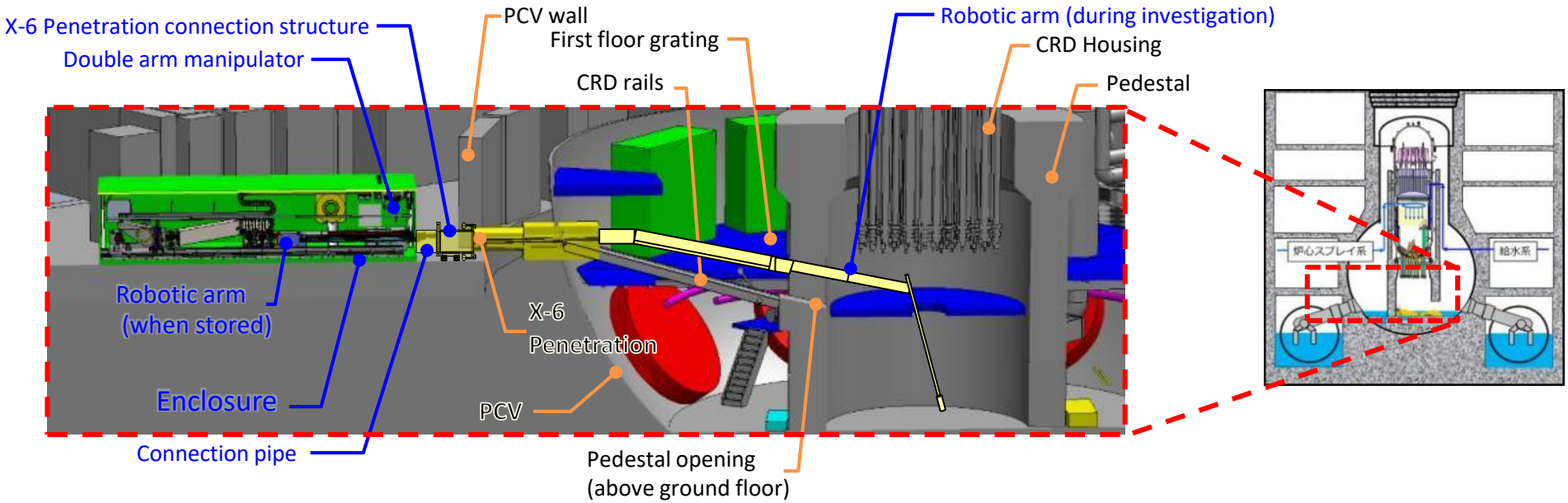
Fukushima Daiichi Nuclear Power Station
Unit 2 PCV Internal Investigation/
Preparation Status of Fuel Debris Trial Retrieval

April 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 telescopic device and 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.
- Run-through test after the installment of robotic arm inside the enclosure and installment of sensors, tools and external cables at the arm are underway. 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

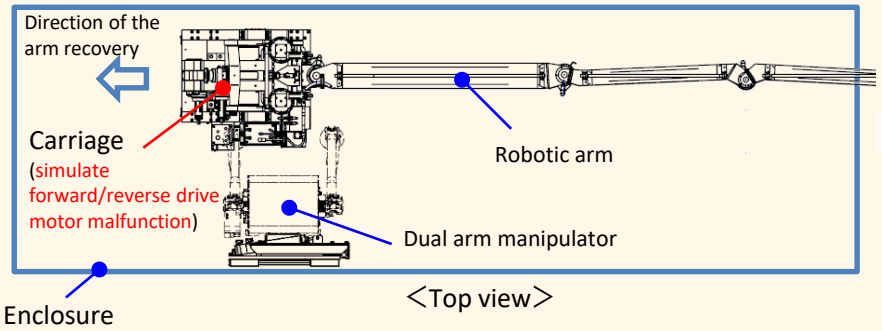
Covered in this report

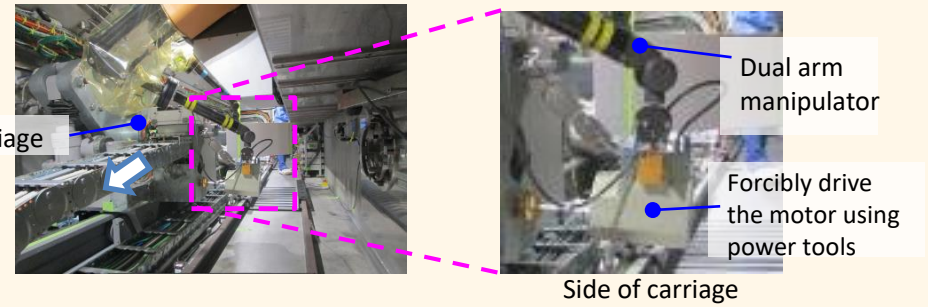
Test category	Test details	Naraha
Robotic arm-related tests	Ability to pass through the X-6 penetration	Completed
	Removing obstacles at the exit for the X-6 penetration using the AWJ	Completed (work efficiency being examined)
	Function tests (deflection management, etc.)	Completed
	Ability to access 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	Completed
Run-through tests (robotic arm + double arm manipulator	Installing sensors, tools and external cables at the arm	Underway
	Constructing an access route (removing obstacles using the AWJ)	To be performed going forward
	Investigation of the top of the pedestal (sensors and wand are installed)	
	Investigation of the bottom of the pedestal (sensors and wand are installed)	

2-2. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment [Forced withdrawal of the arm]

- Forced withdrawal (emergency retrieval) tests of the robotic arm were performed to simulate the malfunction of the arm's drive mechanism (motor) during the internal investigation.

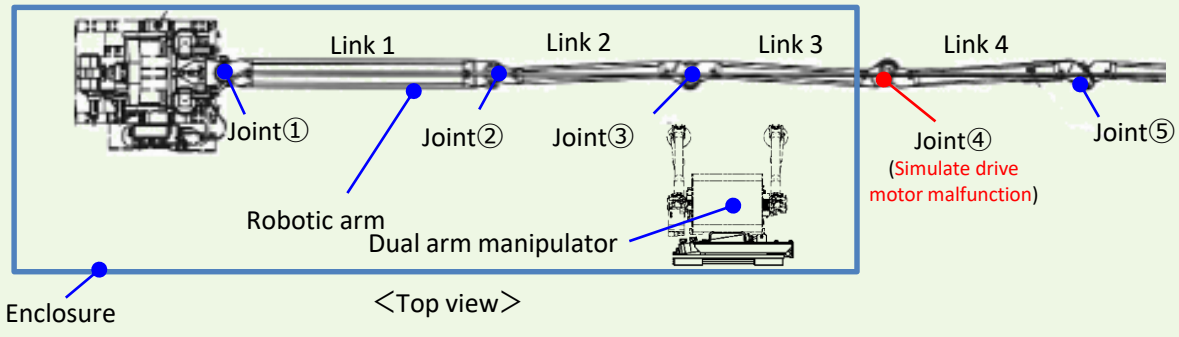
Emergency retrieval test simulating carriage (forward/reverse drive motor) malfunction

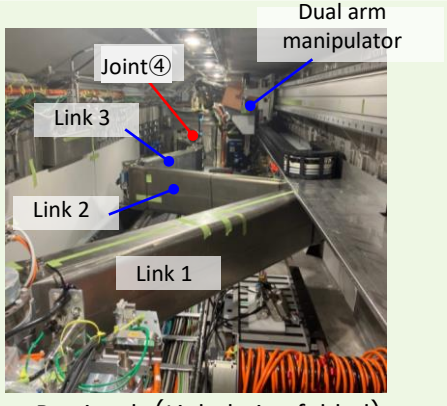




- Using dual arm manipulator equipped by power tools, malfunctioned motor is forcibly driven to move back the carriage and retrieve the arm.
- It was confirmed that the arm can be withdrawn back into the enclosure.

Emergency retrieval test simulating malfunction of link (joint ④ axis drive motor)



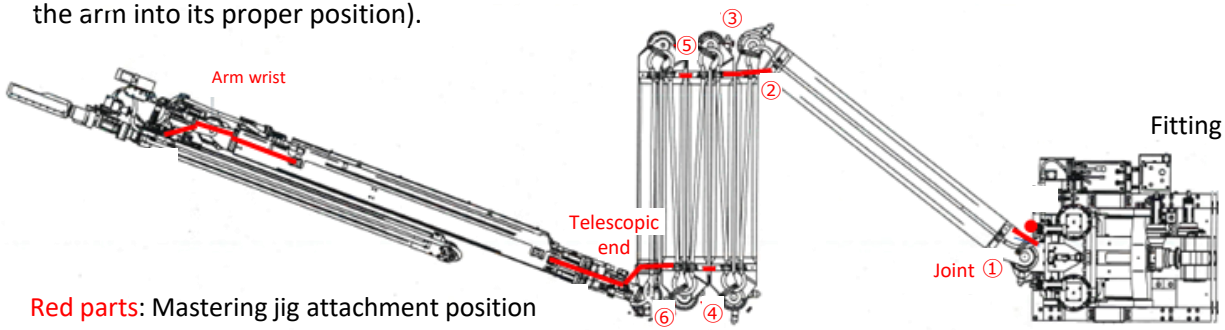


Retrieval (Links being folded)

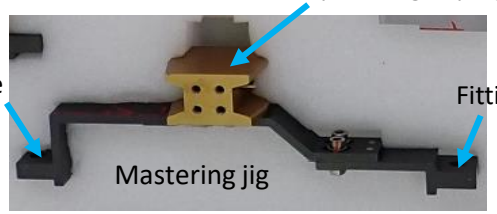
- It was confirmed that the arm can be retrieved back into the enclosure by remotely releasing joint 4 clutch and remotely operating other operable axes and withdrawing (folding) the link using the dual manipulator.

2-3. Status of Testing of Unit 2 Fuel Debris Trial Retrieval Equipment [Improvements to arm mastering jig]

- When the device is used in the field, checking the degree of position offset of the arm (discrepancy between software values and the actual position of the arm), and fine adjustment of the position of the arm (mastering) is planned. Mastering refers to using the dual arm manipulator to attach a mastering jig to a specific location on the arm in order to confirm arm storage. (If there is a discrepancy, a correction will be made to get the arm into its proper position).

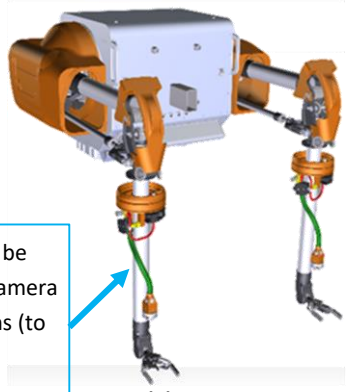


Red parts: Mastering jig attachment position



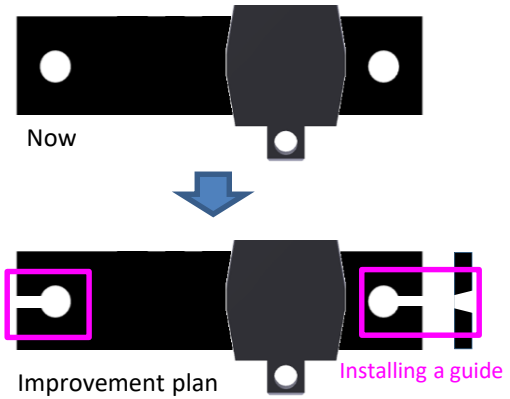
There is a protrusion on the arm that lines up with a hole on the mastering jig.

- After the arm was withdrawn into the enclosure, a test to examine the user-friendliness of the mastering process using the double arm manipulator was conducted, and it was discovered that improvements are needed to both visibility and the jig itself.
  - ➢ Visibility improvement: The camera on the double manipulator arm will be changed to improve visibility
  - ➢ Jig improvement: The fitting hole will be fitted with a guide in order to make mastering jig attachment easier



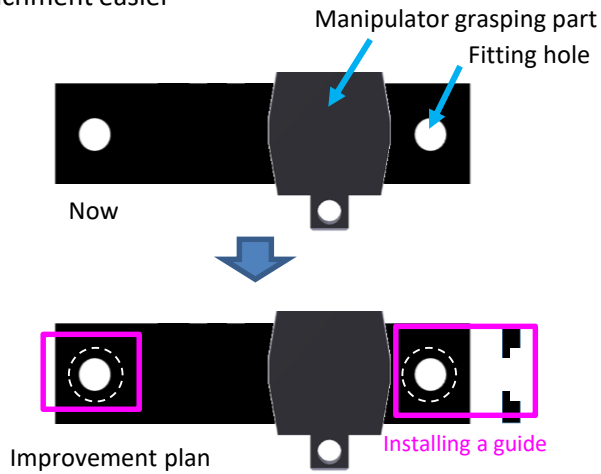
The existing camera will be replaced with another camera of different specifications (to improve visibility during mastering)

Double arm manipulator



Mastering jig

(For joint ②～⑥ axes)



Mastering jig

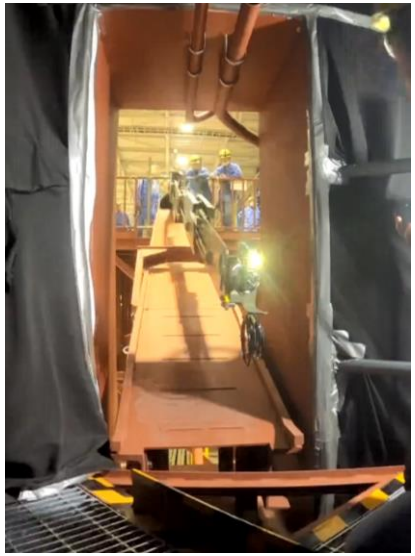
(For joint ①, telescopic end and arm wrist axis)

3. Status of Mockup of the Telescopic Trial Retrieval Equipment (1/2)

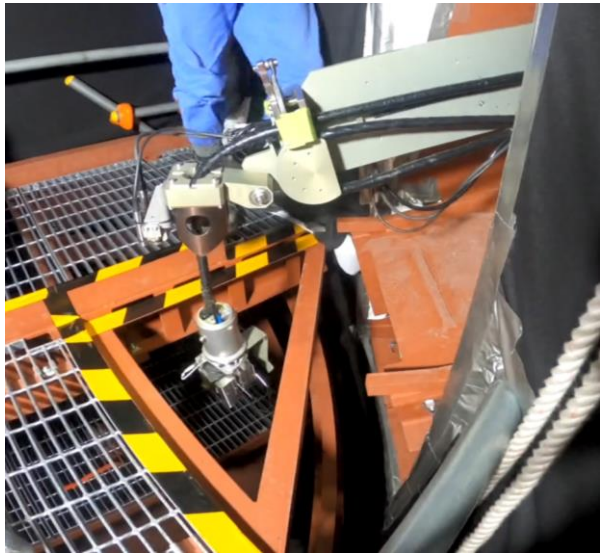
- Mockup testing is currently underway at the manufacturer's factory in preparation for the Unit 2 fuel debris trial retrieval .

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

Inserting the guide pipe



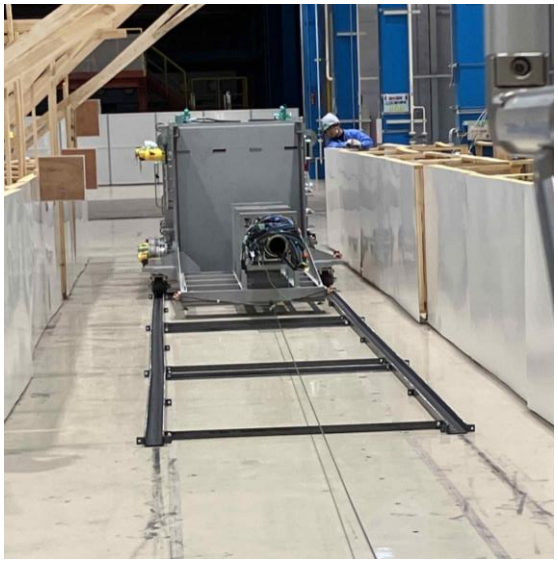
Inserting the equipment into the pedestal opening



Suspending and lowering the end jig through the grating opening

3. Status of Mockup of the Telescopic Trial Retrieval Equipment (2/2)

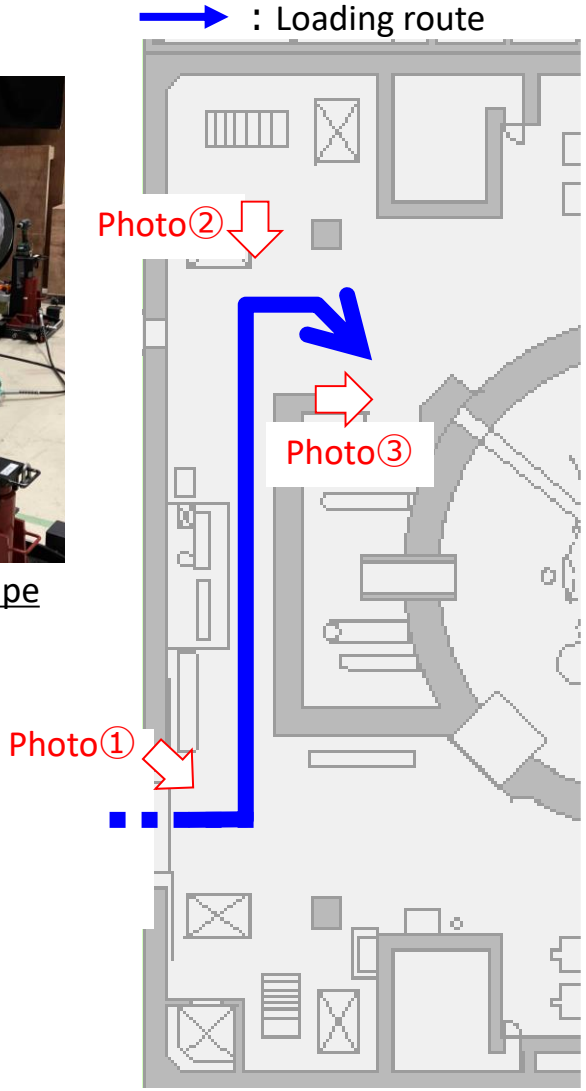
- An enclosure accurate in both weight and dimensions is used to evaluate installation procedures at the manufacturer's factory .



②：Going through the west passage

③：Connecting to the connection pipe

①：Turning the device around in the southwest area

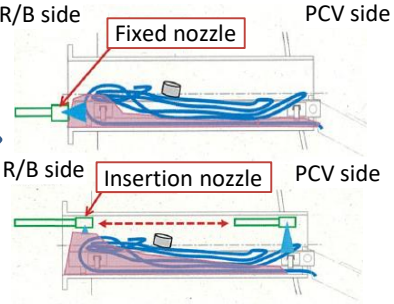


4-1. Deposit Removal Status

- 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



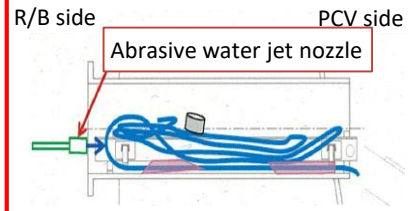
Deposit removal equipment (low pressure water)

※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)

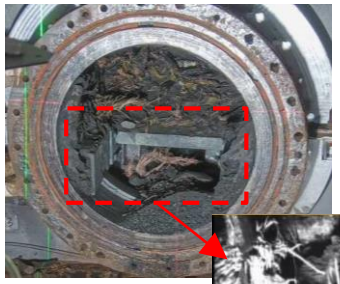
On to next step
Installation of X-6 penetration connection structure

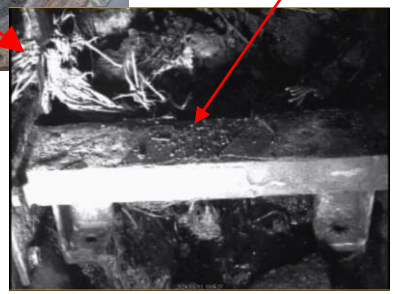
※Photos were taken using the mockup

Reference. Field work Progress Status

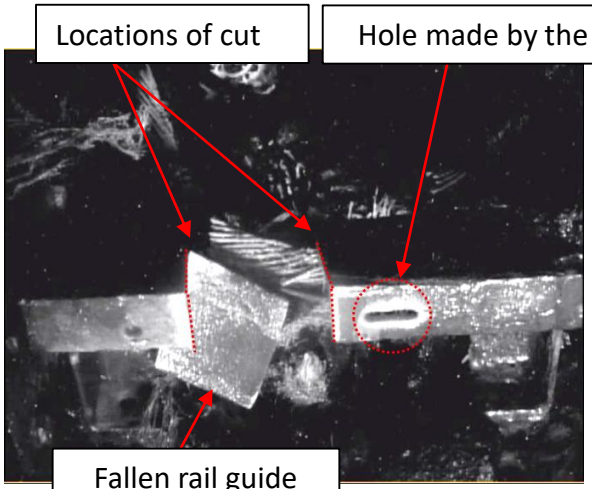
(Removing Deposits from within the X-6 Penetration (High-pressure water/AWJ): AWJ work)

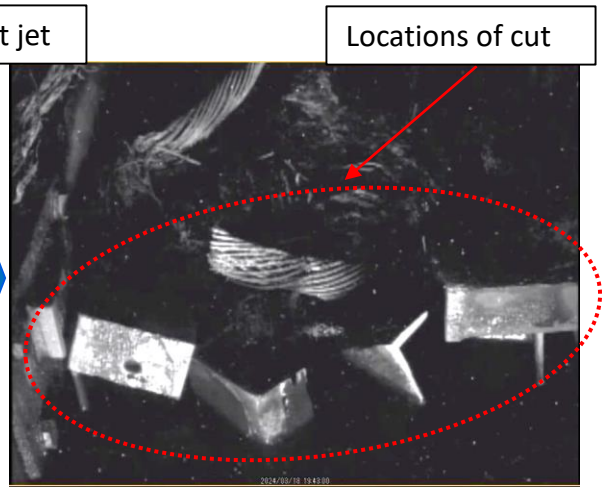
- We started to use the AWJ on March 18, and removed the CRD rail guides that are in front of the X-6 penetration. Since March 22, we have been pushing and cutting the cables using AWJ. Following that, we will remove the CRD rail guides at the back of the X-6 penetration.



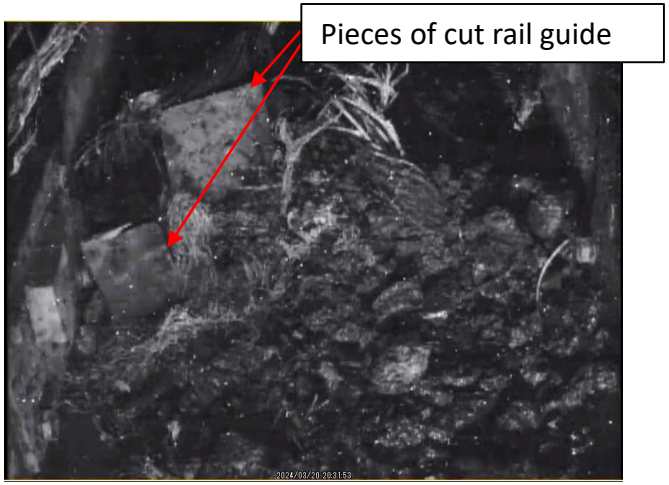


Before cutting the CRD rail guides

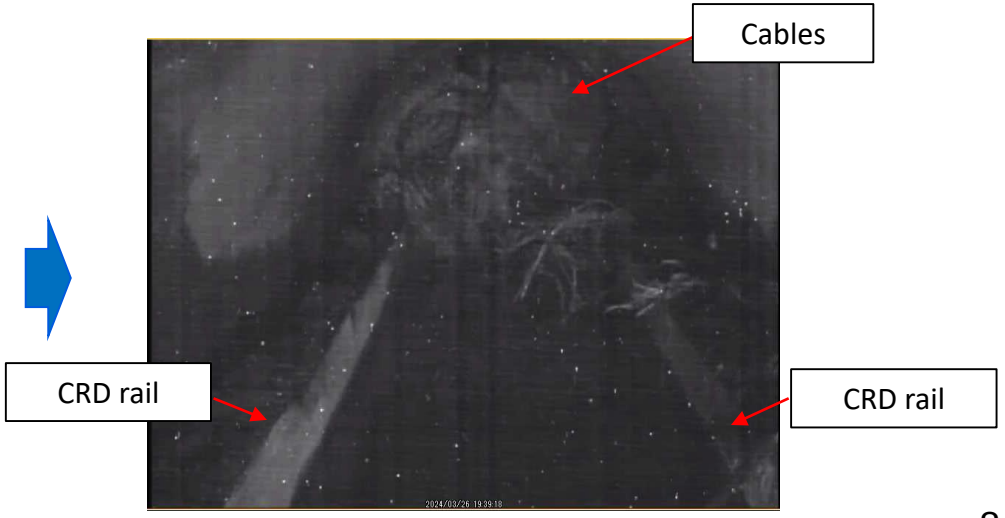




After cutting the CRD rail guides



Bringing the CRD rail guide into the PCV

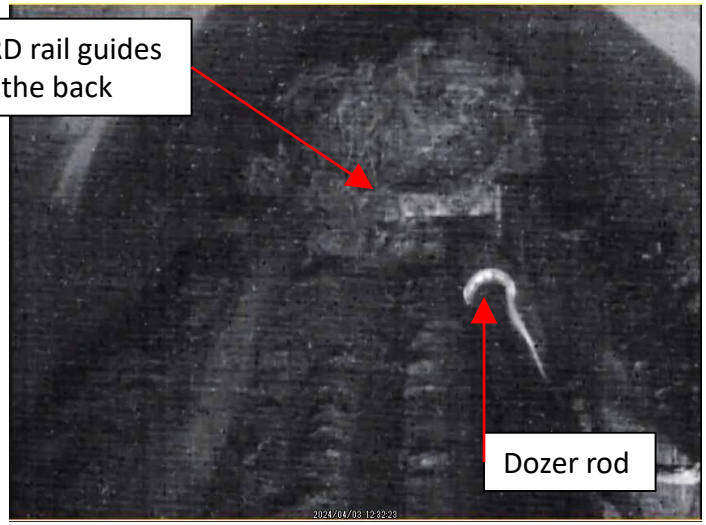


Pushing the cables towards the back of the X-6 penetration

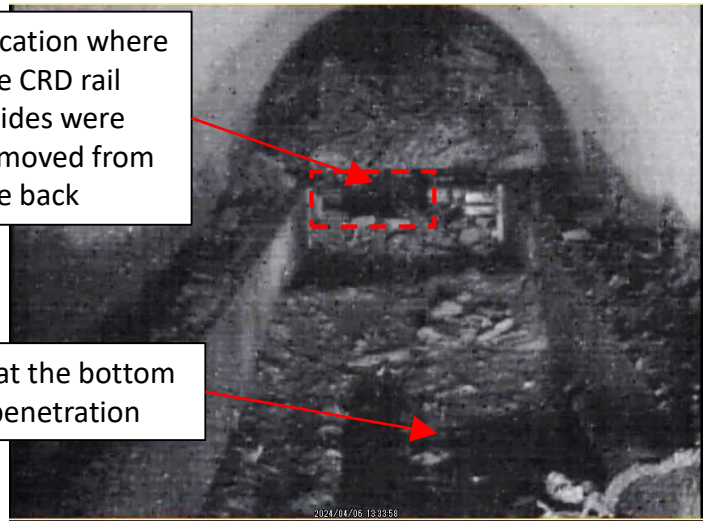
4-2. Field work Progress Status

(Removing Deposits from within the X-6 Penetration (High-pressure water/AWJ): AWJ work)

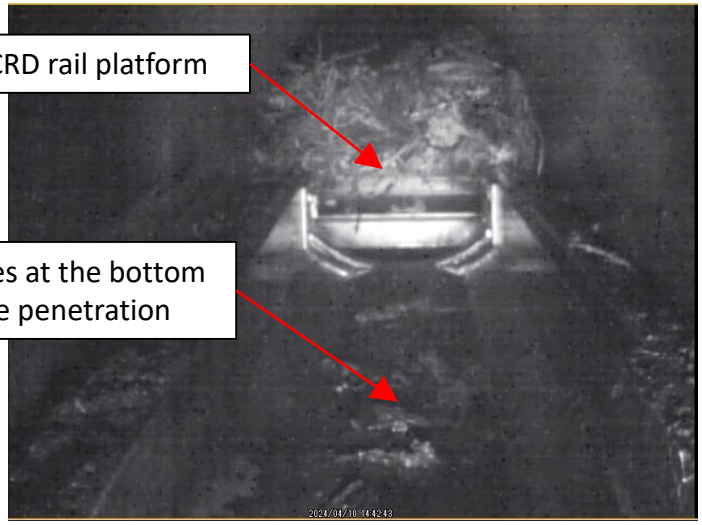
- The AWJ was used to remove the CRD rail guides at the back of the X-6 penetration, the CRD rail platform lock pin on the outside of the X-6 penetration (PCV side), and the cables at the bottom of the penetration.



Prior to removal of the CRD rail guides at the back of the X-6 penetration



During removal of the CRD rail guides at the back of the X-6 penetration



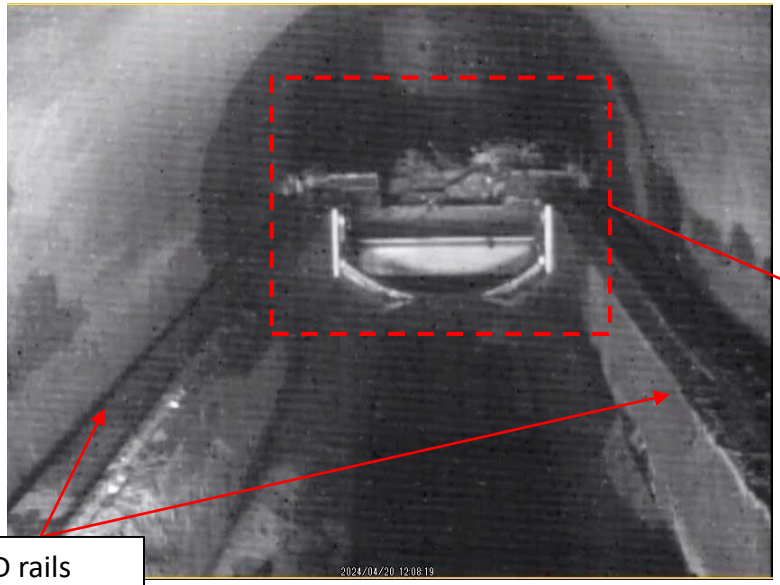
After removal of the CRD rail guides at the back of the X-6 penetration and the rail platform lock pin

After removal of the cables at the bottom of the X-6 penetration

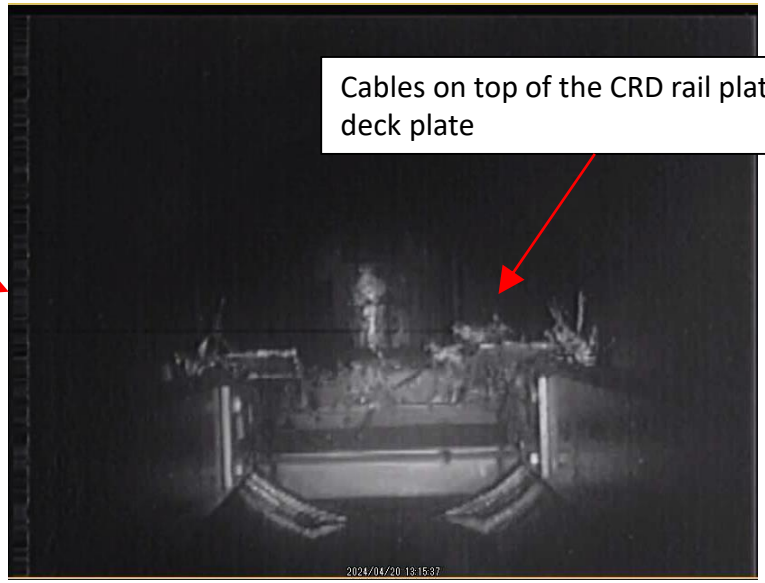
4-3. Field work Progress Status

(Removing Deposits from within the X-6 Penetration (High-pressure water/AWJ): AWJ work)

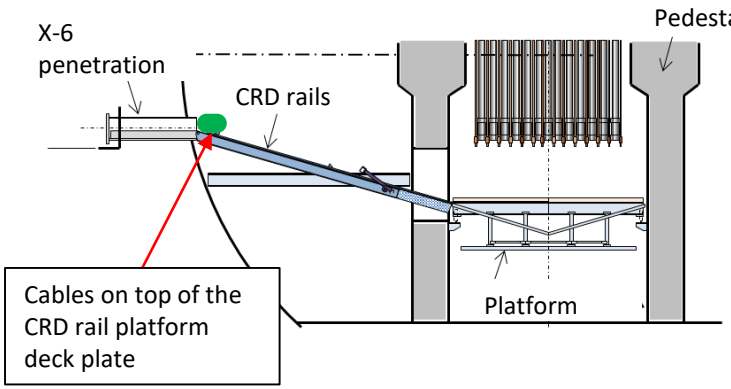
- The cables on top of the CRD rail platform deck plate on the outside of the X-6 penetration (PCV side) and part of the deck plate are being cut away/removed.

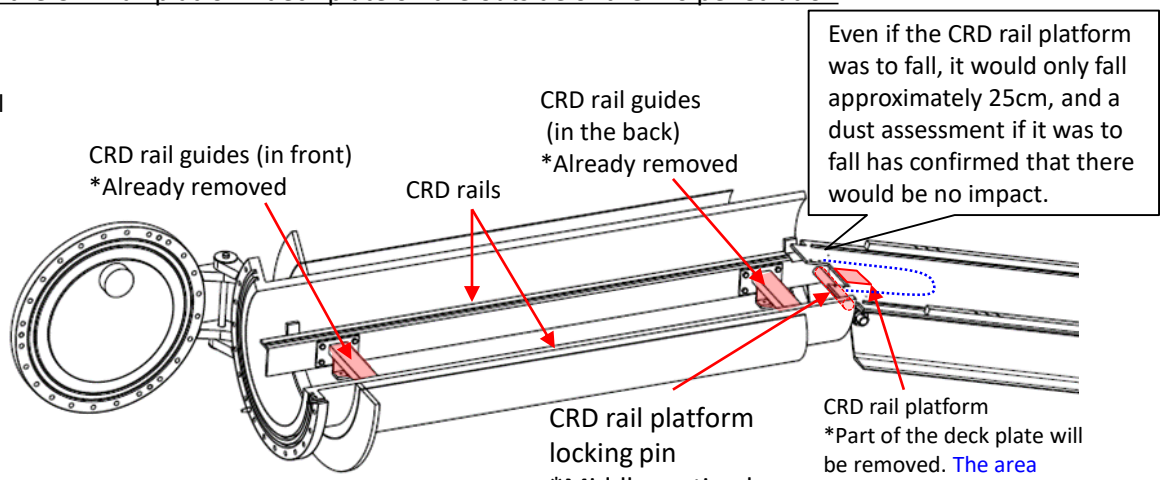


CRD rails



Removing the cables on top of the CRD rail platform deck plate on the outside of the X-6 penetration





5. Schedule

- We are implementing works repeatedly to cut away using the AWJ and wash away with high-pressure water in order to remove the CRD rail guides at the back of the X-6 penetration, the cables on top of the CRD rail platform deck plate on the outside of the X-6 penetration (PCV side) and part of the deck plate. Currently, we are continuing the deposit removal work with the high-pressure water/AWJ.
- After confirming that there is no obstacle to passing the telescoping device and the robotic arm through the X-6 penetration, we will uninstall the deposit removal equipment and install X-6 penetration connection structure and connection pipe.
- 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)

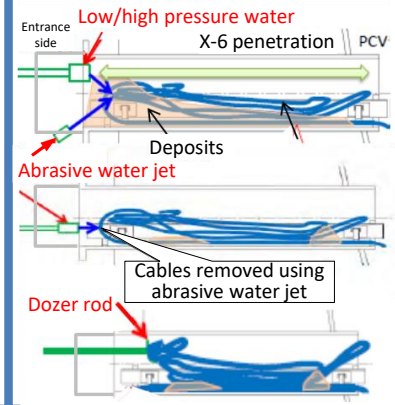
Approved

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

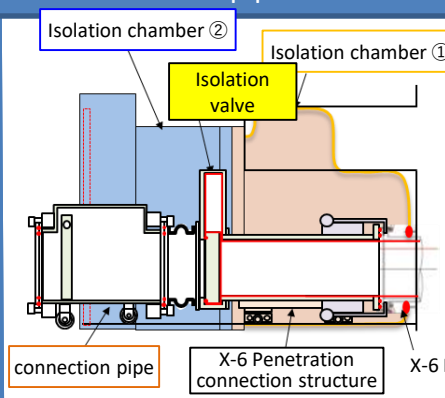
3. Removal of deposits from inside the X-6 penetration

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

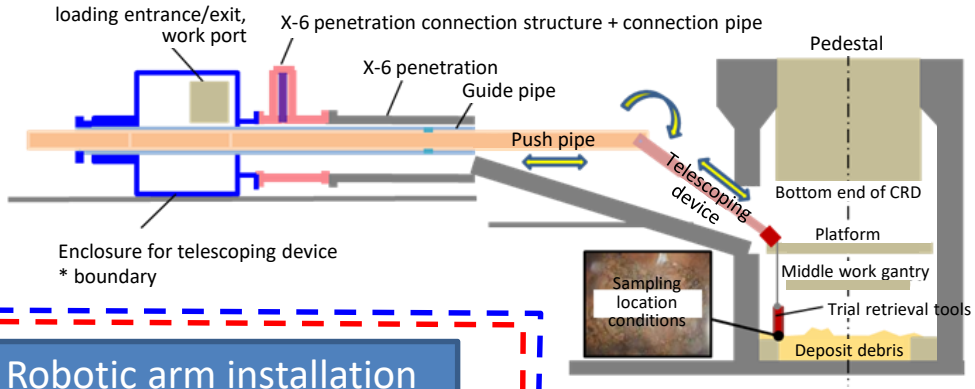
4. Installation of X-6 penetration connection structure and connection pipe



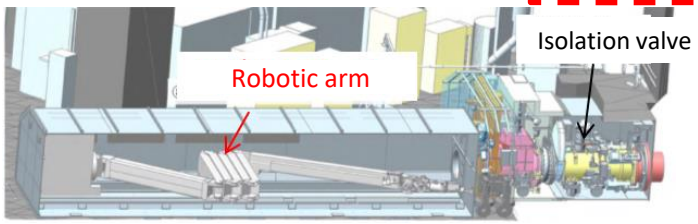
The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

Approval application pending

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

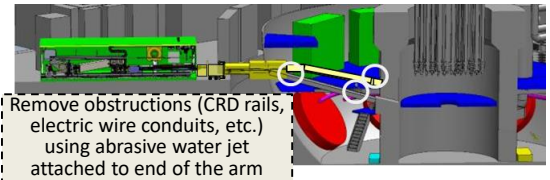


7. Robotic arm installation



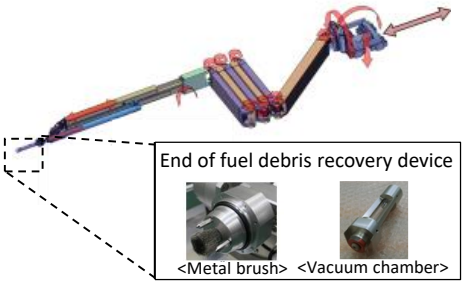
8. Internal investigation/debris sampling using robotic arm

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)

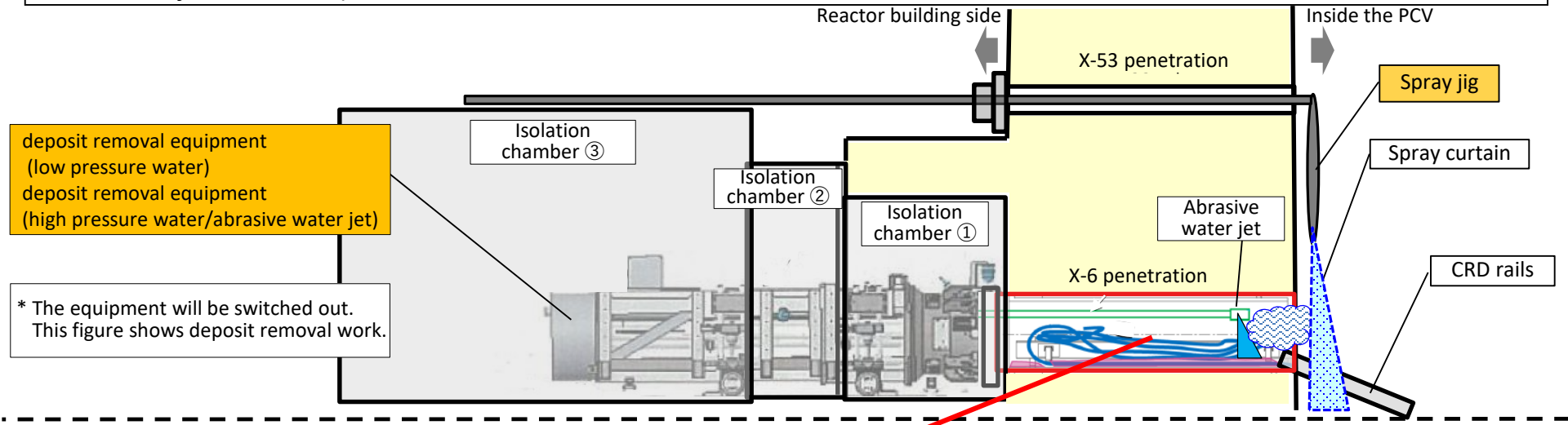
Isolation valve: Valve installed to separate the inside of the PCV from the outside

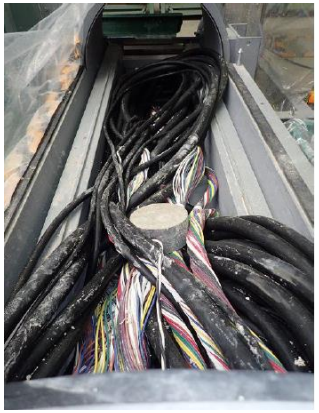
Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

Reference. 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)

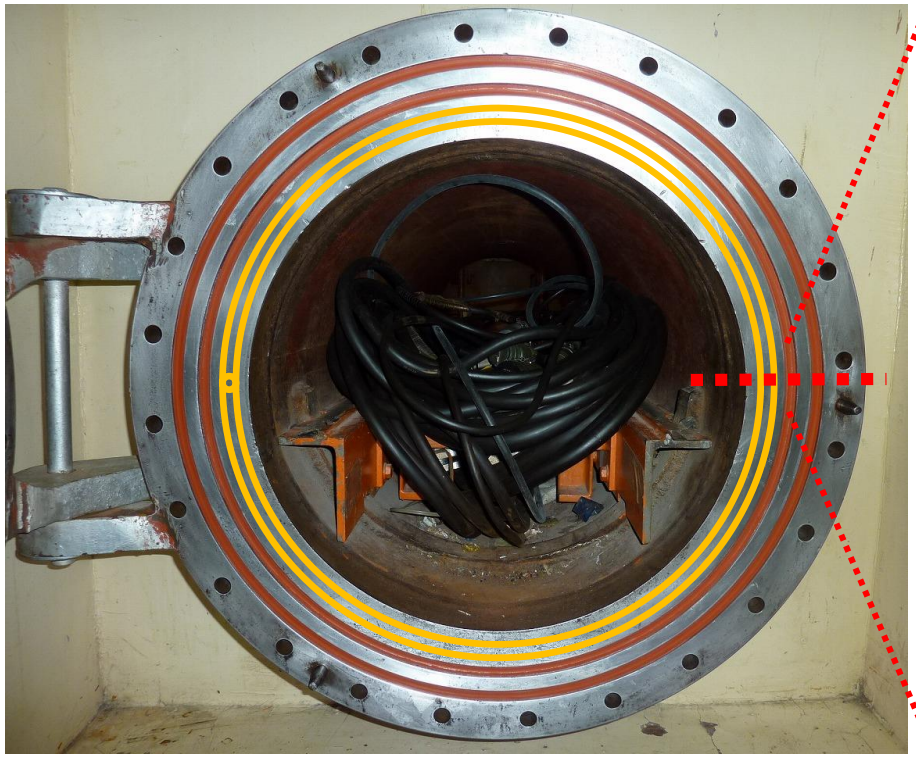




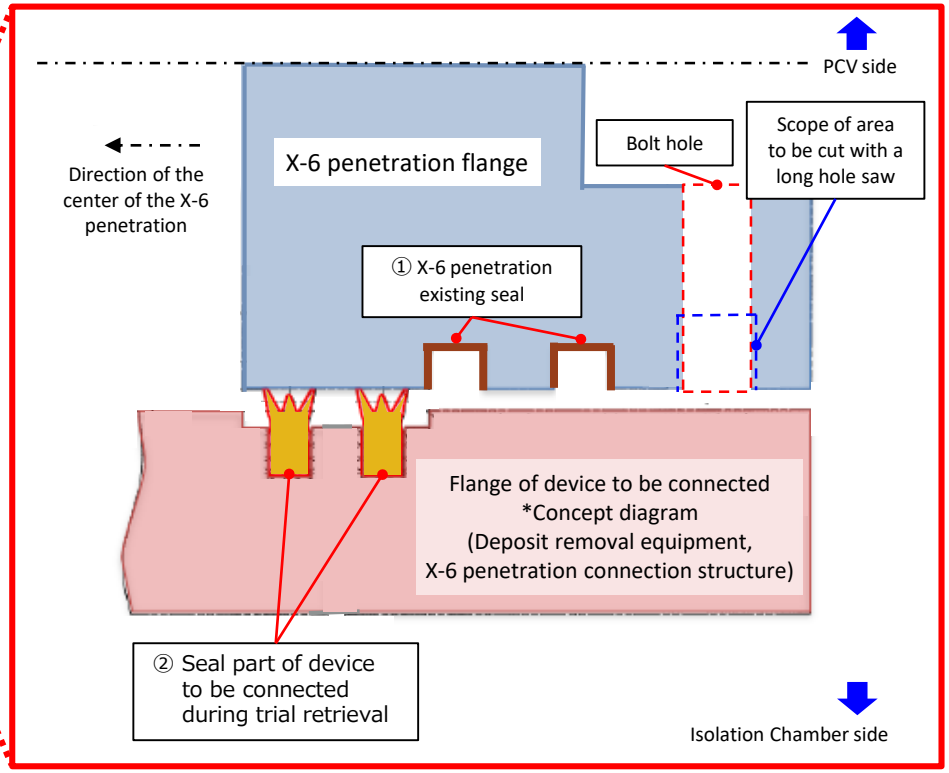
Conditions inside the X-6 penetration (mockup)

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)



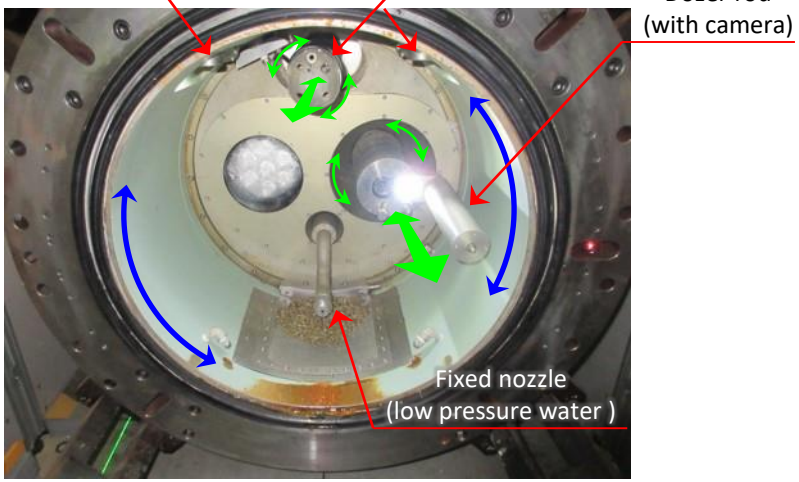
Location of seals when connecting devices to the X-6 penetration (as seen from above)

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

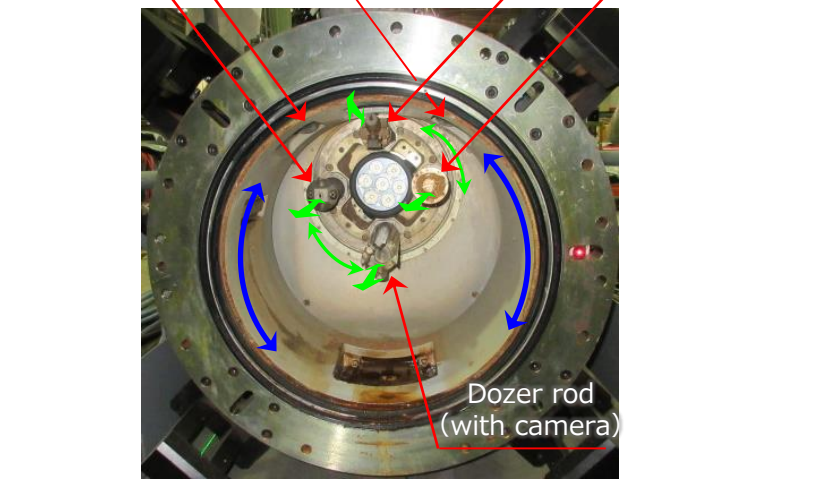
Reference. Deposit removal equipment (low pressure water, high pressure water and abrasive water jet)

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

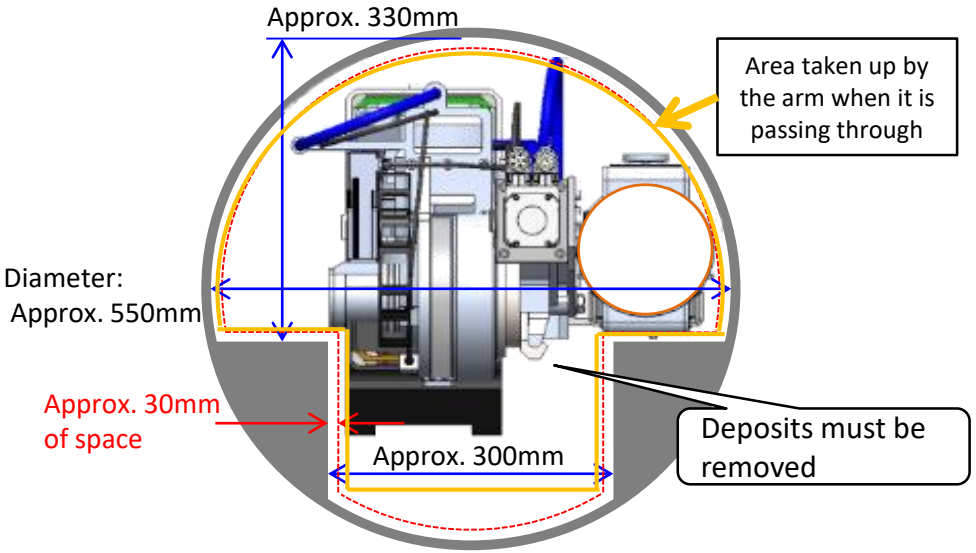


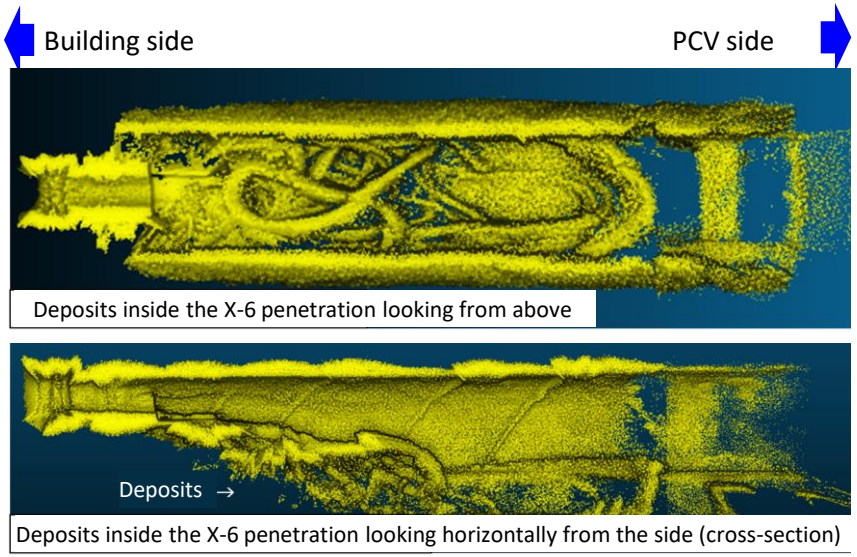
Cross-sectional view of the deposit removal equipment (high pressure water/abrasive water jet) connection to X-6 penetration

Reference. Robotic arm status when passing through the X-6 penetration

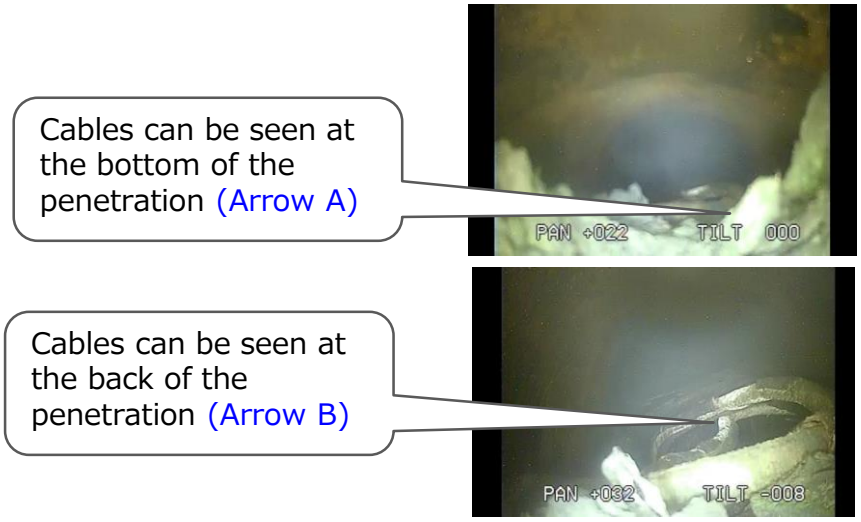
Robotic arm

(cross-section of the X-6 penetration when the arm is passing through)





From a 3-D scan taken in October 2020



Conditions in January 2017 (camera inserted through hole open for X-6 penetration investigation equipment)

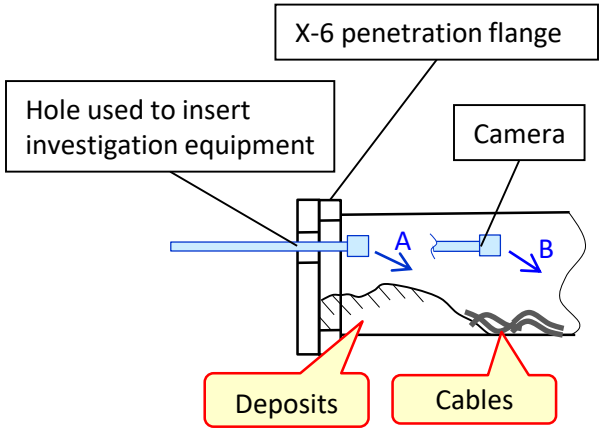


Diagram showing the assumed shape of deposits, etc.

Reference. Environmental Impact (1/2)

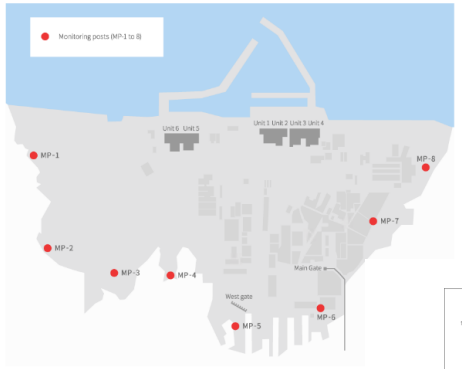
- The removal of deposits from inside the Unit 2 X-6 penetration has been ongoing since January 10, and we have not seen any radiological impact on the surrounding environment.
- During investigations, gases from inside the primary containment vessel have been prevented from leaking to the outside environment 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

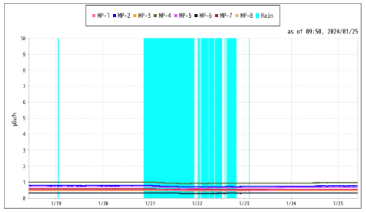
The following is the radiation doses of the air measured by the monitoring posts (MP1-8) at Fukushima Daiichi Nuclear Power Station.

Monitoring post (MP1 - MP8)

Monitoring points



Radiation dose



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

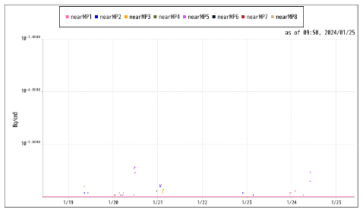
MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	Wind Direction	Wind Velocity	Rain
0.502	0.758	0.478	0.959	0.670	0.309	0.554	0.522	west-northwest	12.4	No

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

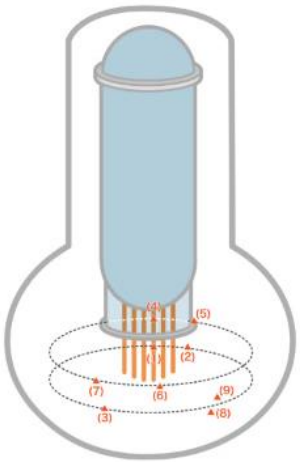
[Reference] Screen image of our website

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

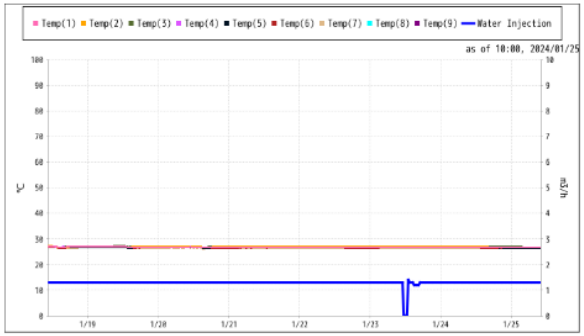
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

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