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

January 30, 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.

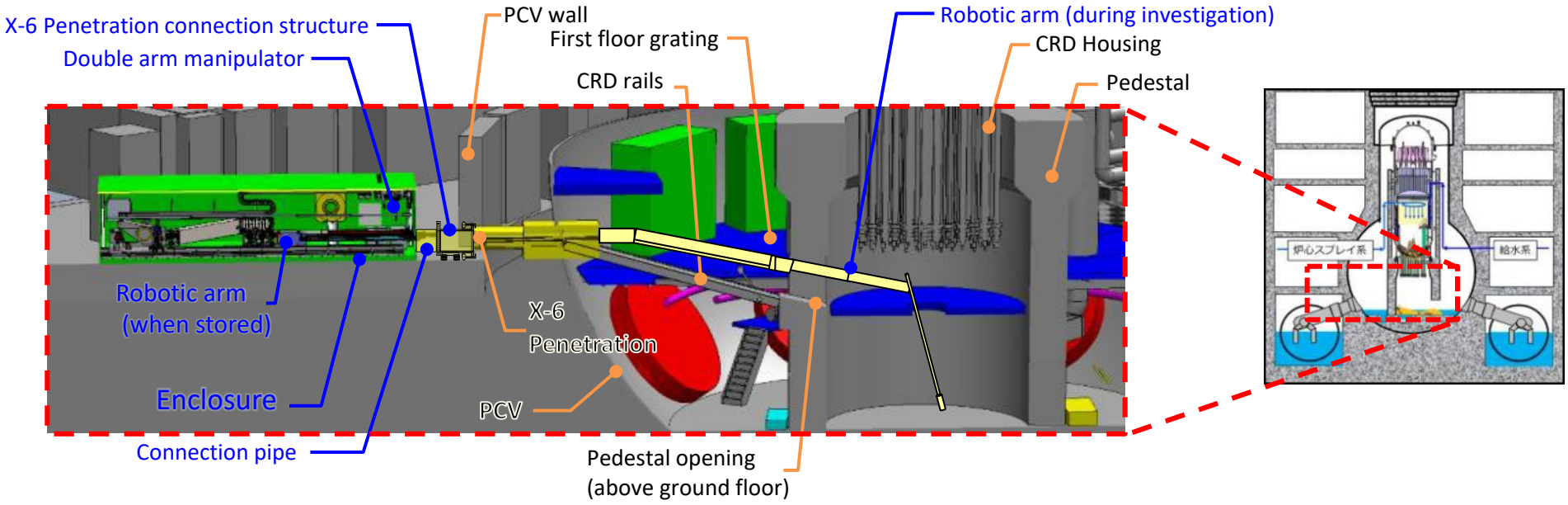
  ＜Already installed＞

  - 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)

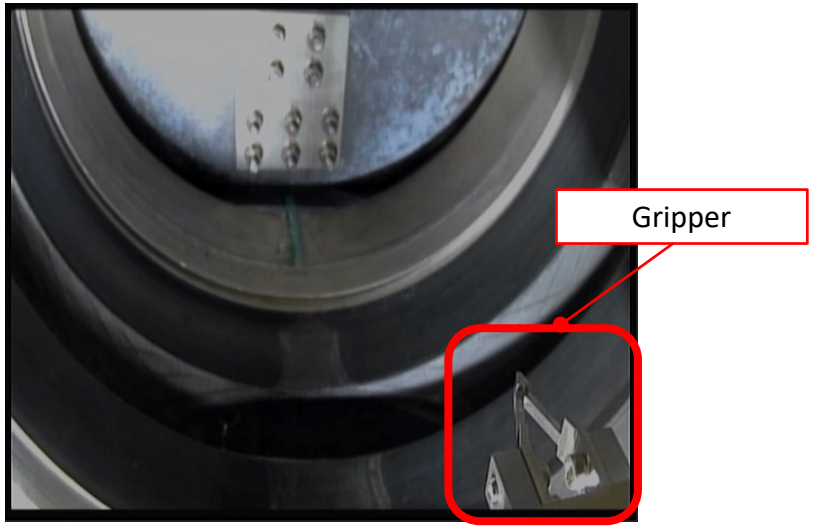
- After installation of the aforementioned equipment, the robotic arm shall be fed into the PCV through the X-6 penetration to remove obstacles inside the PCV while also conducting internal investigations and moving forward with the trial retrieval of fuel debris.



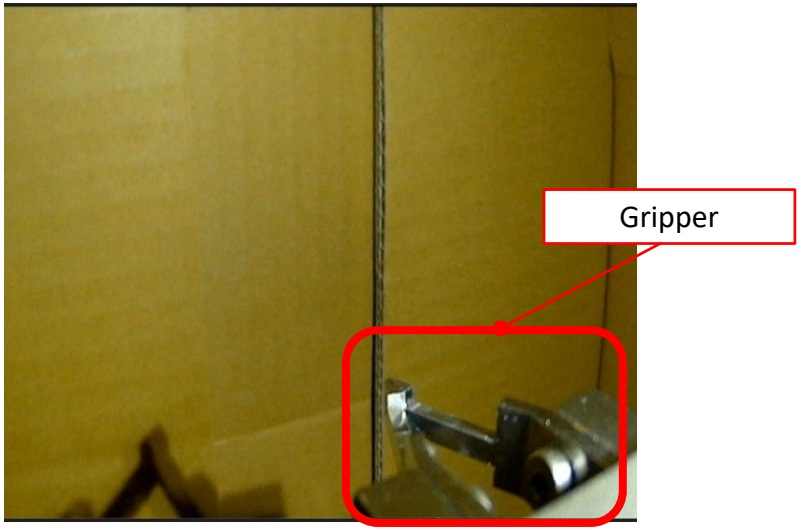
Unit 2 internal investigation/trial retrieval plan overview

2-1. Improvements to the telescopic device end jig (element test)

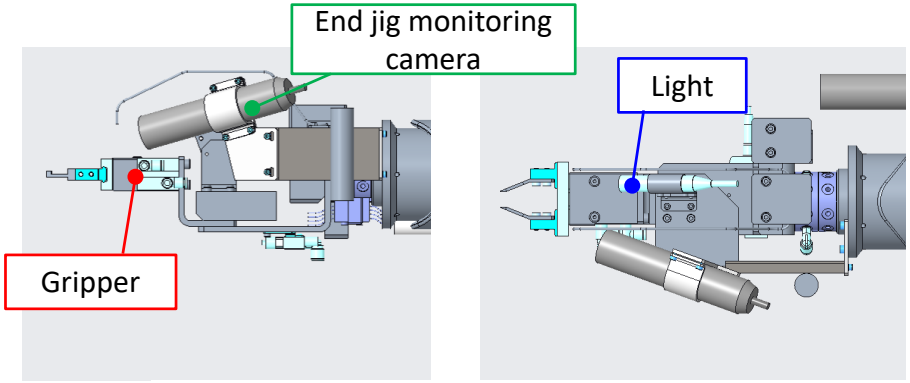
- Element test results showed that there was no problem with post-improvement visibility after comparing visibility of the grasping part prior to and after improvements.
- Going forward, the improved end jig will be manufactured and subjected to verification tests at the factory.



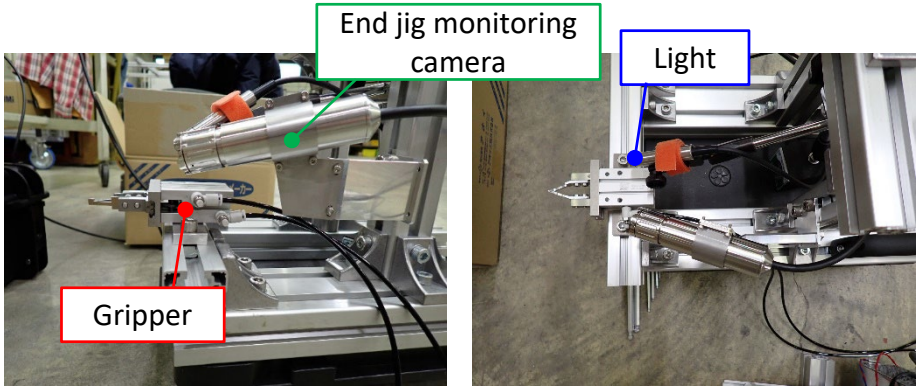
Actual camera footage prior to improvements (current specifications)



The camera footage after improvements(during verification)
※With the end jig light mockup turned on in the dark



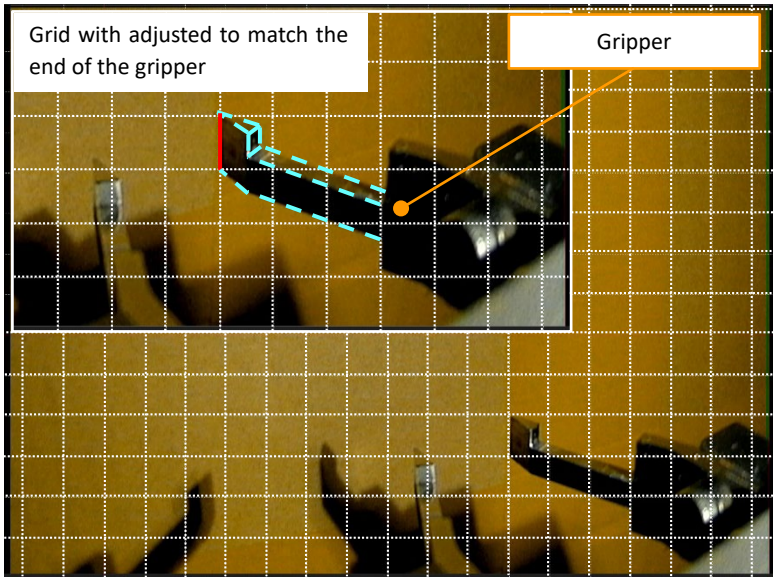
After improvements (Concept diagram)



Verification mockup ※Reproduce the positional relationship with the improved model

2-2. Improvements to the telescopic device end jig (element test)

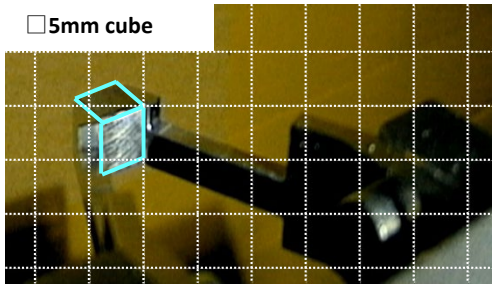
- Under after improvement dimensional conditions, a grid was laid over the camera footage to measure the size of simulated fuel debris that had been grabbed. We confirmed that there were no problems with grid adjustment or measuring the size of the simulated fuel debris that was grabbed.



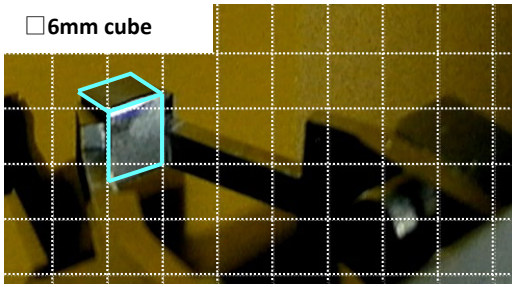
Camera footage after adjusting grid width

Measuring the size of grasped fuel debris①(cube)

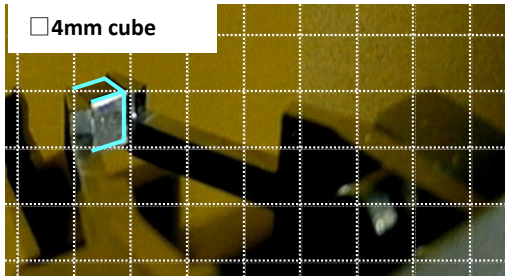
□5mm cube



□6mm cube



□4mm cube

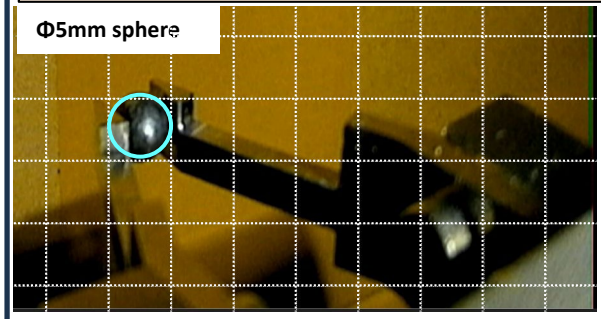


※ The ridgeline that can be seen with the camera is shown in blue lines

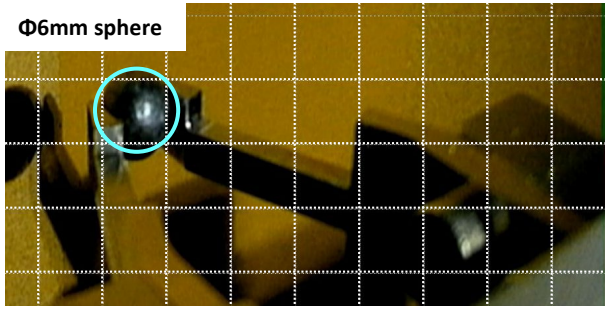
Cube-shaped simulated debris was grasped. It was confirmed that the ridgeline did not exceed the grid width

Measuring the size of grasped fuel debris ②(Sphere-shaped)

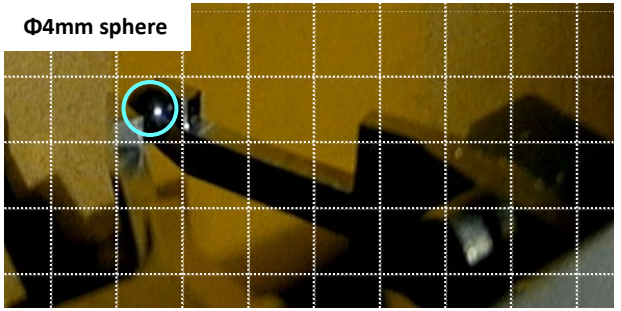
Φ5mm sphere



Φ6mm sphere



Φ4mm sphere



Sphere-shaped simulated fuel debris was grasped. It was confirmed that the grid width was not exceeded

※ The outer shape of the simulated fuel debris estimated from the camera footage is shown in blue lines

3-1. Status of robotic arm tests (Performance tests)

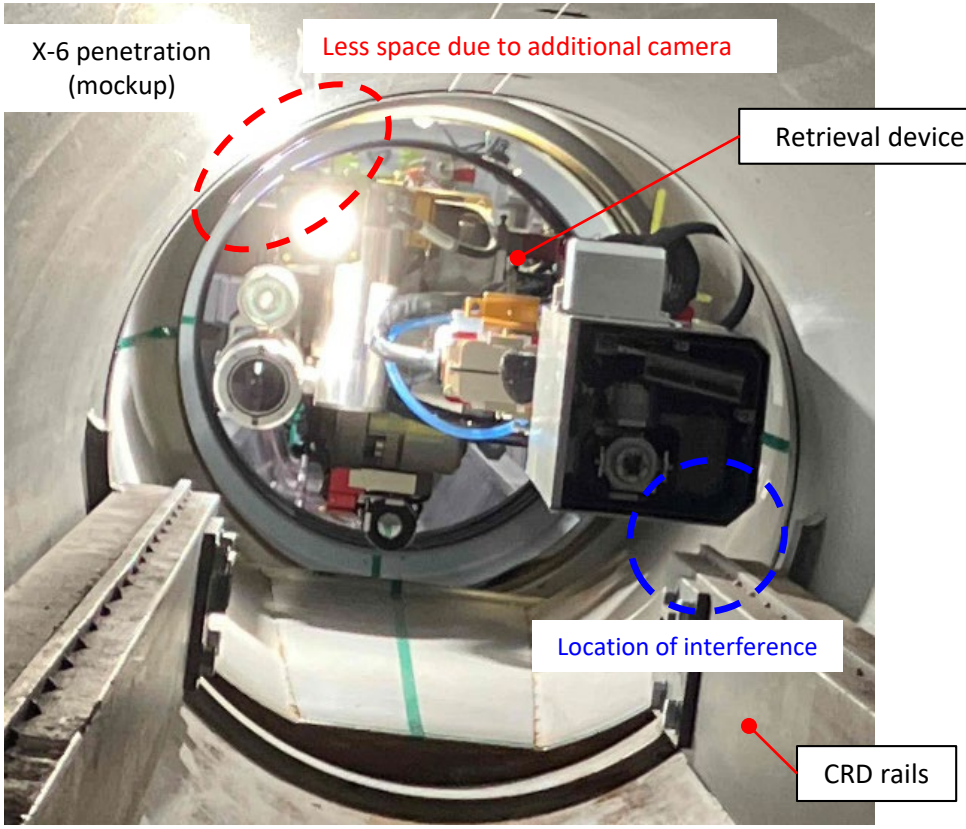
- Tests on a mockup of the decommissioning site are being implemented at the Naraha mockup facility and combined once-through tests are underway.
- In the field, the arm will have to be repeatedly passed through narrow access ways, so the control program is being continually Since the robotic arm will 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. Other tests are also being performed simultaneously.
- Furthermore, in addition to robotic arm developing, we are also confirming this technology applicability to the actual worksite by looking at procedures that simulate actual work tasks, operator operability, and equipment reliability.

Performance tests

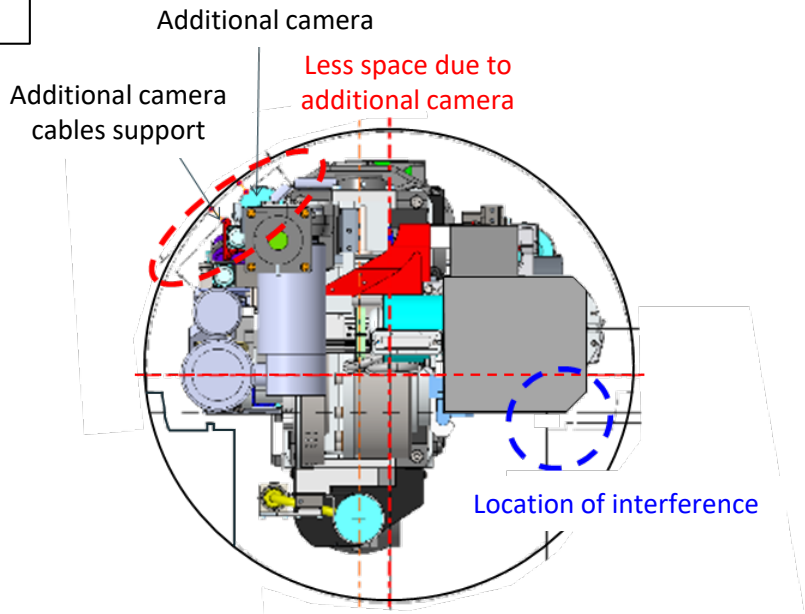
Test category	Test	JAEA Naraha
Robotic arm-related tests	Ability to pass through the X-6 penetration	Completed
	Removing obstacles at the exit for the X-6 penetration using the AWJ	Completed（Work efficiency being examined）
	Function tests (deflection measurements, etc.)	Completed
	Ability to access the inside of the PCV (accessing the top and 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
Combined once-through tests (robotic arm + double arm manipulator)	sensors/external cables, tools/Installing external cables at the arm	Completed
	Investigation of the top of the pedestal (sensors and wand are installed)	Underway
	Investigation of the bottom of the pedestal (sensors and wand are installed)	Underway
	Constructing an access route (removing obstacles using the AWJ)	Underway

3-2. Robotic arm tests status (retrieval work)

- A retrieval device was mounted on the robotic arm and when it was extended from the enclosure into the simulated PCV, we found that the retrieval device interfered with the CRD rails of the X-6 penetration.
- It is assumed that this was caused by deflection of the robotic arm body and a decrease in the space between the X-6 penetration caused by cameras that were added in order to improve visibility.
- As a result of these test, we are deliberating making changes to the mounting position of the retrieval device.



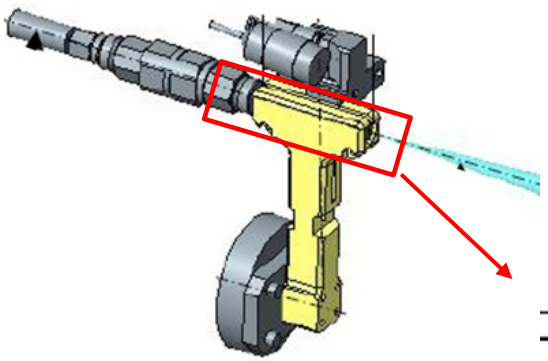
Retrieval device passing through the X-6 penetration (as seen from the PCV side)

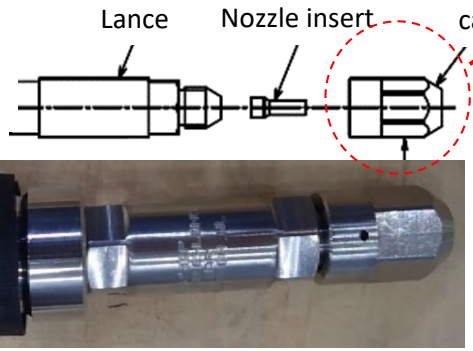


Retrieval device passing through the X-6 penetration (Diagram)

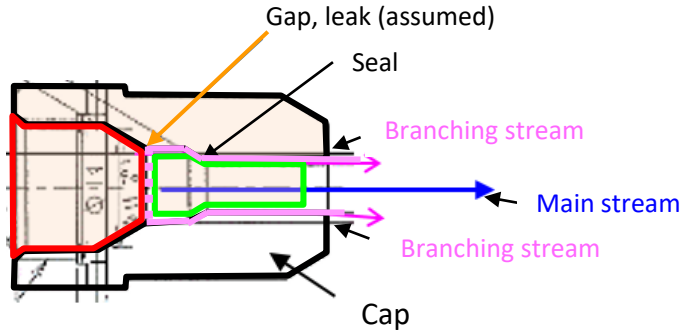
3-3. Robotic arm tests status (Access route construction)

- We are deliberating how to remove deposits that still remain inside the X-6 penetration during the course of access route construction (removing obstructions with the mounted AWJ tool) (using high-pressure water that does not contain abrasives). Normally there is only one stream of water from the AWJ nozzle, but we found that the water branched three streams.
- It is assumed that for some reason a gap was created between the lance and the nozzle insert thereby splitting the stream.
- The AWJ nozzle has been replaced and verification tests are underway.

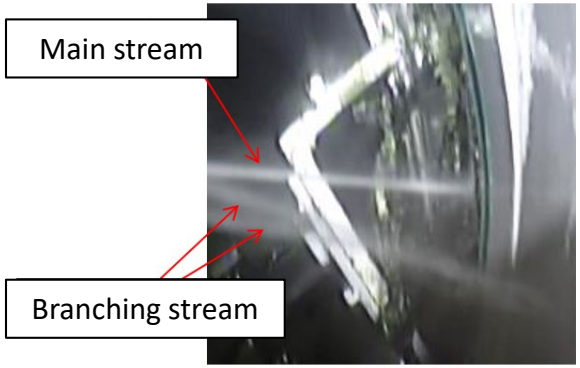




AWJ nozzle



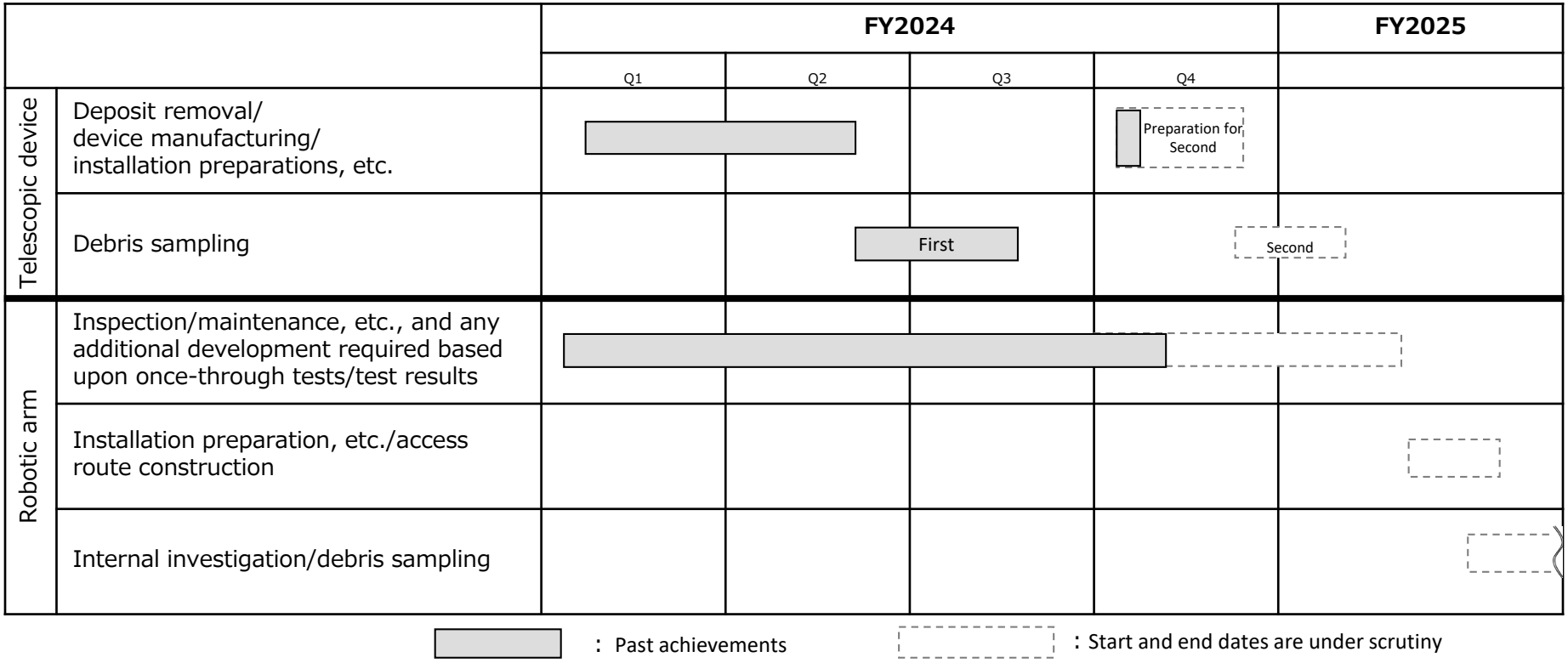
AWJ nozzle and (enlarged) nozzle flow (assumed)



Water stream from the AWJ nozzle

4. Work schedule

- 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.
- In preparation to sample additional fuel debris with the telescopic device we will the process of studying improvements to conduct improvements to replace camera attached to the end of the telescopic device and to stabilize lowering of the end jig at the end of the device and mastery training. In the future, workers which is based on previous work results as we aim to begin taking more samples in the spring of 2025.
- Based on information obtained through tests of the robotic arm on a mockup of the decommissioning environment at the Naraha mockup facility, improvements have been made to the control program to reduce the risk of contact with surrounding structures during the retrieval of fuel debris. Furthermore, in addition to improving the accuracy of arm positioning, we are in the process of deliberating how to share information pertaining to the maintenance of aging components discovered during testing and also nonconformities with cameras attached to the telescopic device.
- 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.



[Reference] Sampling Debris with the Telescopic Fuel Debris Trial Retrieval Device

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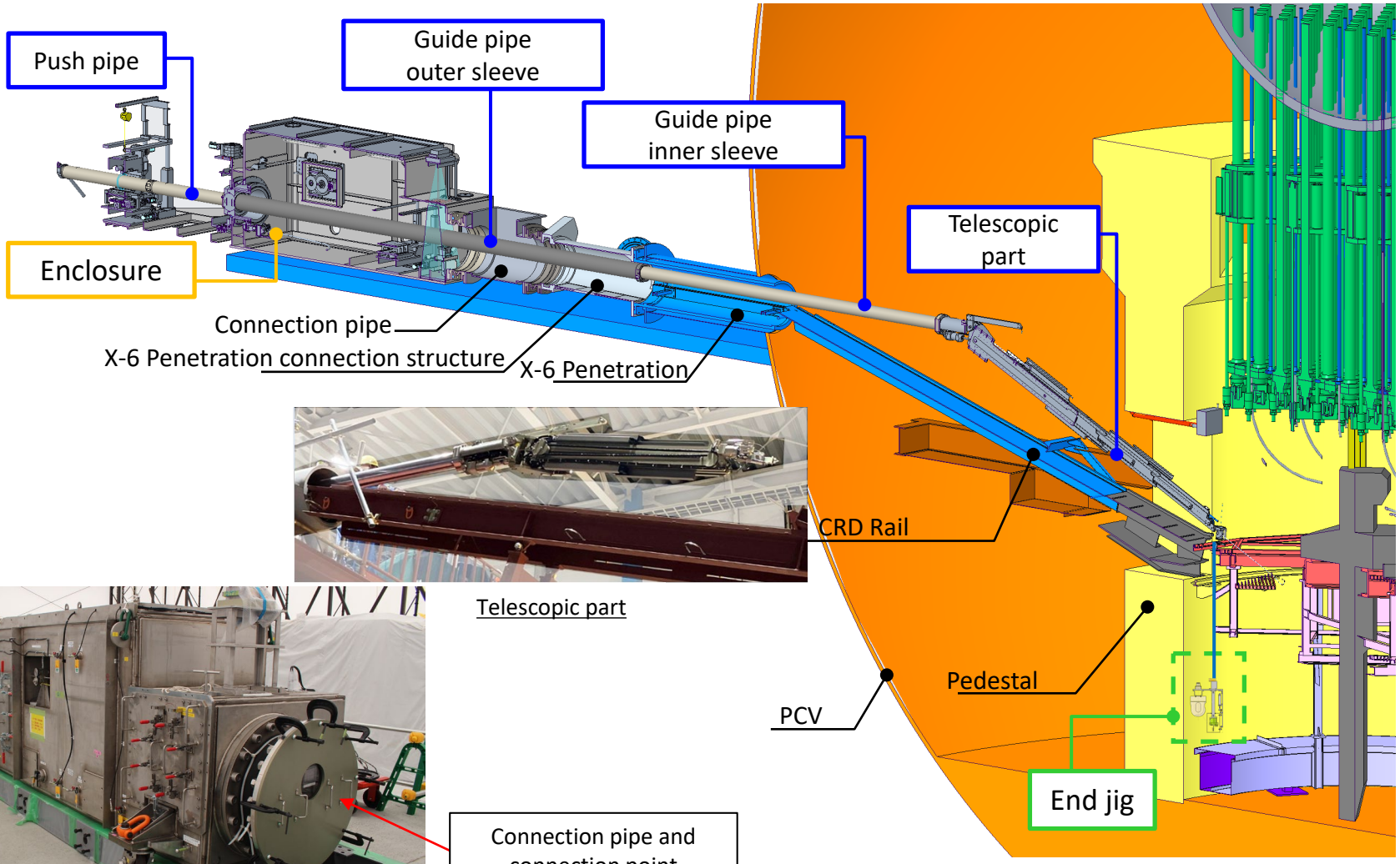


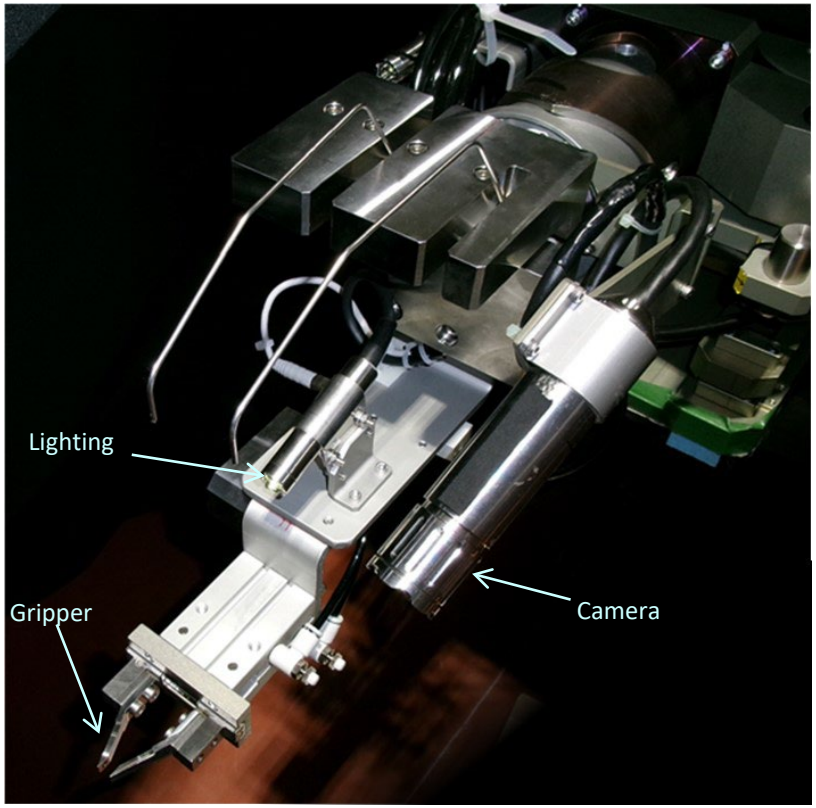
Telescopic part

Connection pipe and connection point

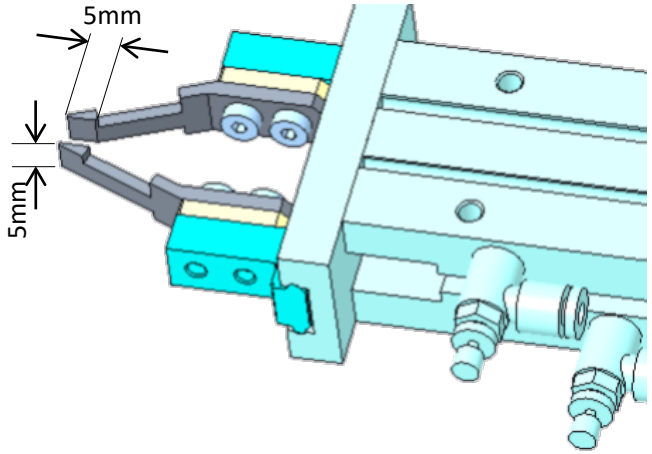
Telescopic device

[Reference] Sampling Debris with the Telescopic Fuel Debris Trial Retrieval Device

- The gripper tool has been selected as the end jig that will be used during the trial retrieval of fuel debris with the telescopic device
- The end jig camera will be used to determine the size of the fuel debris sampled



Gripper tool

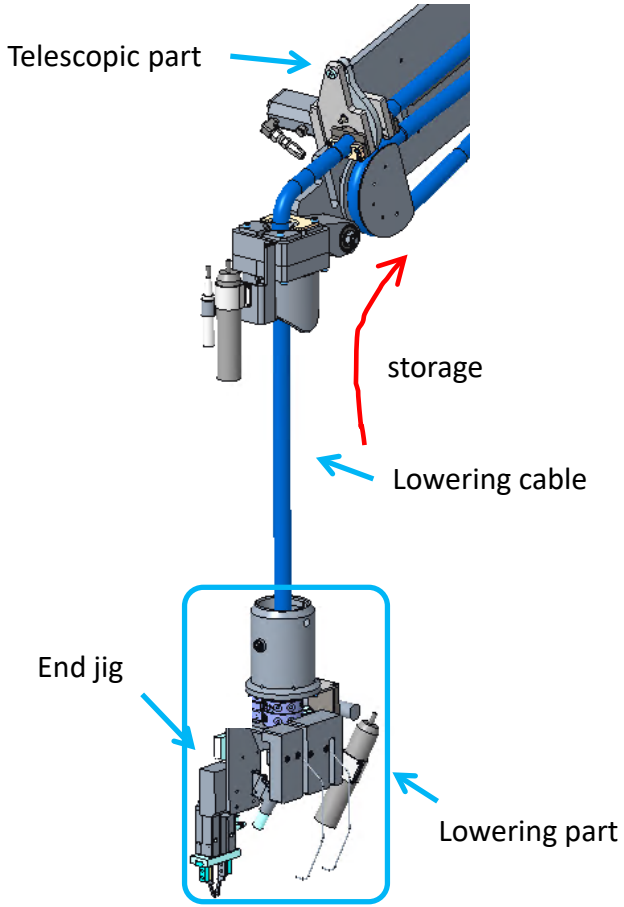


Gripper claws will be used to determine the size (gripper tool)

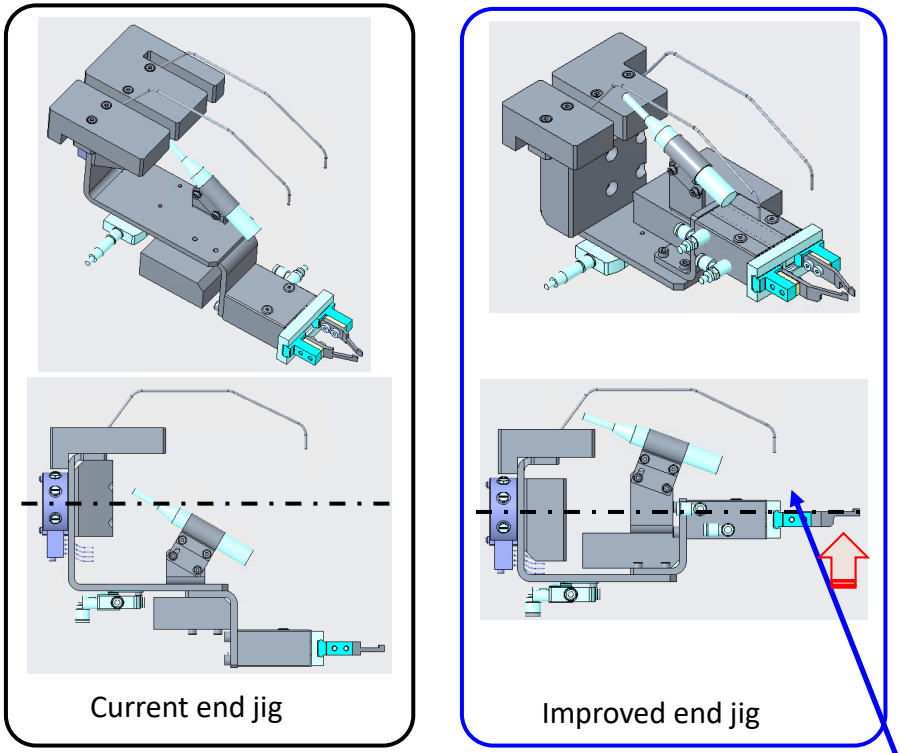
Camera footage of the gripper tool holding a sphere and a cube shaped simulated fuel debris (gripper tool)

[Reference] Additional Debris Sampling with the Telescopic Fuel Debris Trial Retrieval Device

- During the first fuel debris sampling, time was required to maneuver the end jig because the lowering part was not stable. So we are deliberating how to improve the maneuverability of the end jig before sampling additional fuel debris.



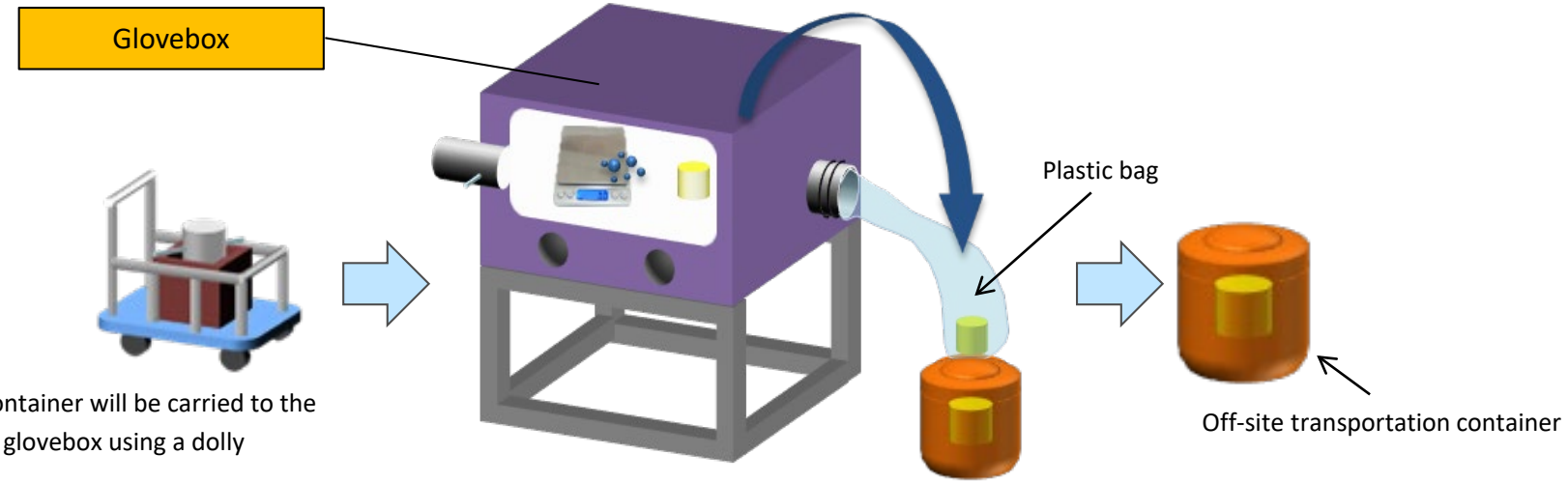
End jig components

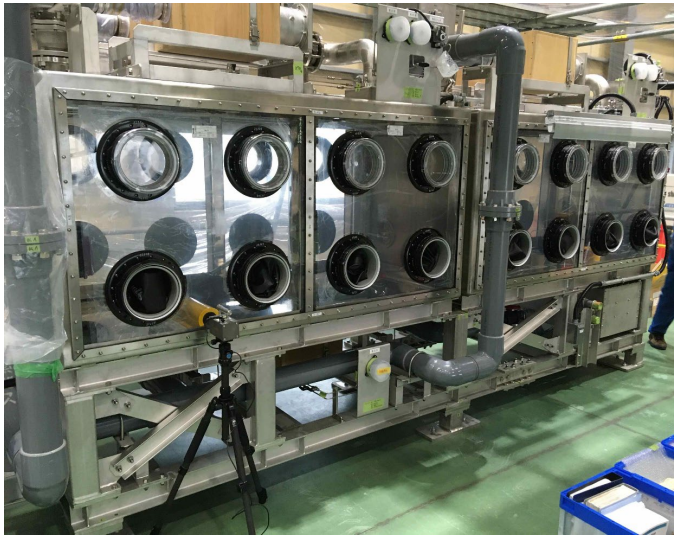


Concept diagram of end jig improvements

[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

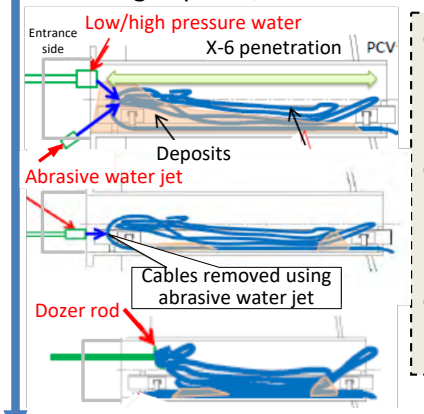
[Reference] Field Preparation Work Progress
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

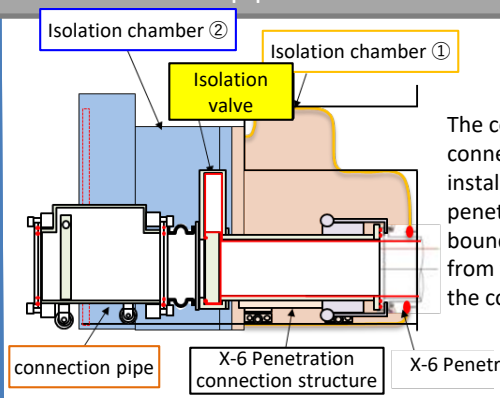
3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



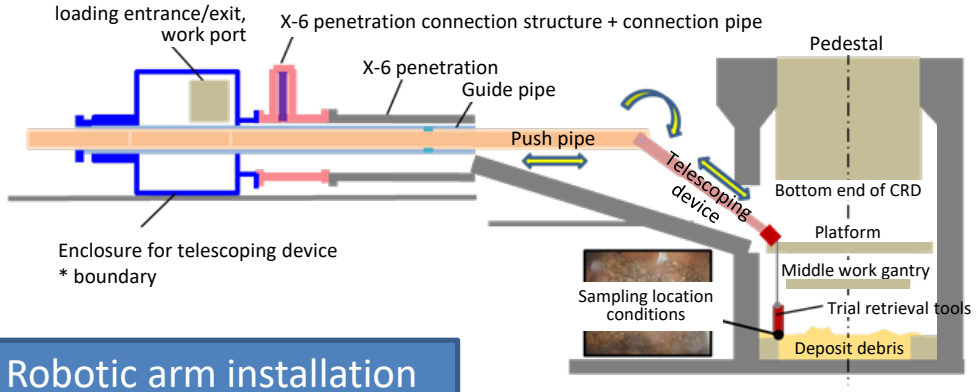
- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

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

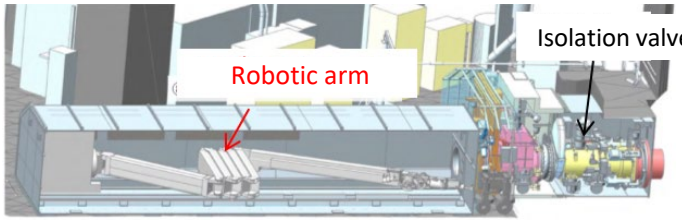


The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

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

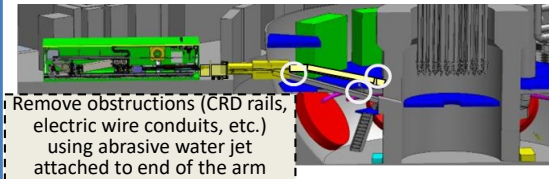


7. Robotic arm installation

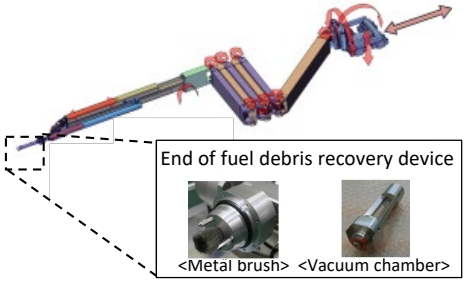


8. Internal investigation/debris sampling using robotic arm

① Internal investigation



② debris sampling using robotic arm



(Note)

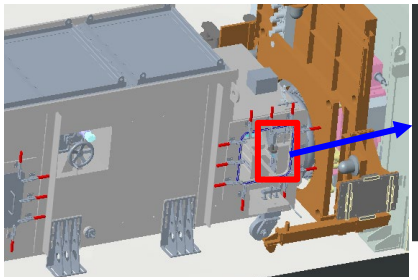
Isolation valve: Valve installed to separate the inside of the PCV from the outside

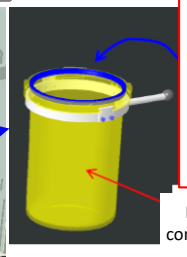
Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

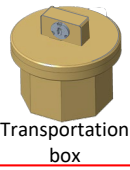
[Reference] Field Preparation Work Progress
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

(From Step 6 on the previous slide)

9-1. Collection of fuel debris





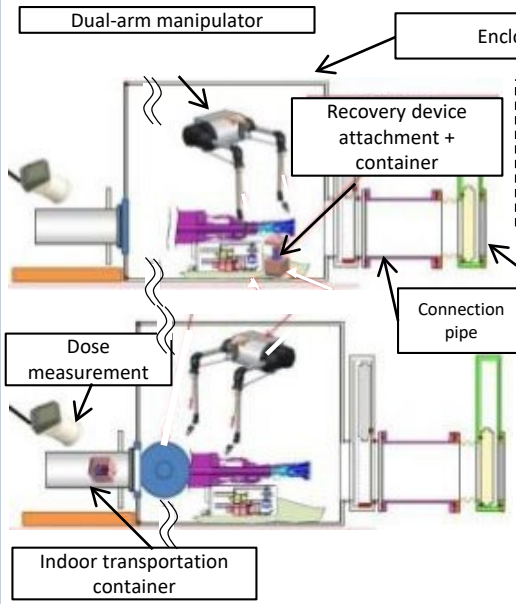


Transportation box

Indoor transportation container (DPTE container)

(From Step 8 on the previous slide)

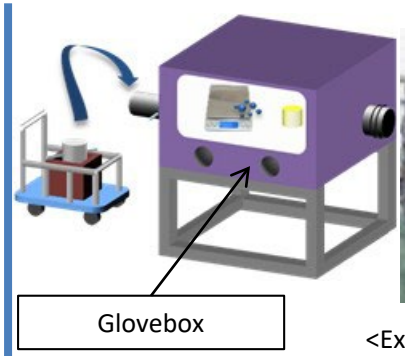
9-2. Inserting the fuel debris recovery device attachment into a container, Inserting into an on-site transportation container/Dose measurements



- 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

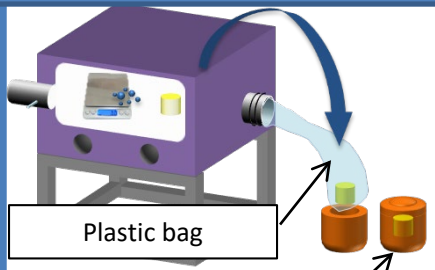


Glovebox

<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)

- Although the removal of deposits from inside the Unit 2 X-6 penetration has been ongoing since January 10, and we are planning to begin the trial retrieval of fuel debris in the future, but we have not seen any radiological impact on the surrounding environment.
- During investigations, 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

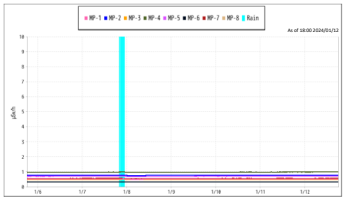
Radiation Dose measured at Monitoring Post of Fukushima Daiichi Nuclear Power Station

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)

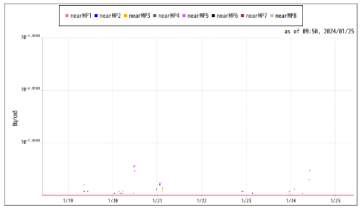
MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	Wind Direction	Wind Velocity	Rain
0.517	0.783	0.490	0.987	0.703	0.315	0.566	0.530	North-northwest	1.4	No

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)

- Although the removal of deposits from inside the Unit 2 X-6 penetration has been ongoing since January 10, and we are planning to begin the trial retrieval of fuel debris in the future, 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

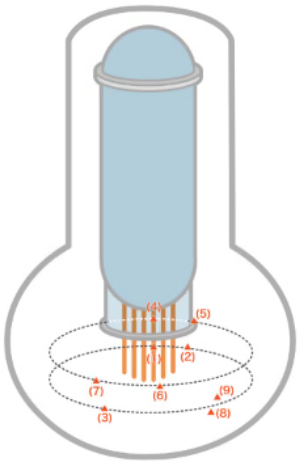
[Reference] Screen image of our website

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

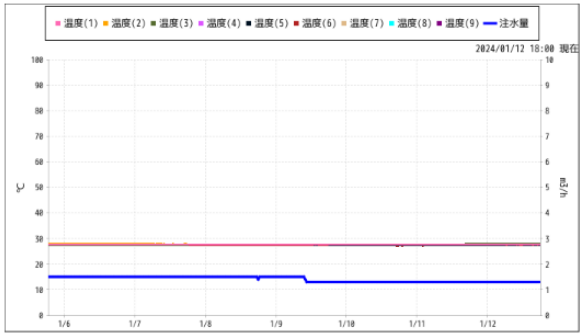
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

Monitoring points

Unit 2 reactor containment vessel



Temperature



Temperature Unit:℃, Water Injection Unit : m^3/h

○Measurement value (2024/01/12 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