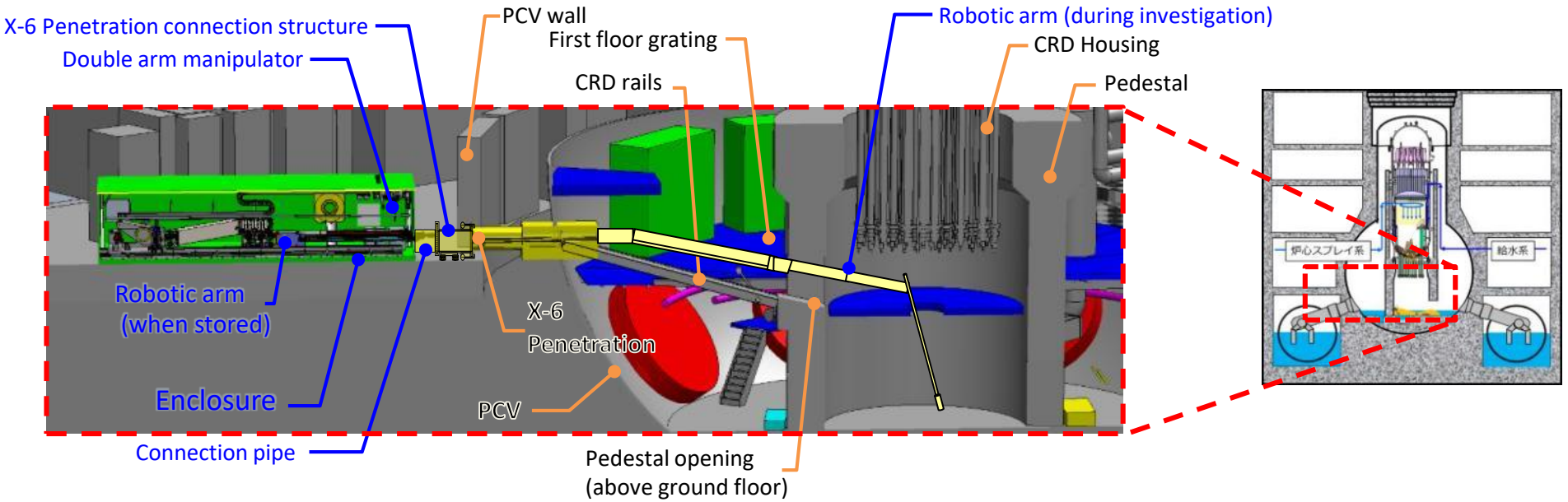
Fukushima Daiichi Nuclear Power Station
Unit 2 PCV Internal Investigation/
Preparation Status of Fuel Debris Trial Retrieval

February 29, 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

2-1. 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 was implemented and completed.
- Currently, the arm is being installed inside the enclosure in preparation for a run-through test. Since the arm will have to repeatedly pass through confined spaces, we will continue even after the run-through test to optimize the control program in order to reduce risks of hitting obstacles, by improving positioning accuracy and the coordination between hardware and software.
- 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	Completed
	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	Completed
	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

2-2. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment [Pedestal Access Tests]

- We have completed 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” in order to ascertain arm functions/applicability, 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

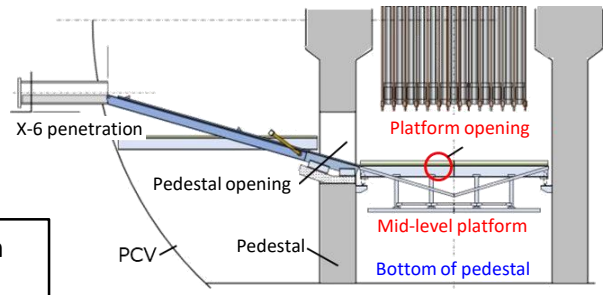
Attaching a laser scanner to the arm in order to acquire data on the position/shape of obstacles around the arm (point cloud data) [Completed]

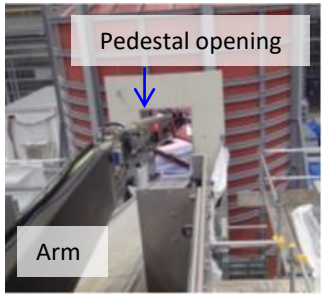
Step 3

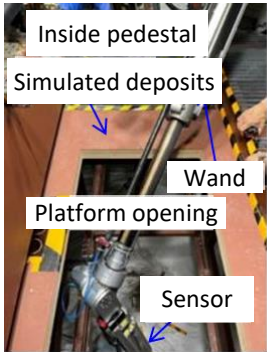
Reflecting point cloud data in the arm’s VR system [Completed]

Step 4

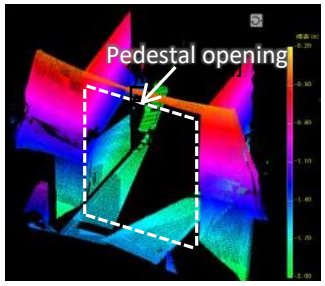
Accessing the bottom of the pedestal using the T&RF*, VR and cameras
- Ascertain VR accuracy
- Confirm camera visibility [Completed]





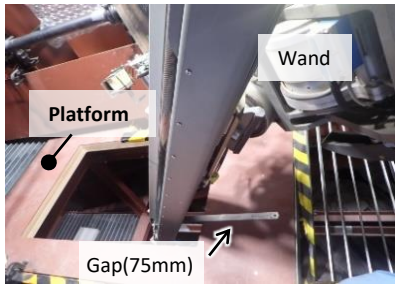


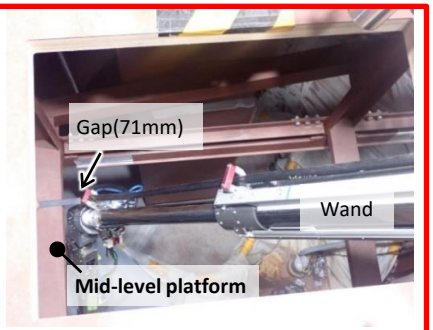
Step 1. Accessing the Bottom of the Pedestal with the Arm (Worker-assisted)



Laser scanner data

Step 2, 3. Acquiring Point Cloud Data

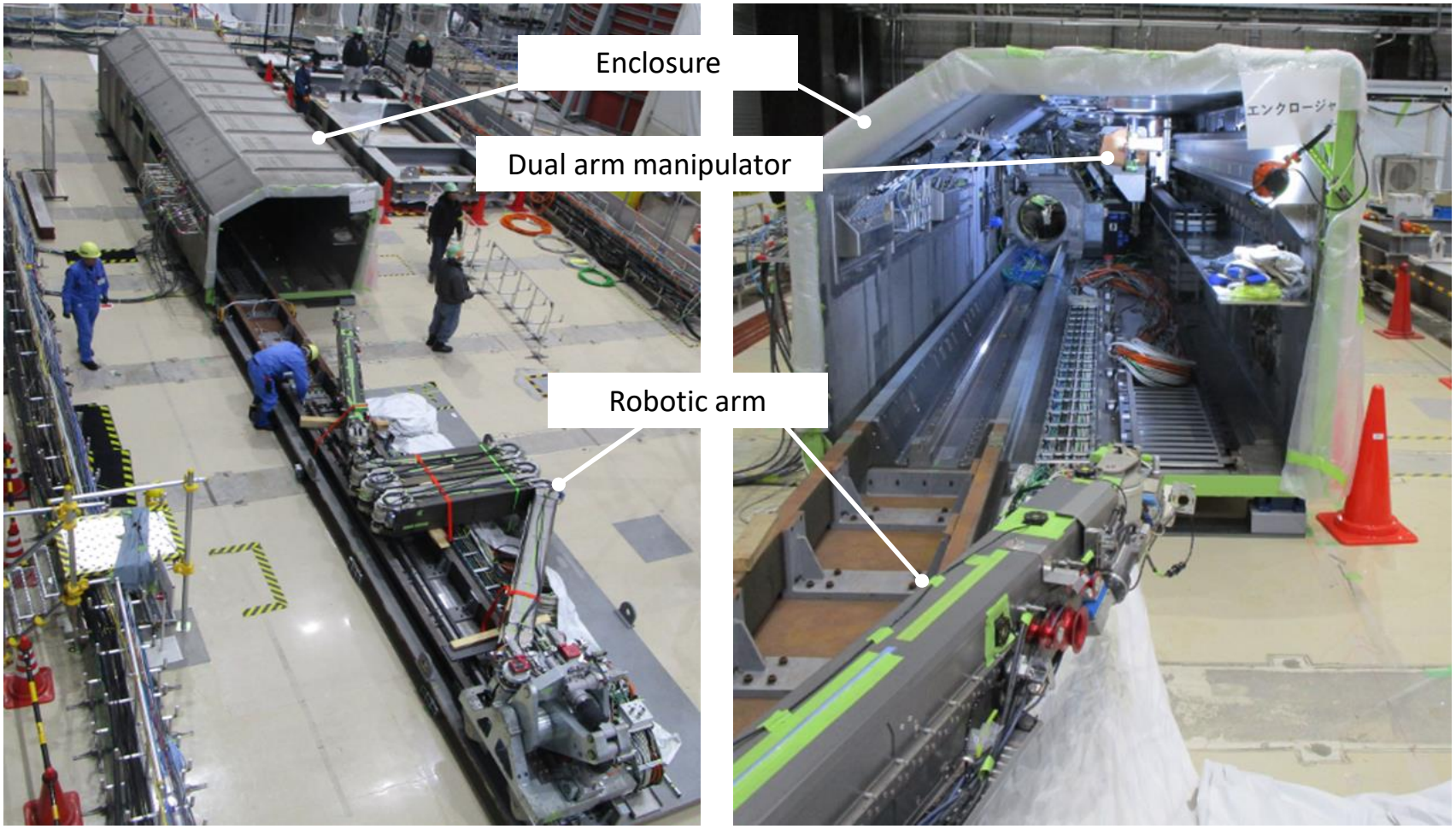




Step 4. Reflecting Point Cloud Data, Remote Access Status

2-3. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment [Run-through Test]

- Currently, the arm is being installed inside the enclosure in preparation for a run-through test



The arm being installed inside the enclosure

3. Manufacturing of the Telescopic Trial Retrieval Equipment

- Manufacturing of primary components has been completed, and mock-up testing is currently underway at the Kobe factory.

Telescopic arm (being assembled)

Enclosure (being assembled)

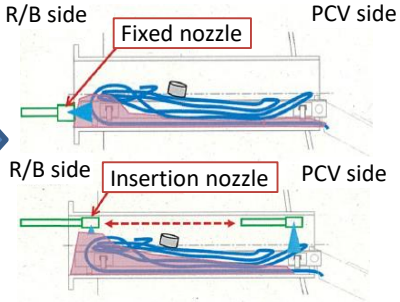
Telescopic trial retrieval equipment (photo taken from above the equipment)

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.

Installation of deposit removal equipment (low pressure water)

Spray jig installation
※Connected to X-53 penetration



Deposit removal equipment (low pressure water)

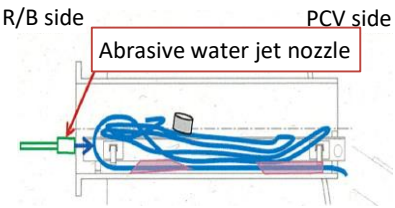
※Remotely operated

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)

Red outline indicates current progress;
X-6 penetration deposit removal
(high-pressure water, abrasive water jet) are underway

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

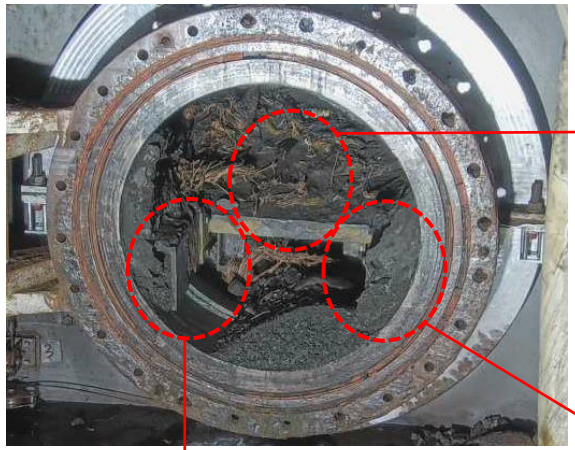
Removal of deposit removal equipment (high pressure water, abrasive water jet)

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

※Photos were taken using the mockup

4-2. Field work progress
(Removing deposits from inside the X-6 penetration (High-pressure water/Abrasive water jet):
Removing deposits with high pressure water)

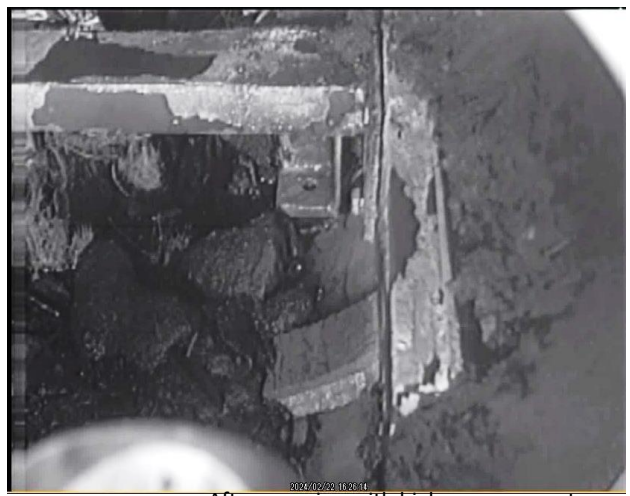
- We started to remove deposits from inside the X-6 penetration by spraying the deposits with high-pressure water.
- By spraying high-pressure water, we were able to remove deposits around the CRD rail guide.
- Currently, we are spraying the deposits with the abrasive water jet to test performance (This will be done multiple times by adjusting the position of the nozzle)
- We are also preparing for off-site transportation and analysis of the deposit that fell when opening the hatch.



X-6 penetration flange: Before connecting deposit removal equipment

After spraying with high-pressure water (center of the X-6 penetration)

After spraying with high-pressure water (bottom left of the X-6 penetration)



After spraying with high-pressure water (bottom right of the X-6 penetration)

5. Schedule

- We have completed the deposit removal work with low-pressure water and have begun the deposit removal work using high-pressure water/AWJ. We have been able to remove deposits around the CRD rail guide using high-pressure water. We are currently testing the AWJ, and after completing these tests, we are planning to conduct continuous spraying by the AWJ.
- There are uncertainties of removing deposits with low pressure water, high pressure water and 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
	4Q	1Q	2Q	3Q	4Q	
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)

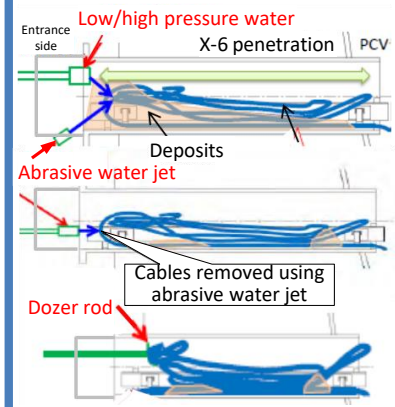
Approved

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

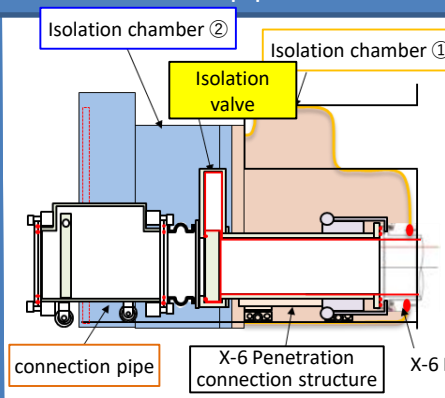
3. Removal of deposits from inside the X-6 penetration

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

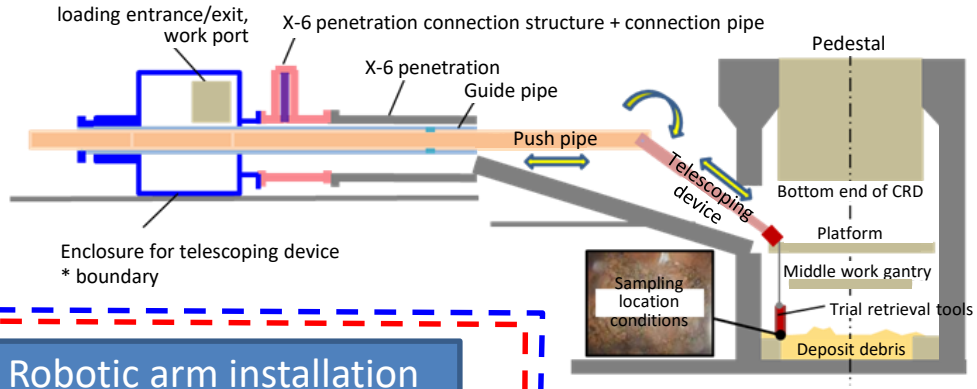
4. Installation of X-6 penetration connection structure and connection pipe



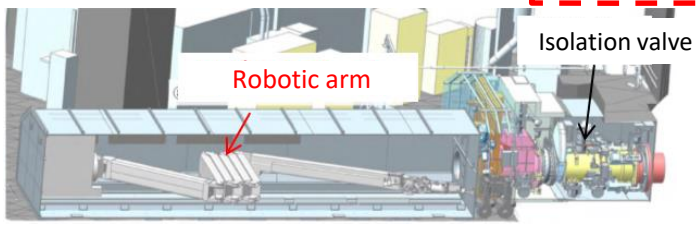
The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

Approval application pending

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

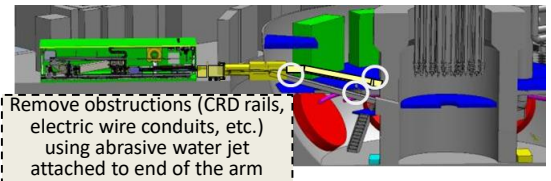


7. Robotic arm installation



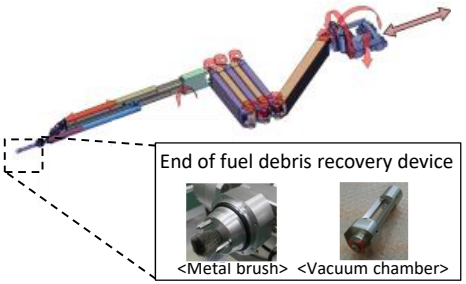
8. Internal investigation/debris sampling using robotic arm

① Internal investigation



Remove obstructions (CRD rails, electric wire conduits, etc.) using abrasive water jet attached to end of the arm

② debris sampling using robotic arm



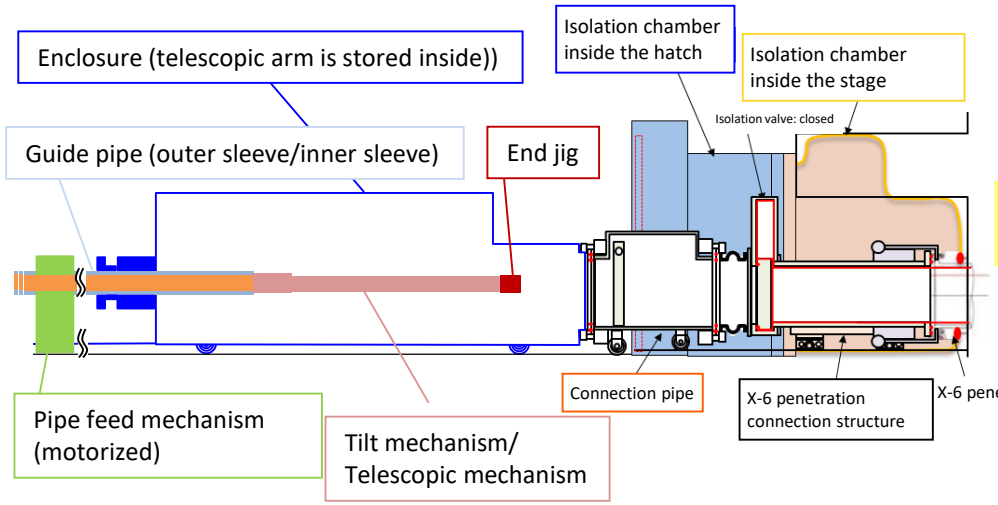
(Note)

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

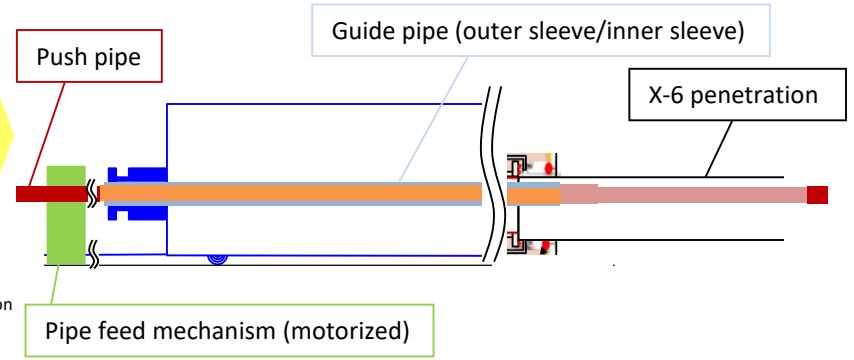
Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

[Reference] Work overview of Telescopic Fuel Debris Trial Retrieval (1/3)

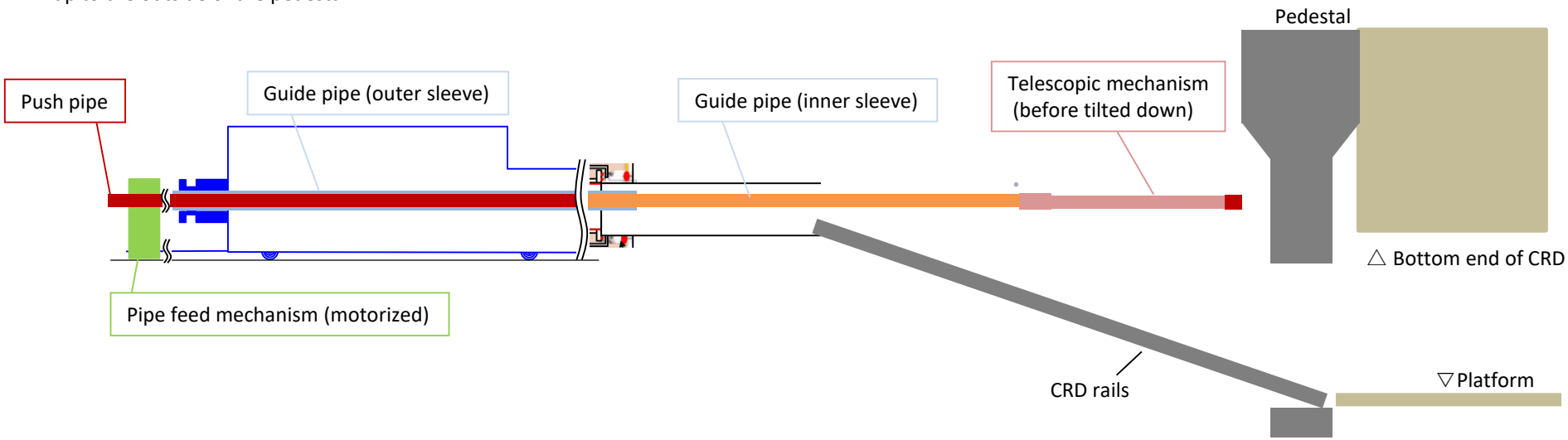
①An enclosure is installed behind the X-6 penetration connection structure and connection pipe



② The guide pipe (outer sleeve/inner sleeve) is pushed (push length: 6.5m) (when pushing to the end of the enclosure, the push pipe is pushed by motorized mechanism, after it is attached manually to the inner sleeve of the guide pipe)

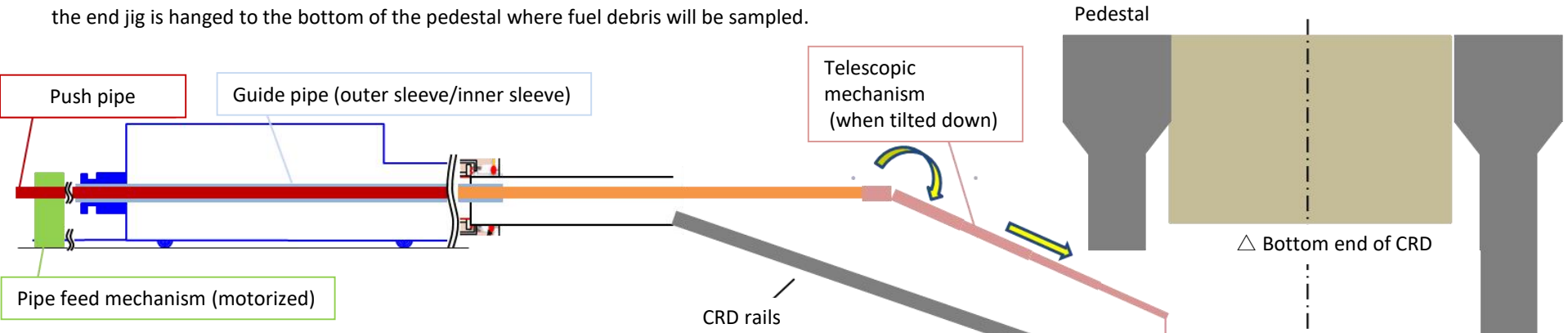


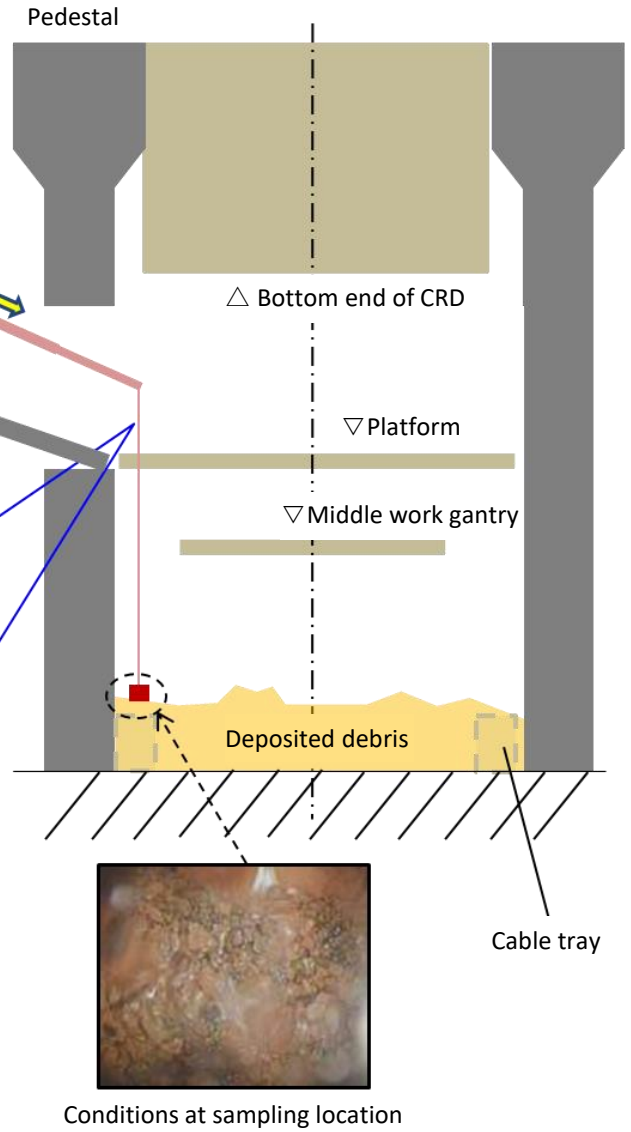
③ Push pipe is successively connected and fed in to push only the inner sleeve of the guide pipe (push length: 5.0m), pushing the telescopic arm right up to the outside of the pedestal



[Reference] Work overview of Telescopic Fuel Debris Trial Retrieval (2/3)

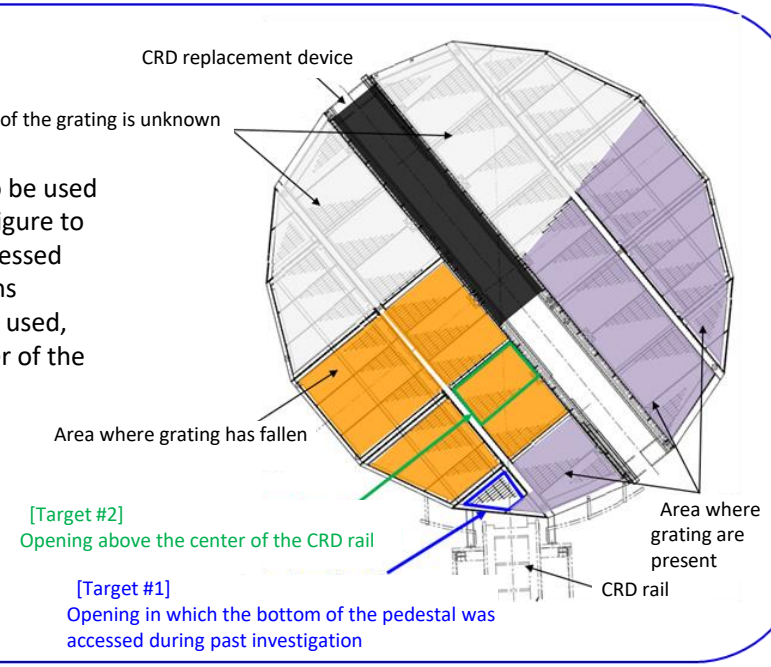
④ A tilting mechanism is used to lower end jig and insert the telescopic arm into the pedestal. Thereafter, the end jig is hanged to the bottom of the pedestal where fuel debris will be sampled.





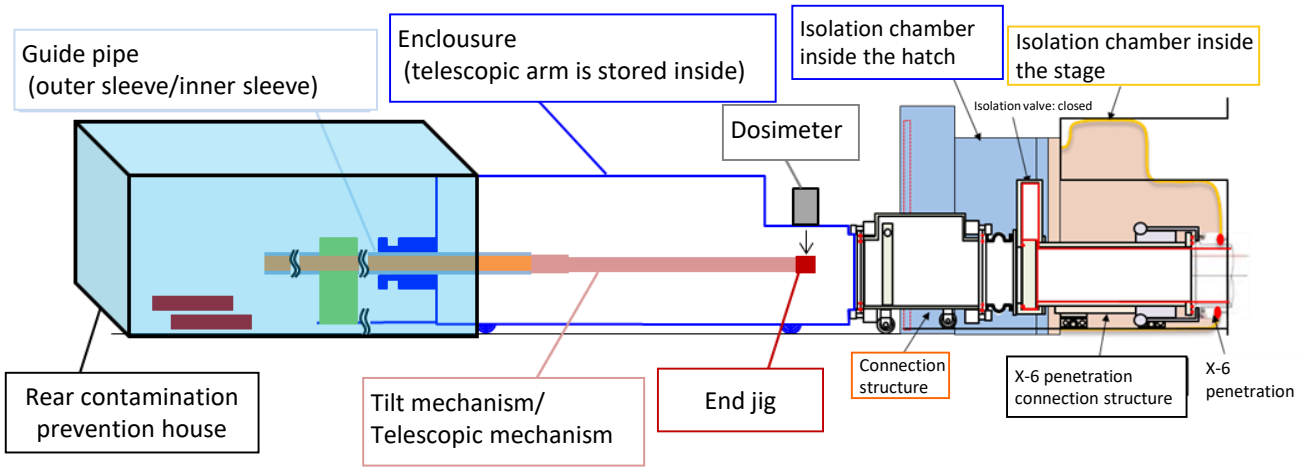
Conditions at sampling location

- The platform opening to be used will be target #1 in the figure to the right, which was accessed during past investigations
- If target #1 could not be used, target #2 near the center of the pedestal will be used



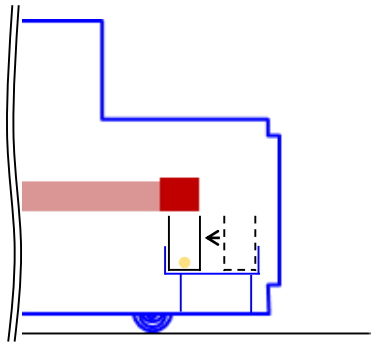
[Reference] Work overview of Telescopic Fuel Debris Trial Retrieval (3/3)

⑤ After the installation of a rear contamination prevention house (hereinafter referred to as, “rear house”) behind the enclosure, the telescopic arm will be withdrawn by the opposite procedure from insertion, and the isolation valve will be closed. After that, the dose of the sampled fuel debris will be measured to confirm that it is at a dose level that can be handled.

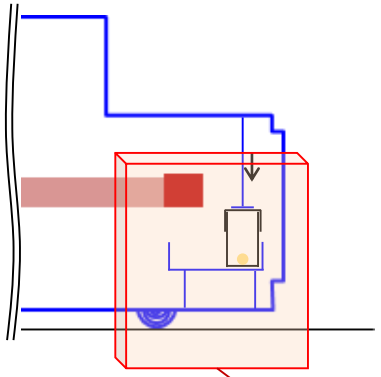


※**D**ouble **P**orte pour **T**ransfer **E**tanche (French) is a system that enables the lid and a dedicated port to be open/closed at the same time in order to prevent the spread of contamination.

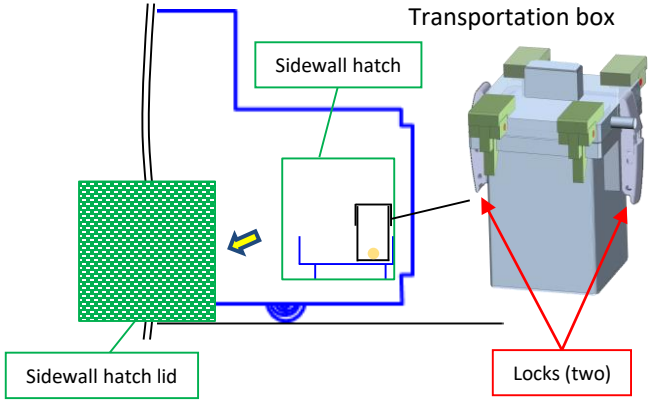
⑥ The transportation box will be moved remotely to underneath the end jig and the fuel debris will be put inside the transportation box



⑦ The transportation box will be moved remotely to underneath the lid. The lid will be firmly attached to the transportation box to ensure that no further dust will rise. After that, sidewall hatch contamination prevention house (hereinafter referred to as, "sidewall house") will be installed.



⑧ The enclosure sidewall hatch will be opened through the sidewall house and the transportation box will be removed after securing its lid. The transportation box will then be put in a DPTE※ container and transported to the glovebox.

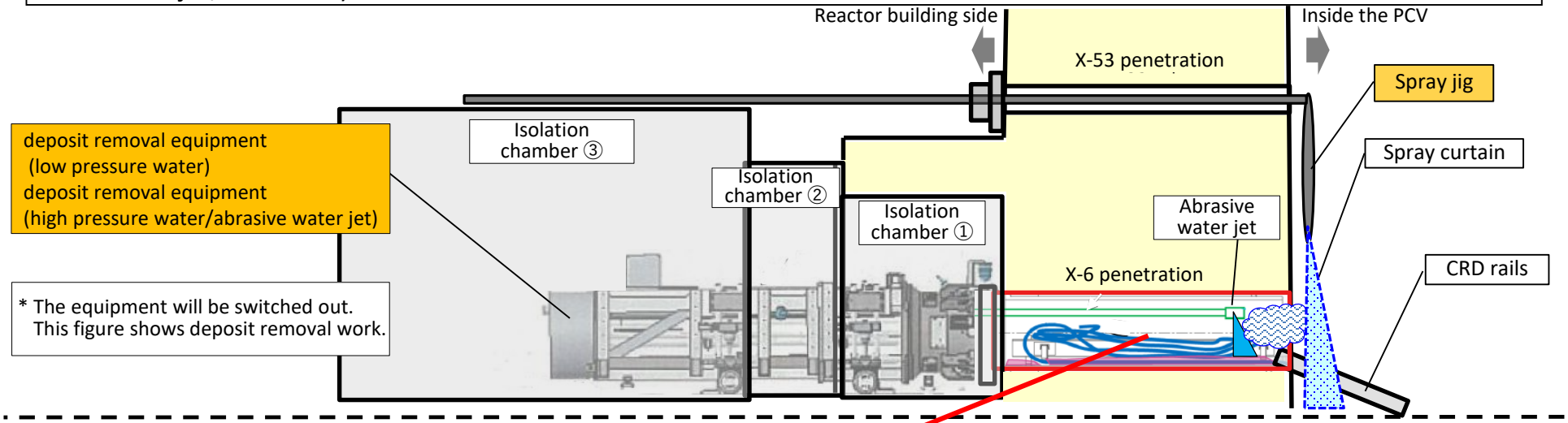


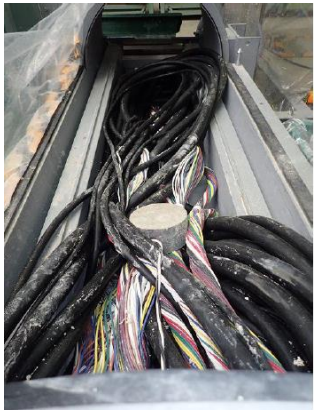
（The diagram of sidewall is omitted）

[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)

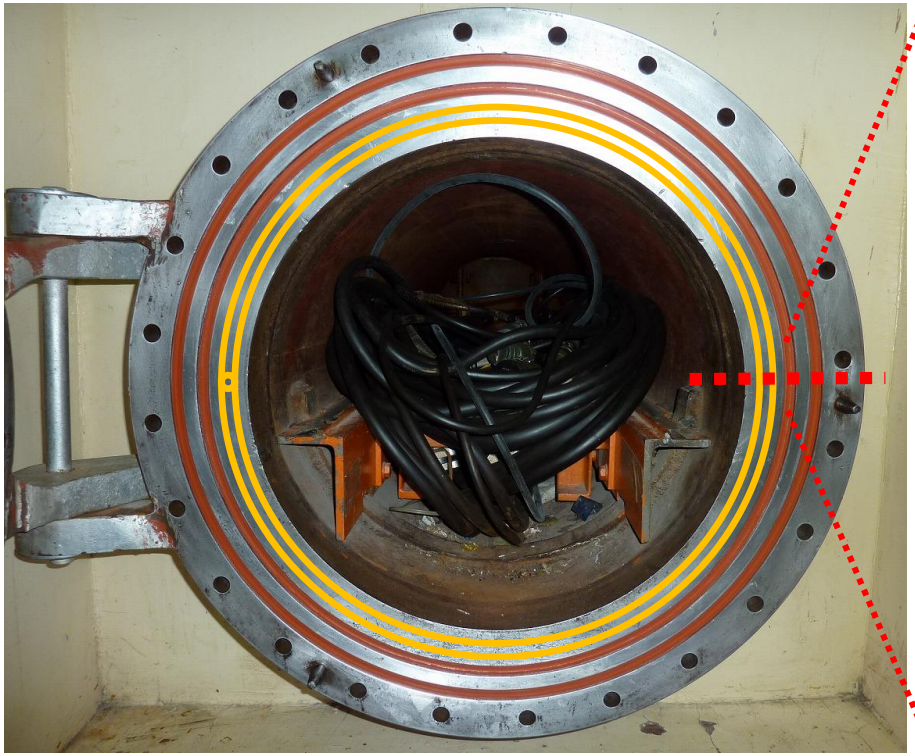




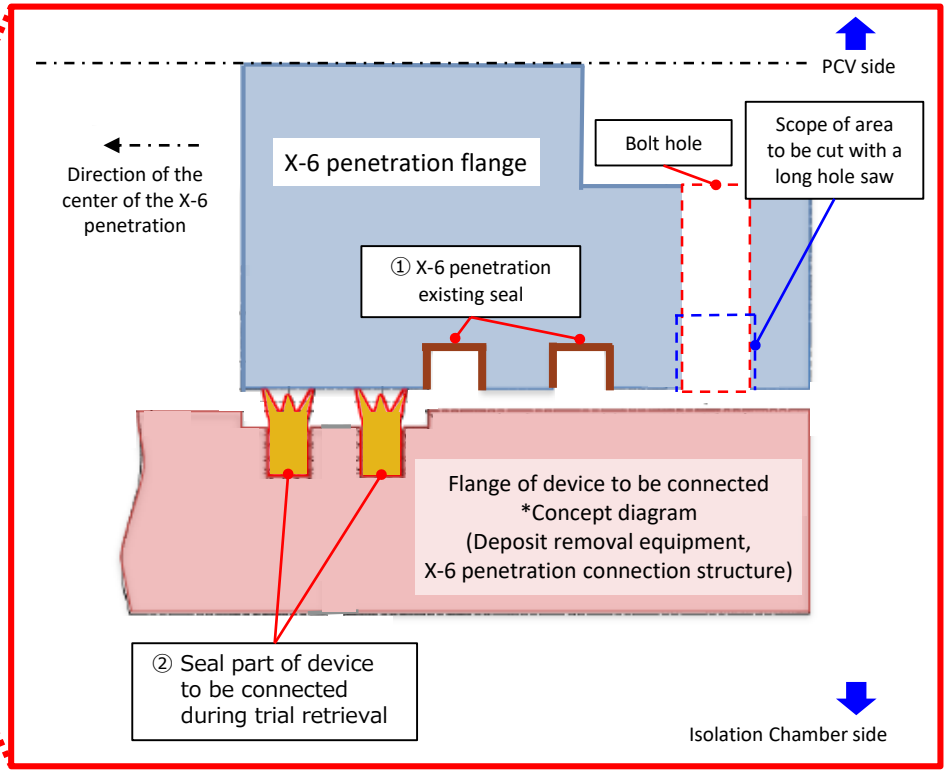
Conditions inside the X-6 penetration (mockup)

[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)



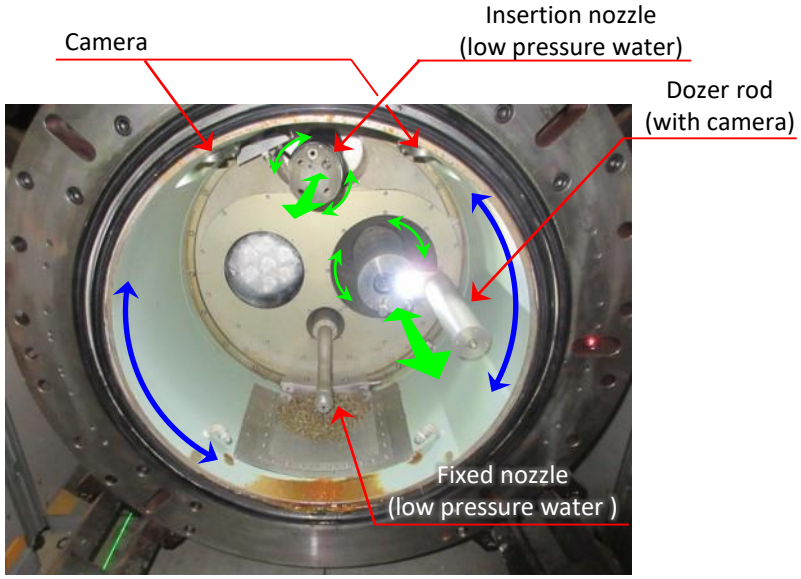
Location of seals when connecting devices to the X-6 penetration (as seen from above)

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

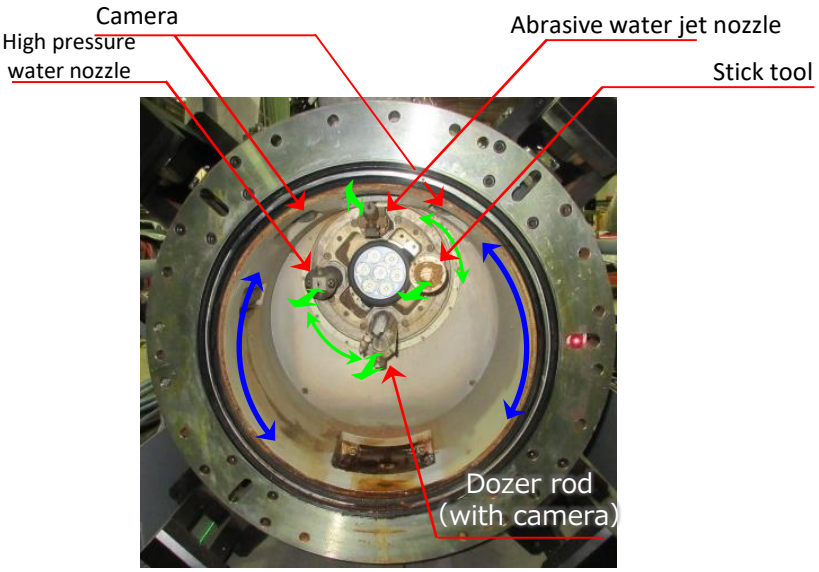
[Reference] Deposit removal equipment (low pressure water/high pressure water and abrasive water jet)

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

[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

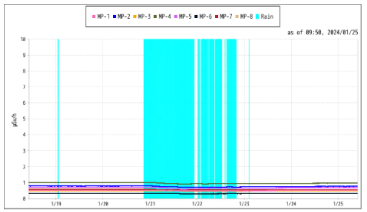
Radiation Dose measured at Monitoring Post of Fukushima Daiichi Nuclear Power Station

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)

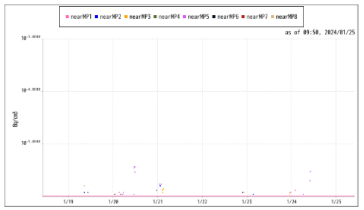
MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	Wind Direction	Wind Velocity	Rain
0.502	0.758	0.478	0.959	0.670	0.309	0.554	0.522	west-northwest	12.4	No

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

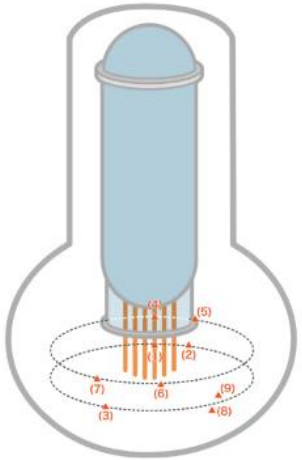
[Reference] Screen image of our website

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

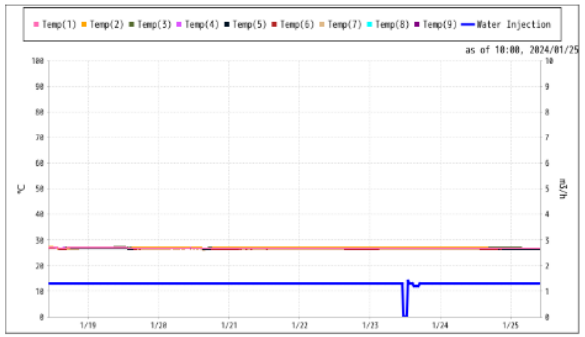
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

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