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

April 24, 2025

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.

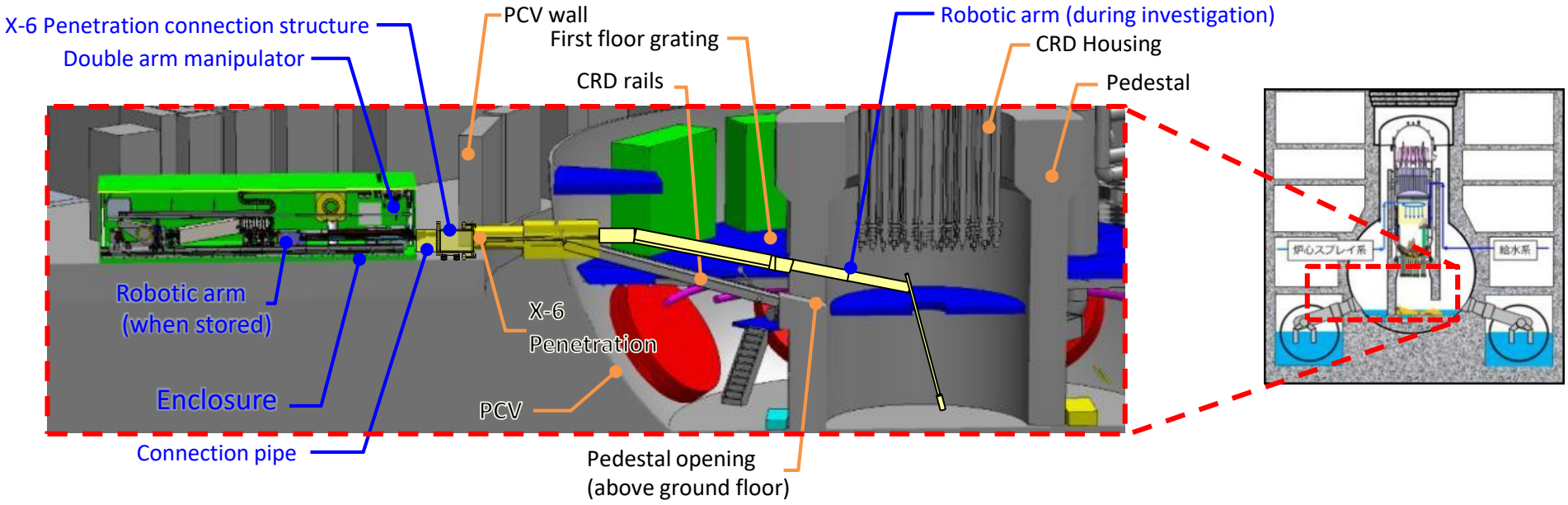
  ＜Already installed＞

  - The X-6 Penetration connection structure isolates the inside of the PCV from the outside
  - The connection pipe shields radiation
  - The telescopic device

  ＜To be installed＞

  - A metal box that contains the robotic arm (enclosure)

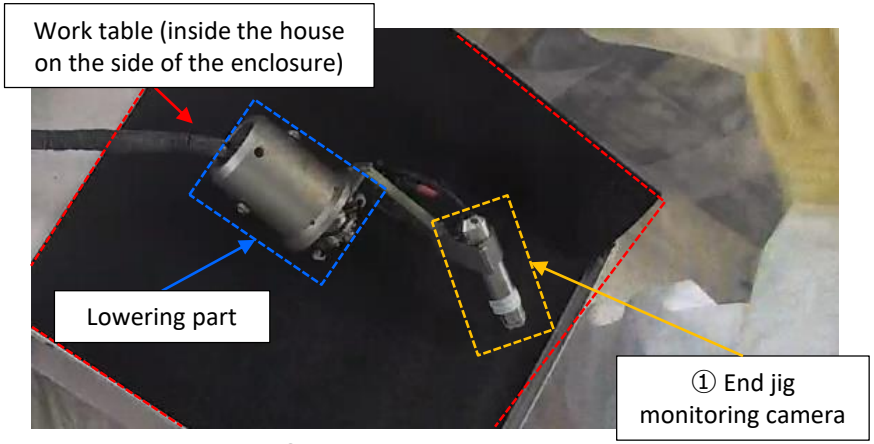
- After installation of the aforementioned equipment, the robotic arm shall be fed into the PCV through the X-6 penetration to remove obstacles inside the PCV while also conducting internal investigations and moving forward with the trial retrieval of fuel debris.



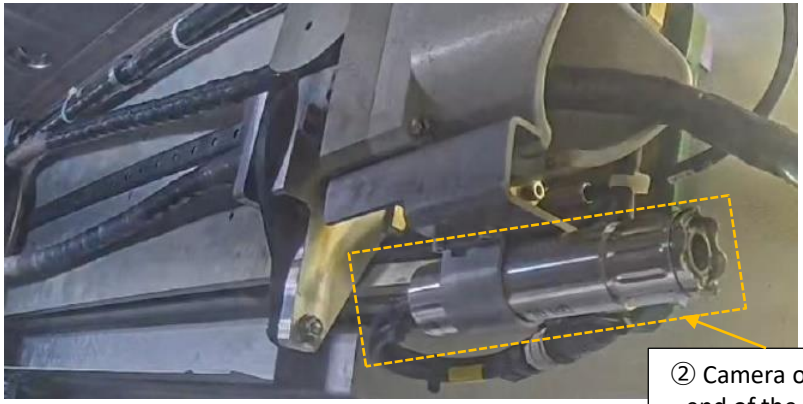
Unit 2 internal investigation/trial retrieval plan overview

2-1. Status of retrieval work using the telescopic device (Camera and end jig replacement)

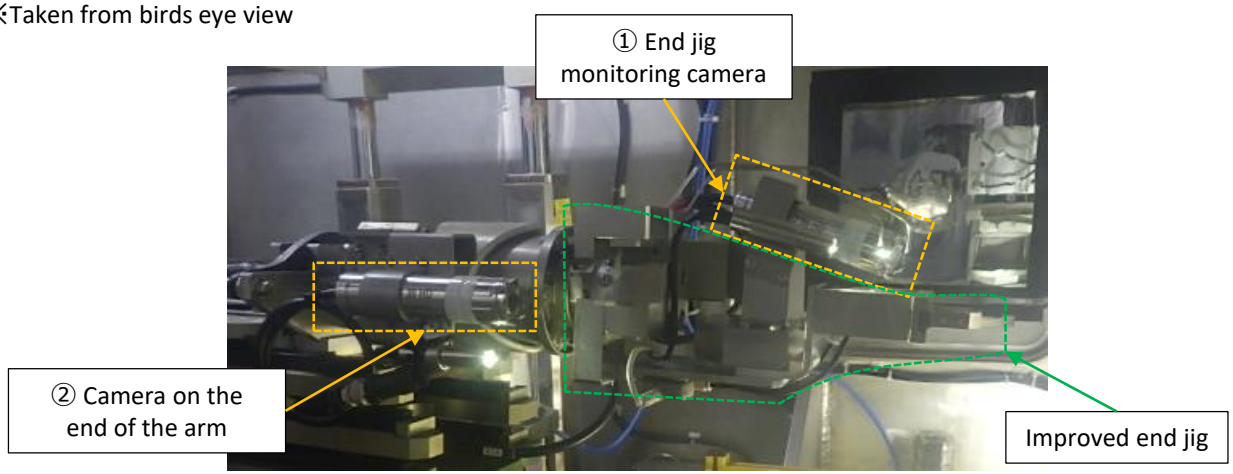
- Field checks by workers and training were implemented using the actual telescopic device push pipe device, etc.
- Some cameras on the telescopic device (① End jig monitoring camera, ② Camera on the end of the arm) were replaced and the end jig was replaced with an improved model after which it was confirmed that all components are functioning properly.
- Thereafter a function test of the entire telescopic device was performed and the temporary work house used for camera etc. replacement was disassembled.



Replaced ① End jig monitoring camera
※Taken from birds eye view



Replaced ② Camera on the end of the arm

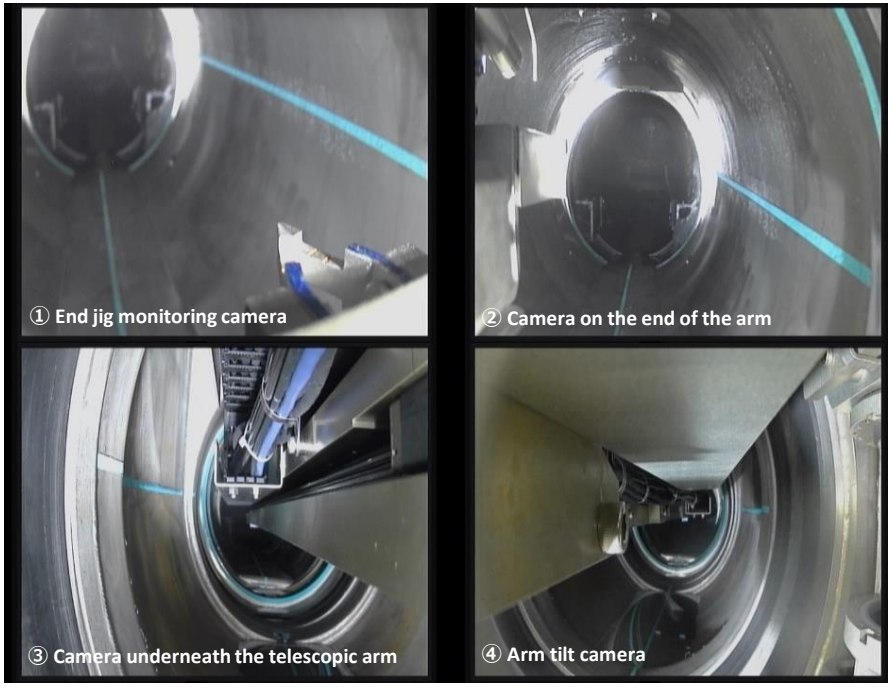


Replaced cameras ① ② and improved end jig

2-2. Status of retrieval work using the telescopic device (Commencement of retrieval)

- Following a leak check of the enclosure, pre-task deliberations and a final check of procedures were conducted.
- The second fuel debris trial retrieval commenced on April 15. The X-6 penetration connection structure isolation valve was opened and the guide pipes inserted.

Remote operations room

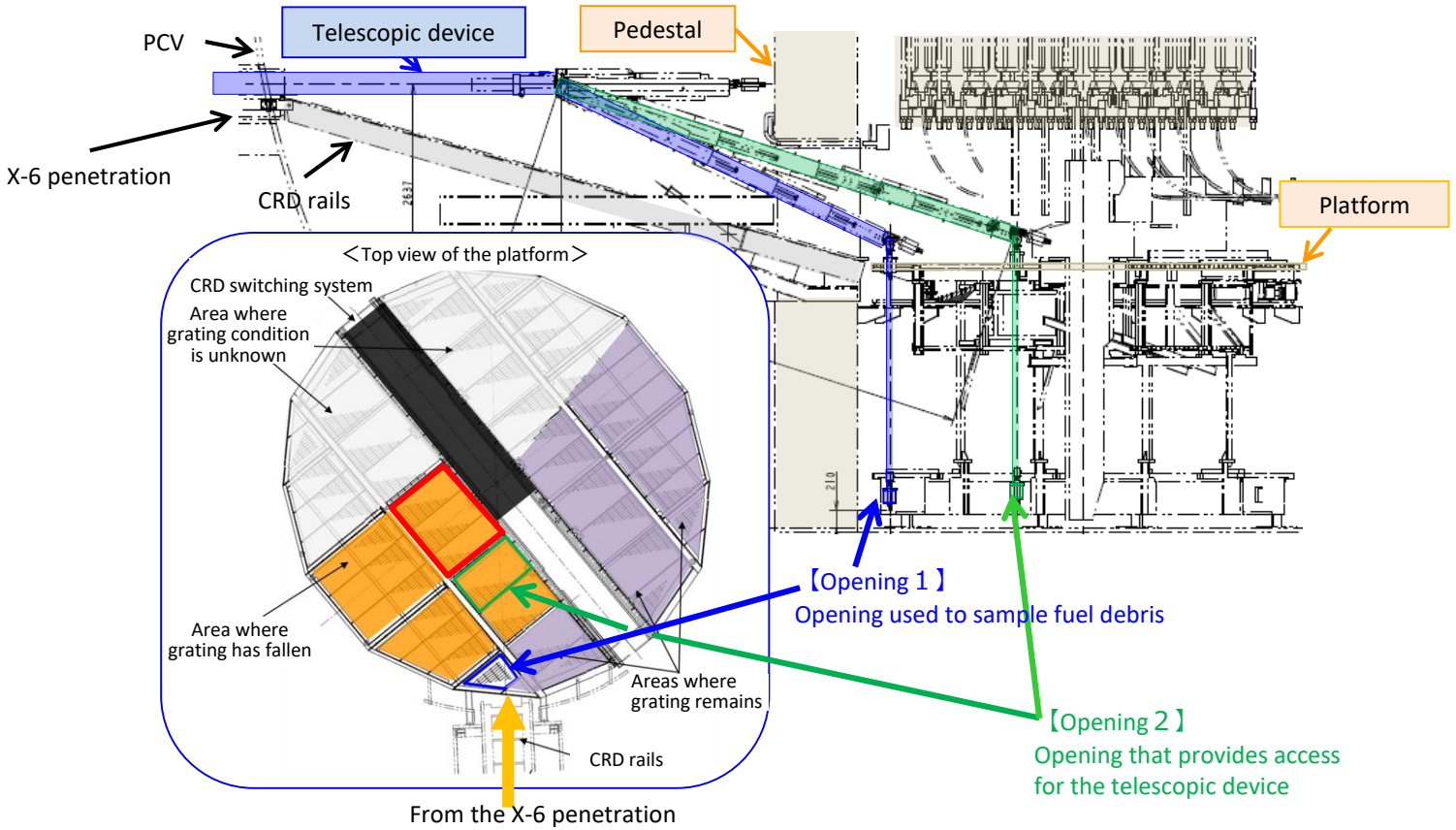


The end jig passing through the isolation valve

Inserted up until near the pedestal wall

[Reference] Workplan for retrieval fuel debris with the telescopic device

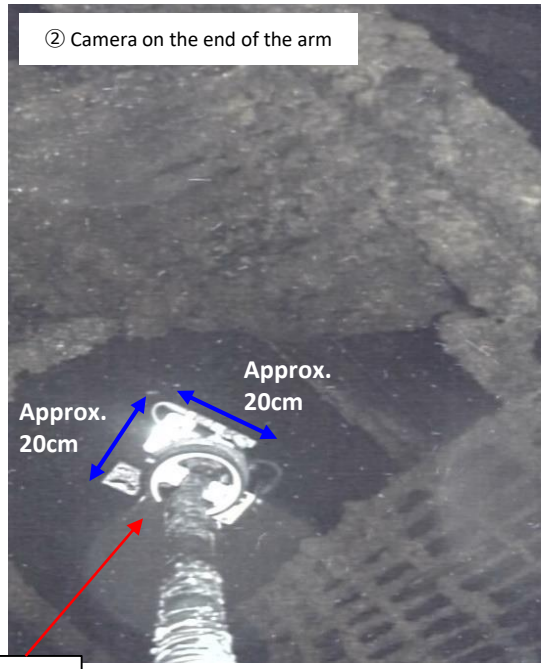
- There are two openings in the platform that provide access to the bottom of the pedestal with the telescopic device (openings 1 and 2 in the figure below).
- During work in October 2024, the tip jig was lowered through the front-most opening 1 in the pedestal (CRD rail side), and sampled fuel debris.
- The details of opening 2 on the far side in the pedestal have not been confirmed in previous Investigation.
- The second trial retrieval is planned from two viewpoint, that are understanding the internal condition of the pedestal and sampling from a different point than the first retrieval point.
  - ① Investigate the condition of opening 2 on the platform.
  - ② Fuel debris sampling is planned from opening 2. However, since the remaining grating on the platform is confirmed in previous Investigation, the status of opening 2 will be checked on the day of trial retrieval to determine whether access to the bottom of the pedestal is possible from opening 2.
  - ③ If the bottom of the pedestal cannot be accessed through opening 2, as with the last retrieval, the end jig will be lowered through opening 1 and fuel debris sampled from the bottom of the pedestal.



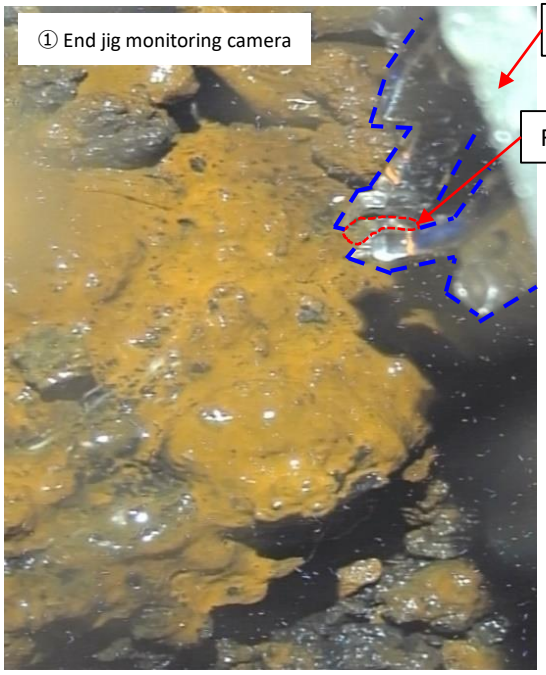
2-3. Status of retrieval work using the telescopic device (Grasping fuel debris)

- On April 17, it was determined based on the conditions of platform opening 2 inside the pedestal that the bottom of the pedestal could be accessed, then the end jig was lowered to the bottom of the pedestal through opening 2 and fuel debris was grasped.
- Thereafter, the telescopic device with the fuel debris in hand was retracted to its original position which was in prior to commencement of this task outside the pedestal.

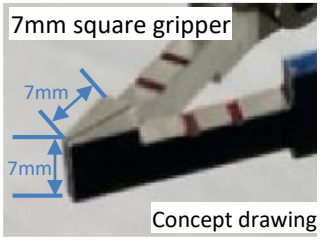
Remote operations room



Above the opening 2

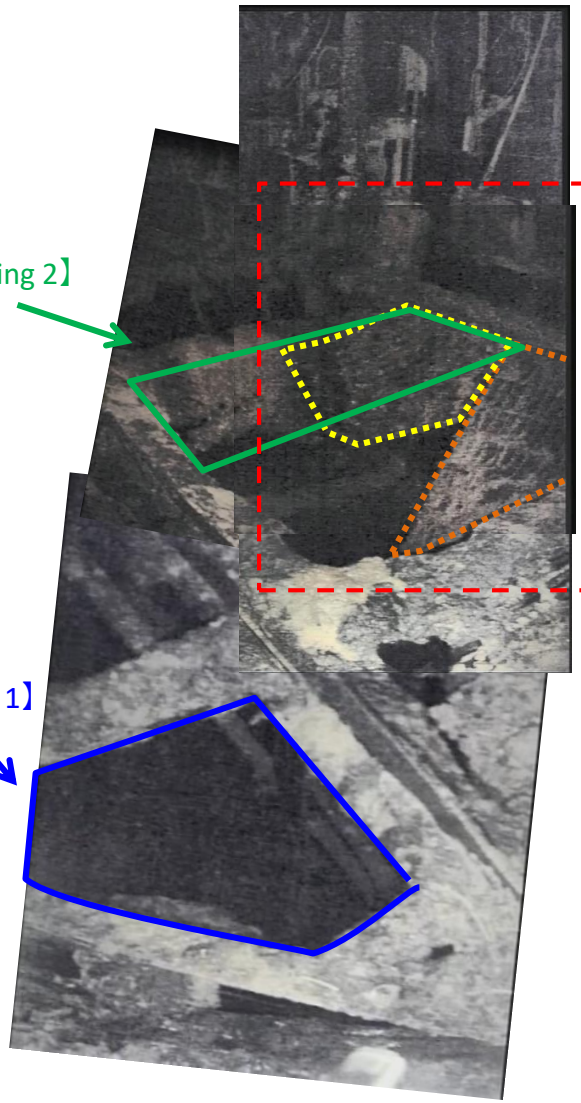


Grasping fuel debris below the opening 2



[Reference] Status of retrieval work using the telescopic device

➢ Camera footage from September 2024



※ Image created by stitching together camera photos

➢ Camera footage from April 2025

※ Image created by stitching together camera photos

- Footage of the area in the vicinity of opening 2 was successfully taken with the camera on the end of the arm of the telescopic device.
- Even though there is some grating left at opening 2, there is enough space to lower the end jig.

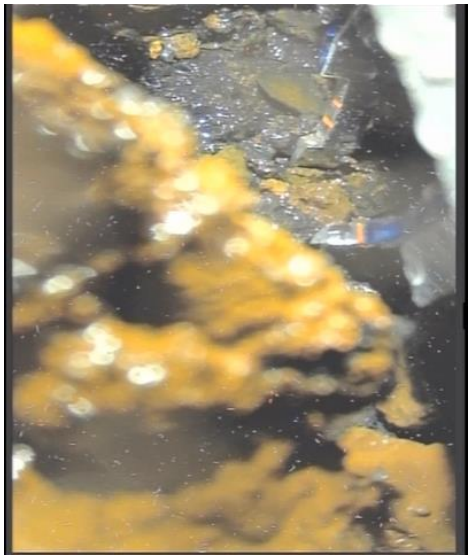
Grating shown by the yellow dotted area

Grating shown by the orange dotted area

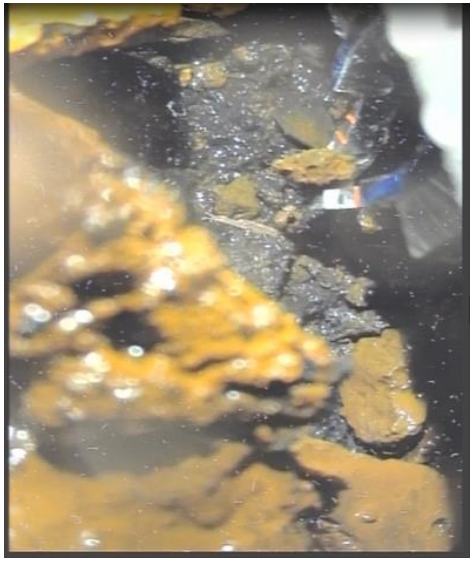
[Reference] Status of retrieval work using the telescopic device

- Sampling fuel debris from the bottom of the pedestal

① Conditions at the bottom of the pedestal

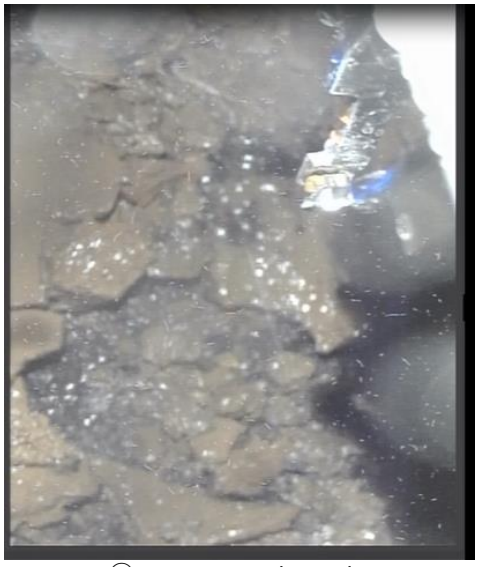


② Prior to grasping fuel debris



③ Lifting up the grasped fuel debris

④ Moving the end jig



⑤ Hoisting up the end jig

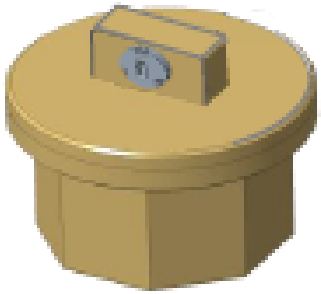
We successfully took footage under the opening 2 and retrieved a fuel debris sample.

2-4. Status of retrieval work using the telescopic device (Placement of sample in transportation box)

- On April 21, dose measurements of the fuel debris were taken and it was confirmed that the dose rate was below 24mSv/h (at a distance of 20cm), which is the criteria for determining whether or not the sample can be retrieved.
- On April 22, the grasped fuel debris was loaded into a transportation box.

The sampled fuel debris at the bottom of the transportation box (April 22)

End jig grasping the fuel debris
(photographed from above the enclosure on April 22)



Transportation box (Concept drawing)

2-5. Status of retrieval work using the telescopic device (Completion of retrieval)

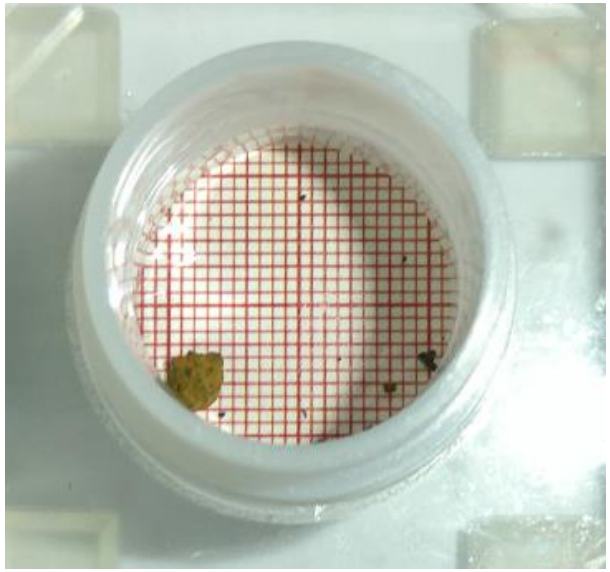
- On April 23, the side hatch of the enclosure was opened after which the transportation box was removed from the enclosure and loaded into an indoor transportation container. (Placing of the sampled fuel debris inside the indoor transportation container marks the completion of the trial retrieval process)
- The weight, etc. of the sample was measured inside a glove box. Continuously, preparations are being made for off-site transport.

【Measurement results】 Mass: Approx. 0.2g, Gamma ray spectrum analysis: ^{154}Eu was detected,
Dose rate (at a distance of 20cm) Gamma rays : 0.1mSv/h, Beta rays: 4.5mSv/h

※BG：0.1mSv/h

Removing the transportation box from the side hatch of the enclosure

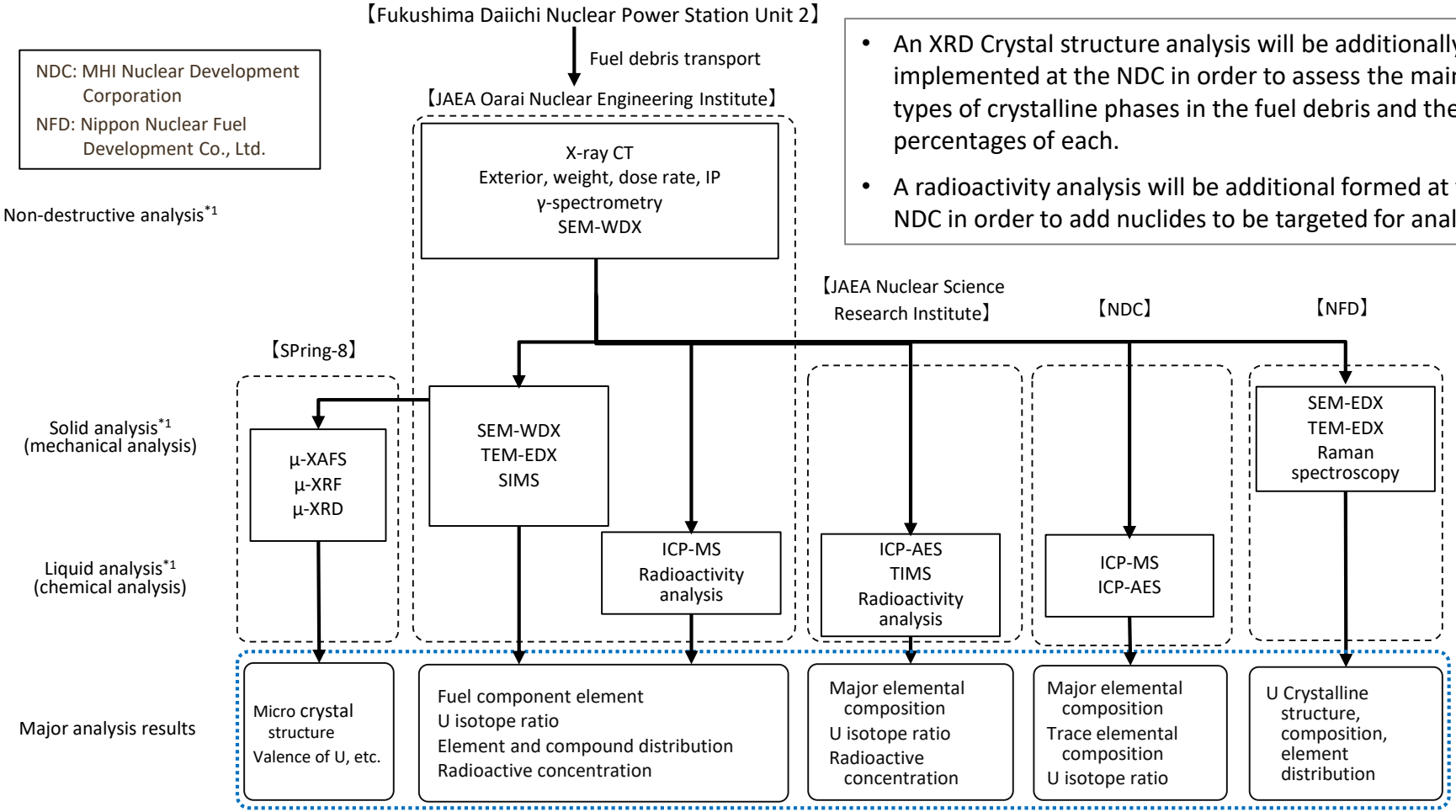
Loading the transportation box into an indoor transportation container



Fuel debris sample in a specimen container inside the glove box

3. Fuel debris analysis flow

- The fuel debris sample will be analyzed in order to ascertain information about the conditions where the fuel debris was sampled and to draw a hypothesis about the mechanism by which fuel debris was created.
- The analysis flow will basically be the same used for the first fuel debris sample with changes made as necessary based on analysis progress.
- In light of the additional analysis, going forward, analysis shall take approximately one year to 18 months after which the results will be compiled.



- An XRD Crystal structure analysis will be additionally implemented at the NDC in order to assess the main types of crystalline phases in the fuel debris and the percentages of each.
- A radioactivity analysis will be additional formed at the NDC in order to add nuclides to be targeted for analysis.

*1 Overview and purpose of each analysis are described in the reference documents

4. Work schedule

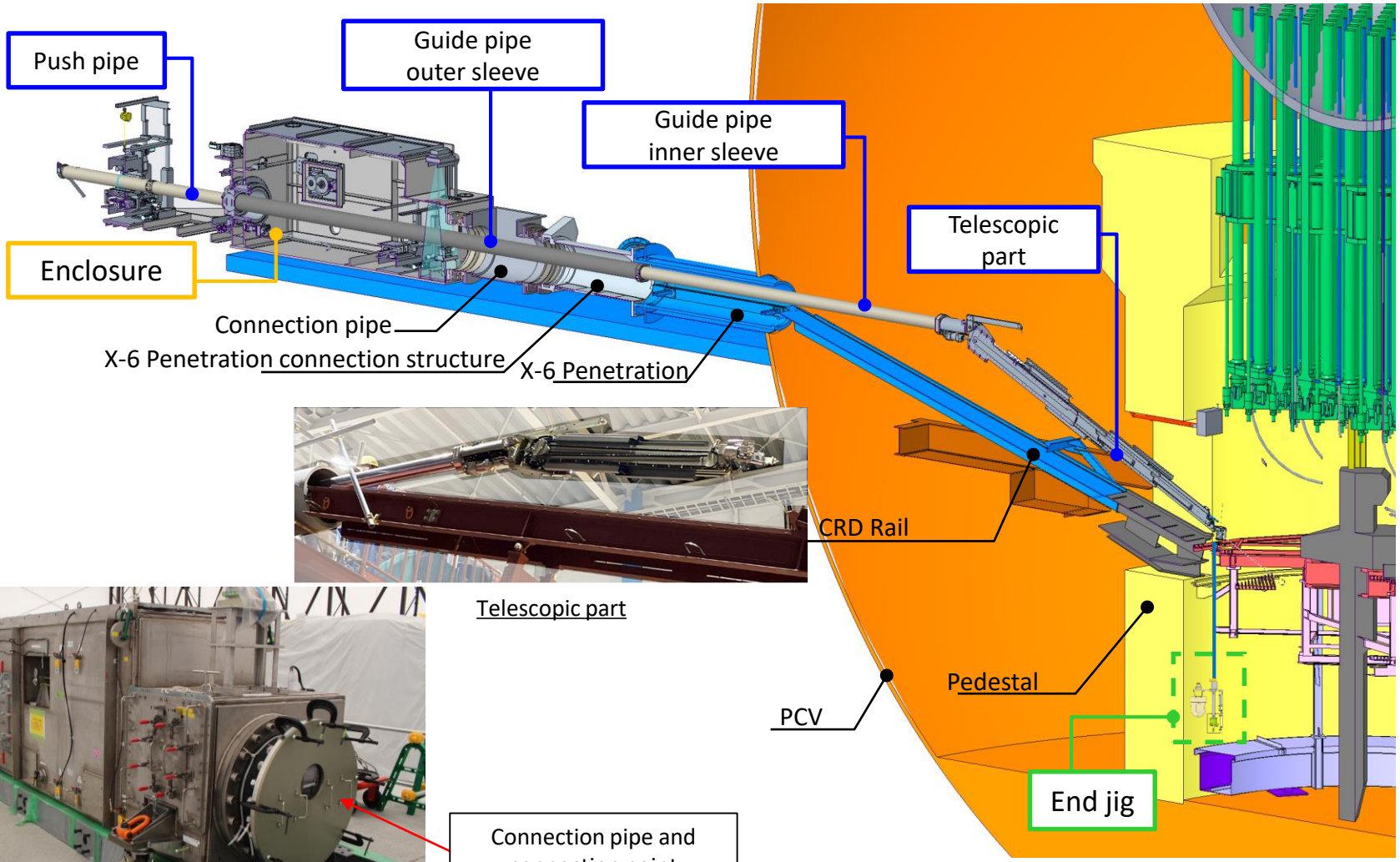
- In preparation to sample additional fuel debris with the telescopic device the improvement to stabilize lowering of end jig of the telescopic device has been completed and verification tests completed at the factory. Also, trainings have been conducted based on previous work results.
- Field checks using the actual telescopic device were performed at Fukushima Daiichi, the cameras on the telescopic device (two end cameras) were replaced, and the end jig was replaced with an improved model .
- The second fuel debris trial retrieval commenced on April 15, the bottom of the pedestal was accessed through the opening 2 on April 17, and fuel debris was grasped. On April 23, the fuel debris sample was loaded into an indoor transportation container thereby concluding the second trial retrieval. Preparations are currently underway for off-site transport.
- For the robotic arm, in light of the discovery of degrading components found during testing, similar components have been replaced and a full inspection is underway. We are also deliberating how to take measures in light of the telescopic device camera nonconformity.
- Based on additional fuel debris trial retrieval using the telescopic device and the test status of the robot arm, we will closely examine the details of the process so that we can safely and carefully proceed with the trial retrieval.

		FY2024	FY2025			
		4Q	1Q	2Q	3Q	4Q
Telescopic device	Deposit removal/ device manufacturing/ installation preparations, etc.	Preparation for Second				
	Debris sampling		Second			
Robotic arm	Inspection/maintenance, etc., and any additional development required based upon once-through tests/test results					
	Installation preparation, etc./ access route construction					
	Internal investigation/debris sampling					

: Past achievements : Start and end dates are under scrutiny

[Reference] Sampling debris with the telescopic fuel debris trial retrieval device

- We assume that the attributes and distribution of fuel debris will be quite varied, so in order to increase sample size and expand our knowledge we will continue to use the telescopic device, which is already installed on site and has proven successful, to take additional fuel debris samples.



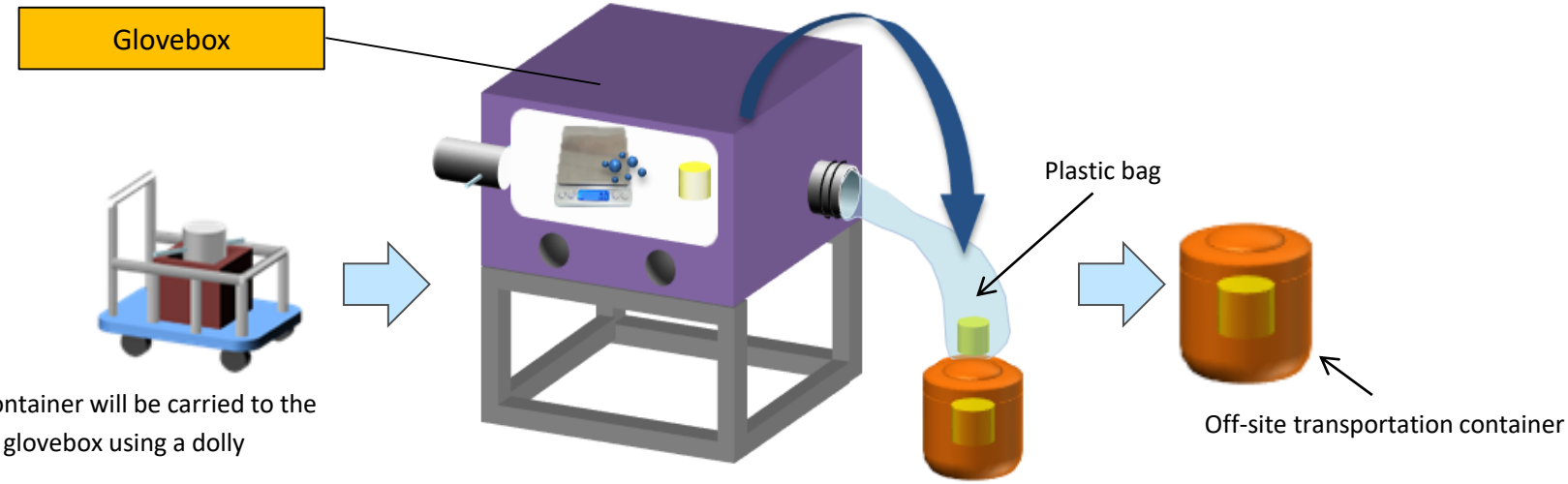
Telescopic part

Connection pipe and connection point

Telescopic device

[Reference] Glovebox

- The sampled fuel debris will be subjected to dose measurements when it is taken out from the enclosure of the telescopic device or the robotic arm, and then transported to a glovebox inside the reactor building where it will be subjected to various measurements. After measurements have been taken, measures to prevent the spread of contamination shall be implemented and it will be transported off-site



- The collected samples will be put into a negative pressure glovebox
- The samples will be subjected to various measurements inside the glovebox and then put into a container
- The container will be removed from the glovebox while preventing the spread of contamination by using a plastic bag
- The container will then be inserted into an off-site transportation container and loaded onto a transport vehicle

[Reference] Safety during Off-site Transport

- The fuel debris sampled during trial retrieval will be transported to an off-site analysis facility (JAEA Oarai).
- We have confirmed that the transport container will remain sealed even when subjected to various test conditions as legally required by law.
- The fuel debris placed inside the specimen container (polyethylene).Then it placed inside a vase-like container (polypropylene, lead).After that it will be sealed inside a bag made of polyvinyl chloride and placed inside the transport container.
- Furthermore, prior to transport we will confirm that surface dose rates and surface contamination density levels fall below legal limits with the fuel debris inside the container.
- Countermeasures have been put in place to prevent the leak of radioactive substances even in the event of an accident.
- In case of a radioactive substances leak, radiation measurements shall be taken and ropes/signs will be used to restrict the area from access after which it will be decontaminated thereby preventing exposure to the general public. All relevant agencies will also be immediately notified.
- Education and training will be provided to parties involved in transport.

Legally required technical standards

Item	Standard
Amount of reactivity	Sum of A2 level ratios is below 1 (Approx. 3.7×10^{10} Bq)
Dose equivalent rate	Surface of transported item: below 2mSv/h 1m from surface of transported item: 100μSv/h
Surface contamination density	Alpha nuclide: 0.4Bq/cm^2 All other nuclides: 4Bq/cm^2
Transport container test conditions	Freefall test, compression test, penetration test, etc.

A-type transport container

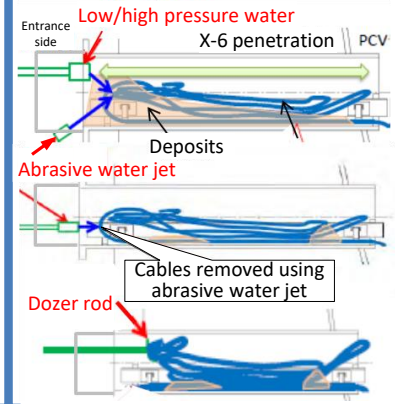
[Reference] Field Preparation Work Progress
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

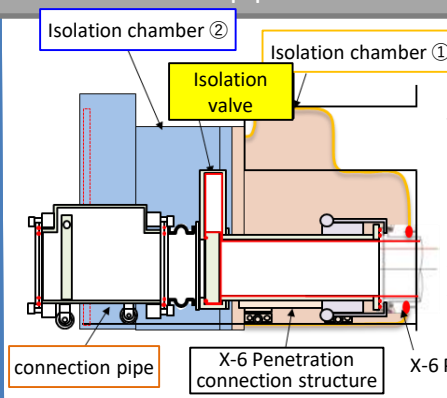
3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



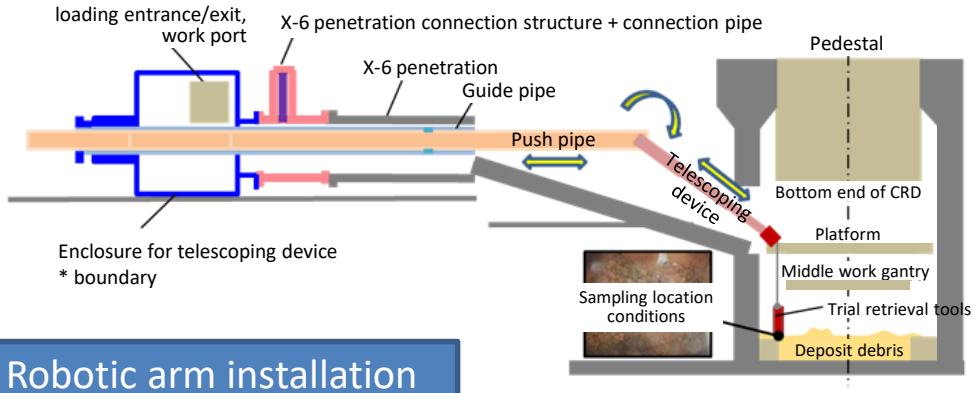
- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

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

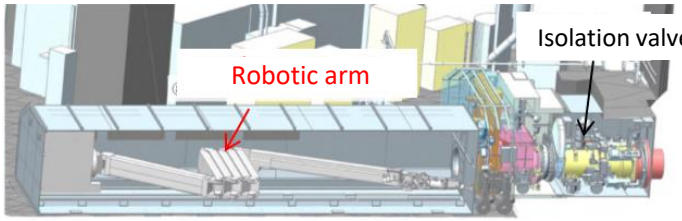


The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

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

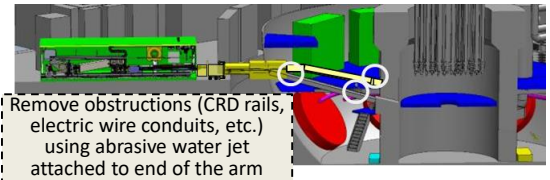


7. Robotic arm installation



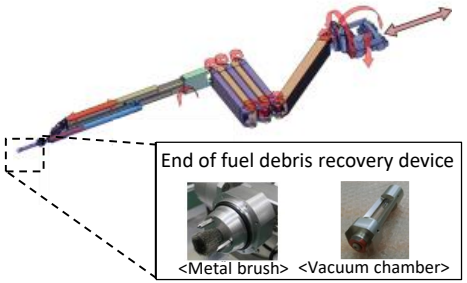
8. Internal investigation/debris sampling using robotic arm

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)

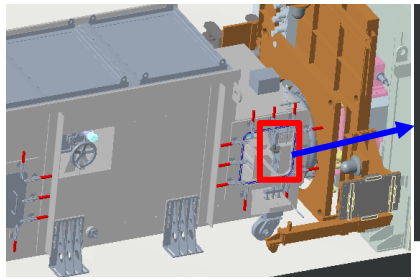
Isolation valve: Valve installed to separate the inside of the PCV from the outside

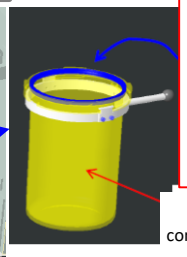
Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

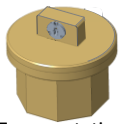
[Reference] Field Preparation Work Progress
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

(From Step 6 on the previous slide)

9-1. Collection of fuel debris





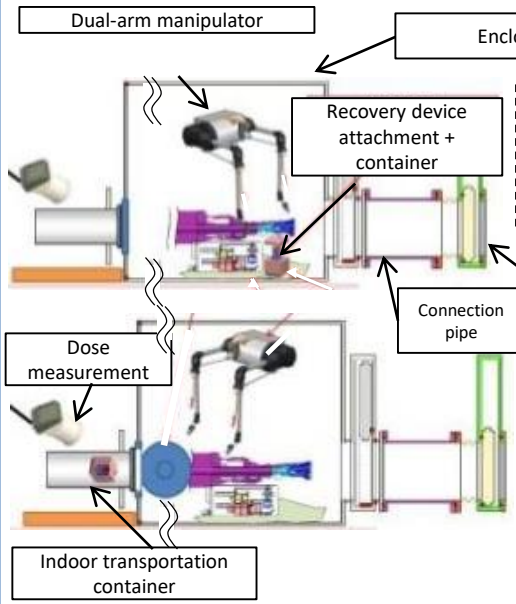


Transportation box

Indoor transportation container (DPTE container)

(From Step 8 on the previous slide)

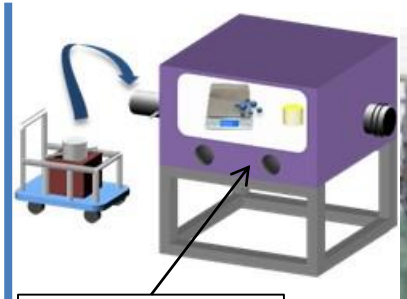
9-2. Inserting the fuel debris recovery device attachment into a container, Inserting into an on-site transportation container/Dose measurements



- The fuel debris recovery device attachment will be put into a container using the dual-arm manipulator inside the enclosure

- Inside the enclosure, the attachment will be put into an on-site transportation container after taking dose measurements
- This will be removed while attempting to prevent the spread of contamination

10. Insertion into glovebox/Measurement

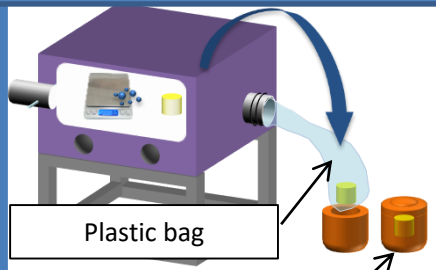


Glovebox

<Exterior view of glovebox>

- The collected samples will be put into a negative pressure glovebox
- The samples will be subjected to various measurements inside the glovebox and then put into a container

11. Container removal/Insertion into transportation container /Removal from premises



Plastic bag

Off-site transportation container ※

Carried to transport vehicle

- The container will be removed from the glovebox while preventing the spread of contamination by using a plastic bag
- The container will then be inserted into an off-site transportation container and loaded onto a transport vehicle

※ Prior to transport, the surface dose/contamination density, etc. of the container shall be measured to ensure that it meets legal requirements

12. Off-site transport and off-site analysis

(Note)
DPTE Container is an abbreviation of “Double Porte pour Transfert Etanche”.
By opening/closing the lid of the container and double door of the glove box at the same time, it allows the items to be transferred while maintaining a sealed environment.

[Reference] Environmental Impact (1/2)

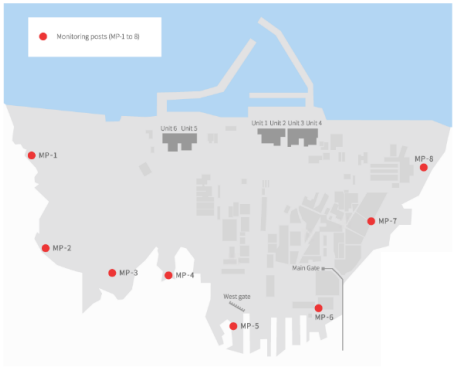
- During fuel debris trial retrieval, the gas from inside the primary containment vessel was prevented from leaking to the outside environment through the construction of a boundary.
- There have been no significant fluctuations in data from monitoring posts or dust monitors neither prior to or after 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

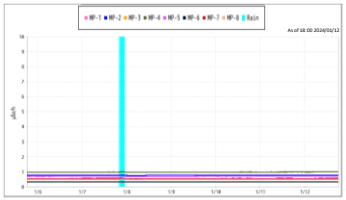
The following is the radiation doses of the air measured by the monitoring posts (MP1-8) at Fukushima Daiichi Nuclear Power Station.

Monitoring post (MP1 - MP8)

Monitoring points



Radiation dose



MP Unit : μSv/h Wind Velocity Unit : m/s
○Measurement value(2024/01/12 18:00)

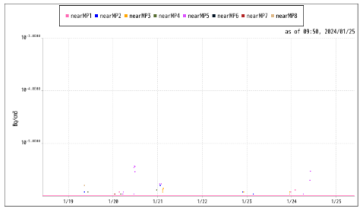
MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	Wind Direction	Wind Velocity	Rain
0.517	0.783	0.490	0.987	0.703	0.315	0.566	0.530	North-northwest	1.4	No

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)

- During fuel debris trial retrieval, the work will be performed with constant monitoring of plant parameters.
- 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

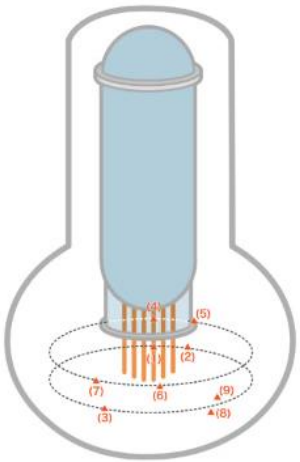
[Reference] Screen image of our website

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

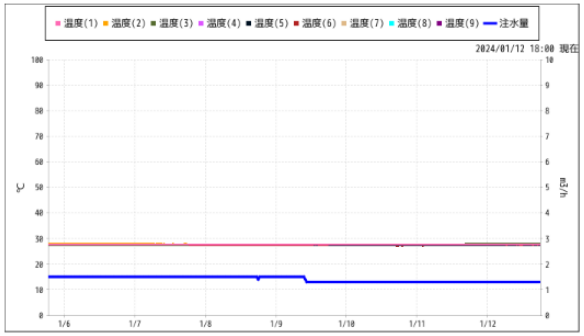
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

Monitoring points

Unit 2 reactor containment vessel



Temperature



Temperature Unit:℃、Water Injection Unit：m³/h

○Measurement value (2024/01/12 18:00)

温度(1)	温度(2)	温度(3)	温度(4)	温度(5)	温度(6)	温度(7)	温度(8)	温度(9)	注水量
27.5	27.8	27.9	27.7	27.4	27.3	27.2	-	-	1.3

[Reference] Abbreviation and overview of analysis methods (1/2)

Analysis method abbreviation	Analysis method name	Analysis method overview
ICP-AES	Inductively coupled plasma atomic emission spectroscopy	Qualitative and quantitative analysis method of elements by introducing atomized samples into high-temperature plasma and obtaining element-specific spectra by spectroscopy of the issued light.
ICP-MS	Inductively coupled plasma mass spectrometry	Method of measuring the concentration of elements and its isotopes by introducing atomized samples into high-temperature plasma, ionizing elements in the sample and measuring the number of ions in ion mass-to-charge ratio (m/z) by mass spectrometry.
TIMS	Thermal ionization mass spectrometry	Method of measuring the concentration of elements and its isotopes by applying samples onto metal filament, ionizing the atoms by heating under vacuum and measuring the number of ions in ion mass-to-charge ratio (m/z) by mass spectrometry.
SEM	Scanning electron microscope	Device that can observe the sample surface by irradiating the surface with electron beams, and can also analyze elements by attaching an X-ray analyzer.
EDX	Energy dispersive X-ray spectroscopy	Method of elemental analysis and compositional analysis by detecting characteristic X-rays generated by electron irradiation and categorizing them by the energy of characteristic X-rays.
WDX	Wavelength dispersive X-ray spectroscopy	Method of elemental analysis and compositional analysis by detecting characteristic X-rays generated by electron irradiation and performing spectroscopy at the wavelength of characteristic X-rays.
TEM	Transmission electron microscope	Method of imaging electrons transmitted through the sample and scattered electrons for observation under high magnification by irradiating thinned samples with electron beams, and also conducting elemental analysis by attaching an X-ray analyzer. Crystal structure can also be obtained from the diffraction image.
SIMS	Secondary ion mass spectrometry	Method of measuring the concentration of elements and its isotopes by measuring the secondary ions generated by irradiating the sample surface with a beam of ions with a mass spectrometer and measuring the number of ions in ion mass-to-charge ratio (m/z) by mass spectrometry.
Raman spectroscopy	Micro Raman spectroscopy	Method of obtaining properties such as molecular structure, temperature, stress, electrical properties, orientation and crystallinity by irradiating the sample surface with light and dispersing Raman scattering light. Information on chemical form of micro-regions on μm order can be obtained by combining Raman spectroscopy with conventional optical microscopes.
X-ray CT	X-ray computed tomography	Method of obtaining density distribution of the sample interior by irradiating the sample with X-rays, capturing the transmitted X-ray intensity by a computer and scanning it three-dimensionally. Distribution of phases of different density can be obtained.

[Reference] Abbreviation and overview of analysis methods (2/2)

Analysis method abbreviation	Analysis method name	Analysis method overview
XAFS	X-ray absorption fine structure spectroscopy	Method of analyzing the internal structure of materials at the molecular and atomic level by irradiating the sample with X-rays and precisely observing the absorbed X-ray energy
XRF	X-ray fluorescence spectroscopy	Method of qualitative analysis of content of constituent elements by measuring the wavelength and energy of X-rays (X-ray fluorescence) generated according to the substance by irradiating the sample with X-rays
XRD	X-ray diffraction analysis	Method of analyzing the crystal structure, crystal orientation, crystal lattice size, etc. of the object by irradiating the sample with X-rays and measuring the resulting X-rays (diffracted X-ray)
IP	Imaging plate	Radiation image measuring instrument that detects radiation energy as stimulable luminescence. Dose distribution of the sample can be obtained.