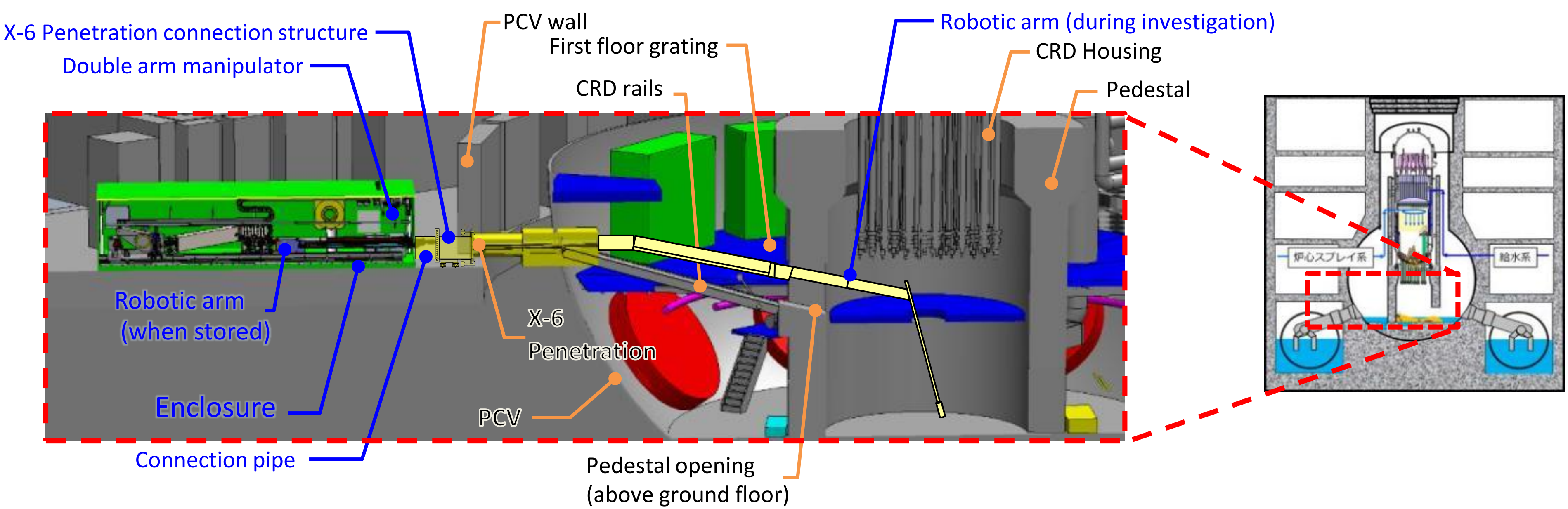
# Fukushima Daiichi Nuclear Power Station Unit 2 PCV Internal Investigation/ Preparation Status of Fuel Debris Trial Retrieval

September 26, 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.
  - 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. Field Preparation Work Progress
# Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

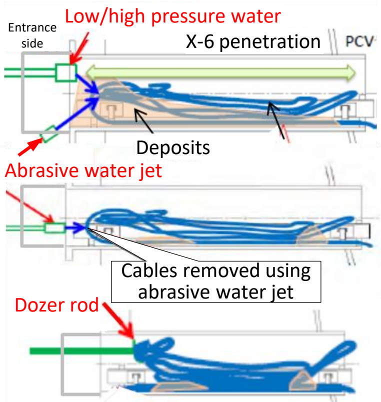
IRID TEPCO

## 1. Isolation chamber installation

## 2. Opening of the X-6 penetration hatch

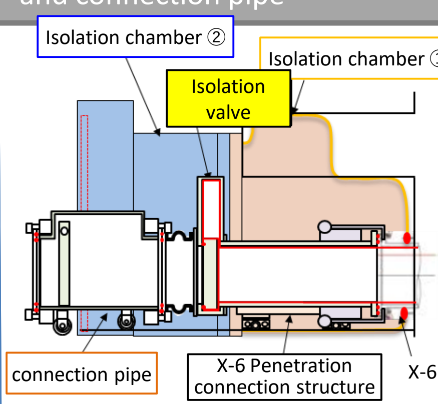
## 3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



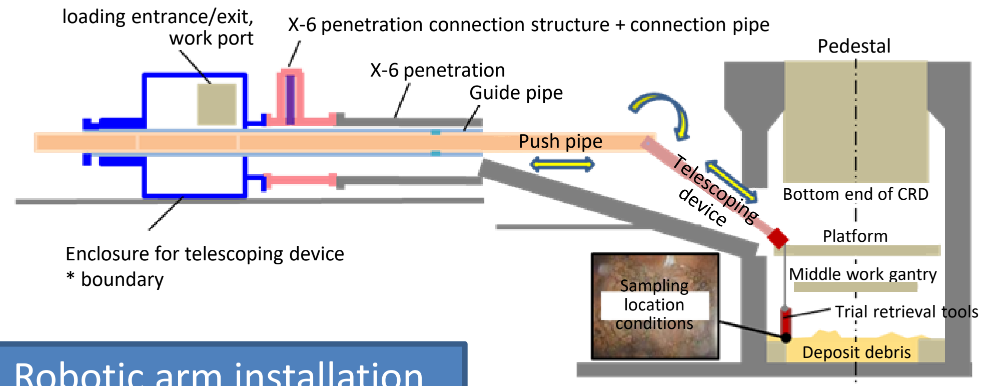

- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

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

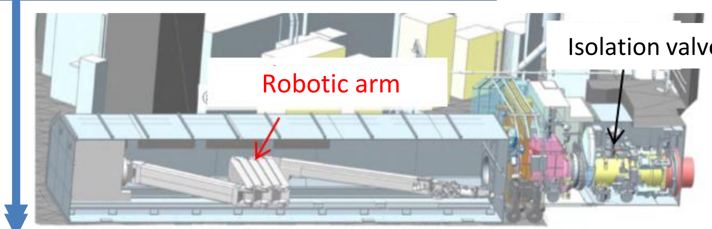



The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

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

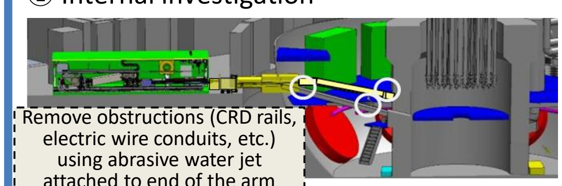



## 7. Robotic arm installation

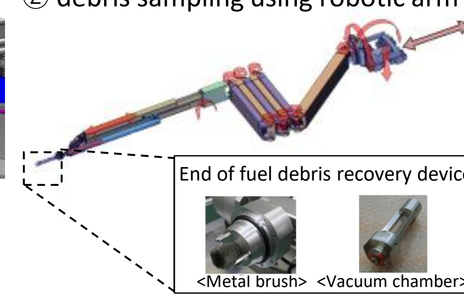



## 8. Internal investigation/debris sampling using robotic arm

① Internal investigation




② debris sampling using robotic arm




(Note)

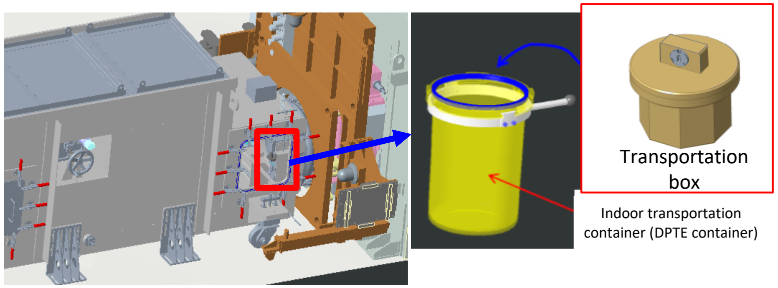
Isolation valve: Valve installed to separate the inside of the PCV from the outside

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

# 2-2. Field Preparation Work Progress
# Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

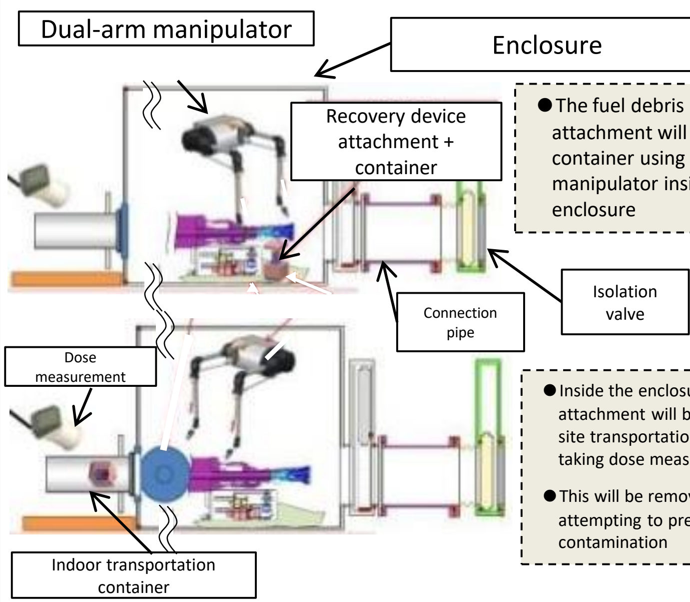
(From Step 6 on the previous slide)

## 9-1. Collection of fuel debris




(From Step 8 on the previous slide)

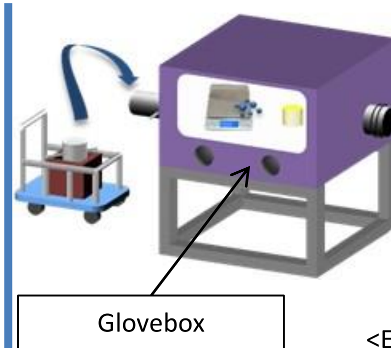
## 9-2. Inserting the fuel debris recovery device attachment into a container, Inserting into an on-site transportation container/Dose measurements




- 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

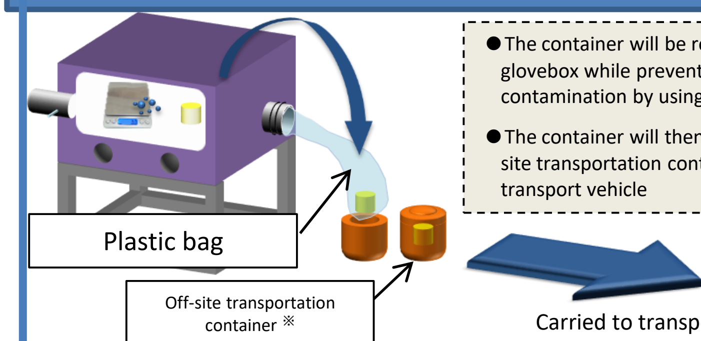
## 10. Insertion into glovebox/Measurement




<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




- 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.

# 3. Field work progress status (Push pipe corrections)

TEPCO

- On September 6, “rechecking/examination of the entire work process”, “further revise procedures”, and the “checking/examination the task training and implementing additional countermeasures for insufficiencies” were completed. Therefore, on September 7-8, the order of the push pipes was corrected and a device function check was performed, and it was confirmed that there are no problems.


Rearranging push pipes in their correct order(field check)

Checking in the remote operations room

- The identification numbers were written in an easily visible position so that it can be identified by wearing full protective equipment and remote cameras as well as by visual inspection.
- Different color tapes were attached to the protective sheet at the end of the push pipes.

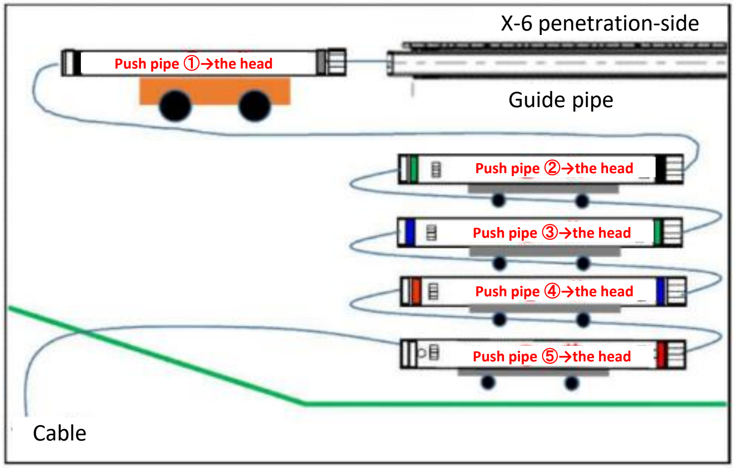
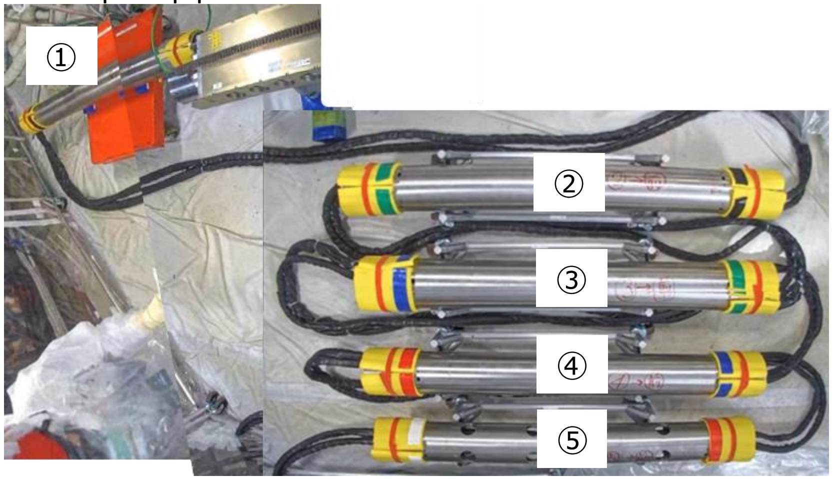


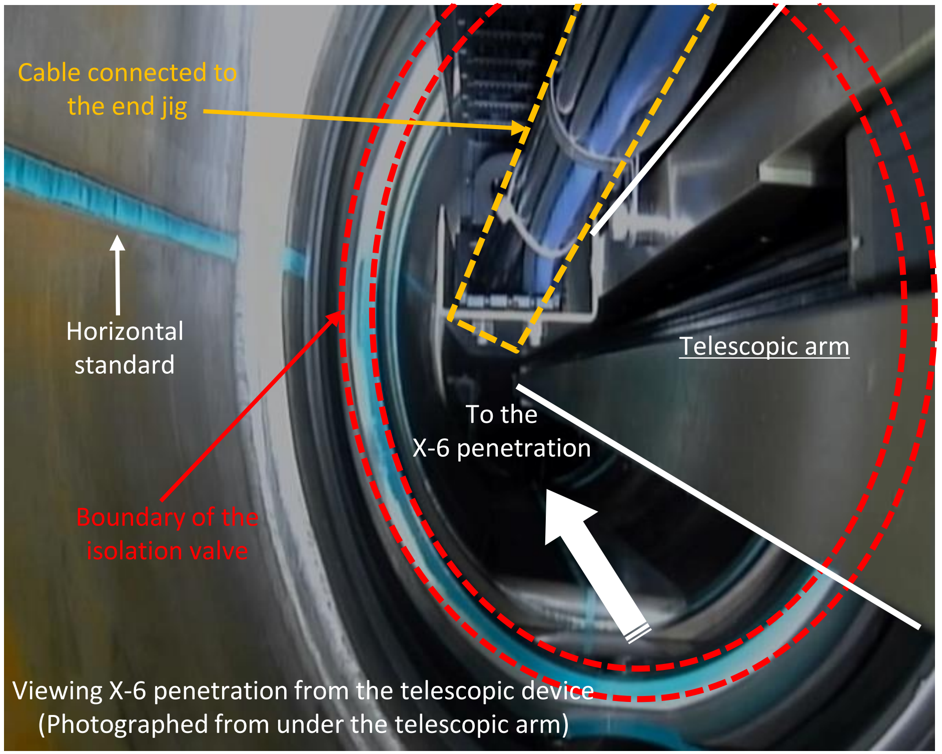

Image of completed push pipes restoration work




Completion of push pipes restoration work

- On September 10, trial retrieval work (inserting the guide pipe) was recommenced.
- Connection of push pipe① to the guide pipe (inner sleeve) and opening of the isolation valve were conducted. By inserting the guide pipe, the end jig of the telescopic device passed through the isolation valve.

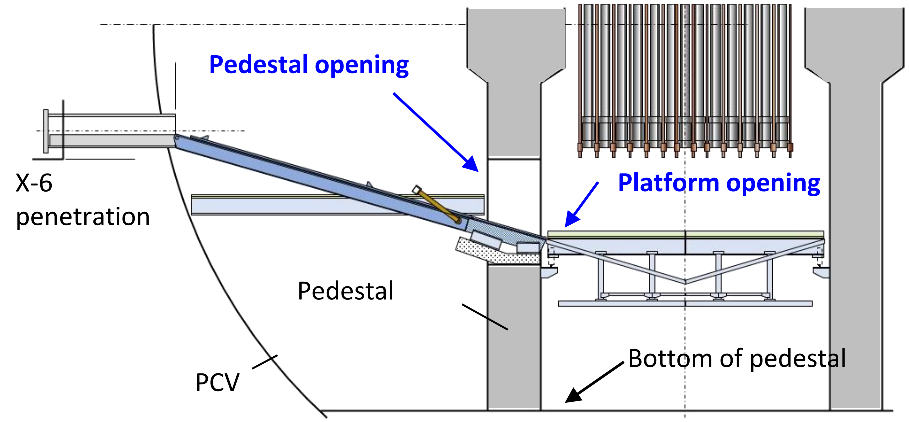




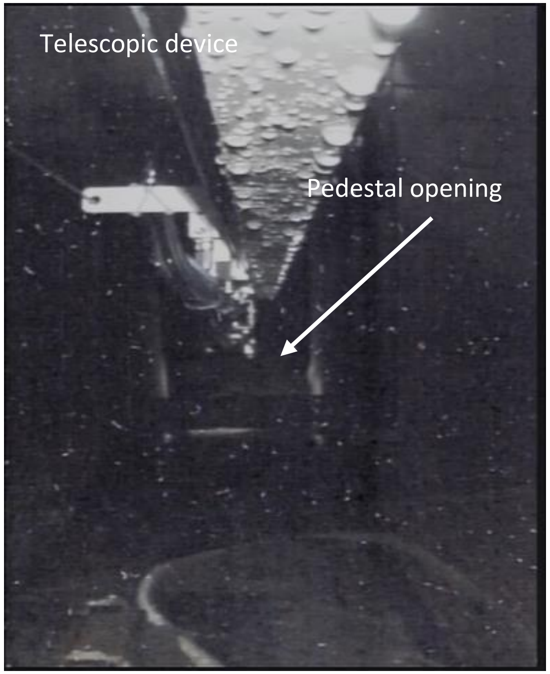

Trial retrieval work status (passing through the isolation valve)

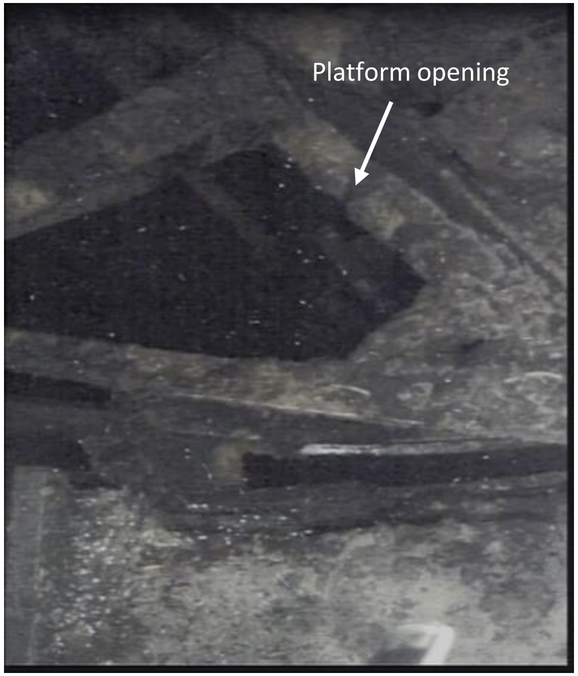
# 5-1. Field work progress status (Guide pipe/telescopic arm insertion)

- On September 14, the telescopic device guide pipe was inserted into the PCV near the pedestal opening. Thereafter a telescopic arm function check (tilt mechanism, telescopic mechanism, end jig) was performed and conditions at the bottom of the pedestal were confirmed.





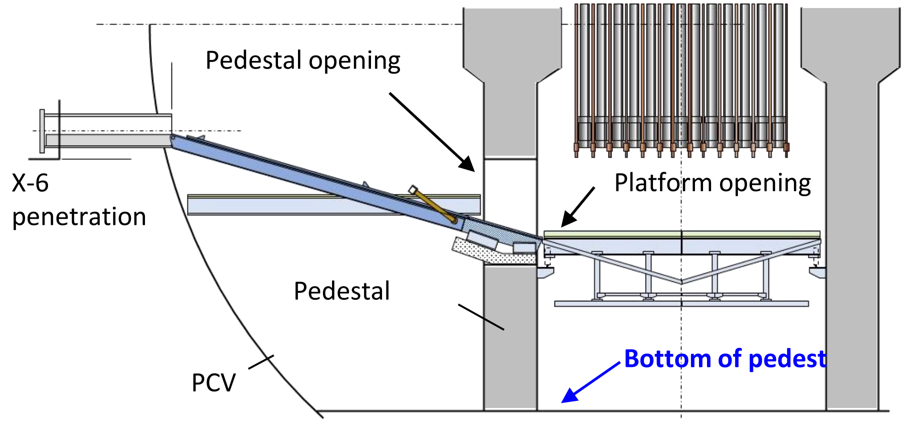


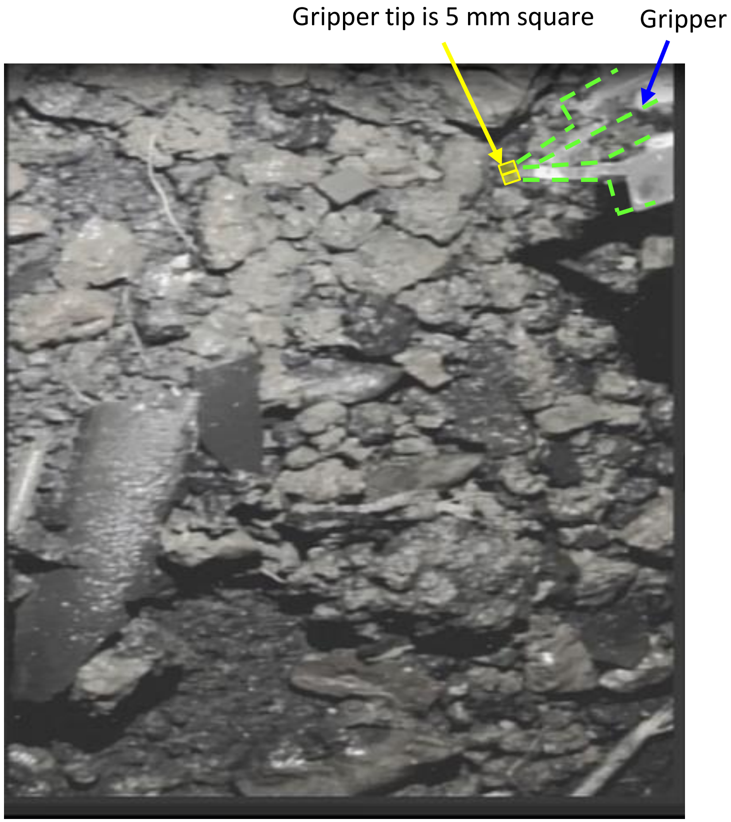



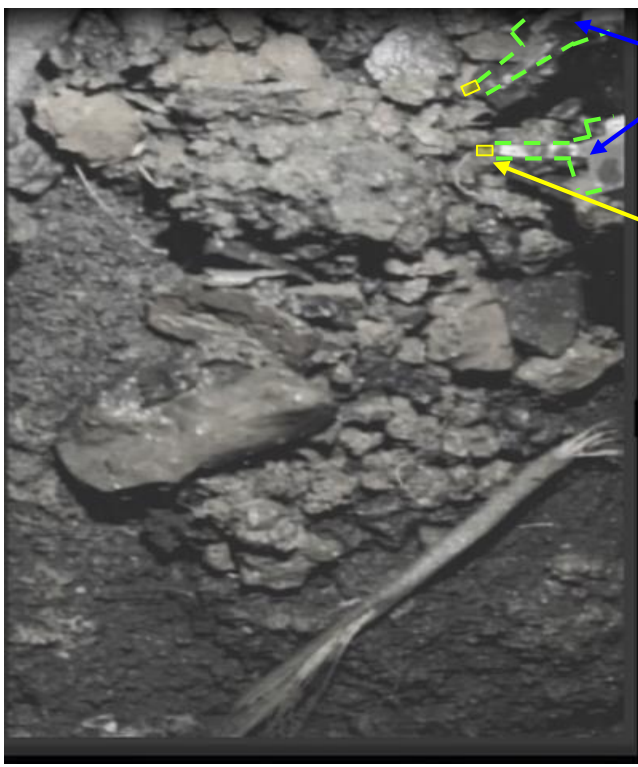

Footage from telescopic arm camera (Pedestal opening, platform opening conditions)

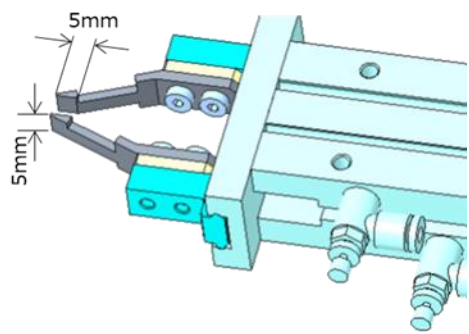
# 5-2. Field work progress status (Examining the bottom of the pedestal)

- On September 14, the telescopic device end jig was lowered to confirm conditions at the bottom of the pedestal. Fuel debris at the bottom of the pedestal could be seen via the end jig camera and the fuel debris was touched with the gripper tool.



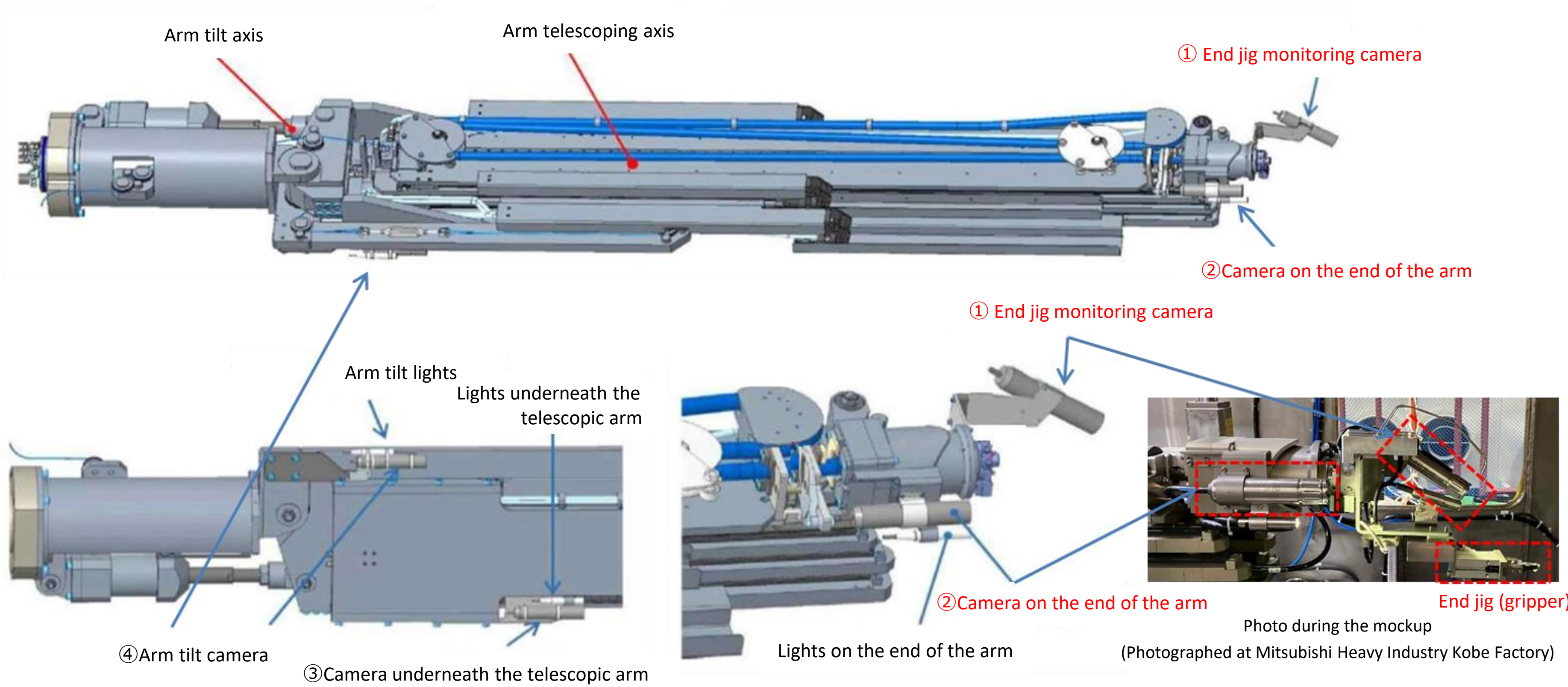




Gripper claws will be used to determine the size (gripper tool)

<u>Footage from the telescopic arm camera (conditions at the bottom of the pedestal)</u>

# 6-1. Field work progress status (Investigation into camera malfunctions)

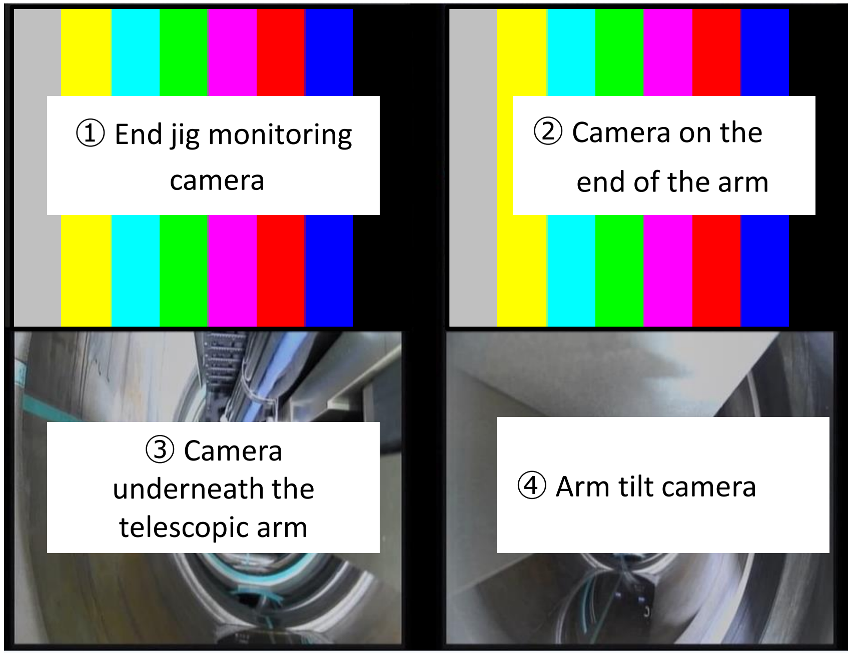
■ On September 17, as a preparation to grasp fuel debris, conditions inside the primary containment vessel was being checked and a functions check of the telescopic device was being performed. As a result, it was detected that footage from the cameras on the end of the telescopic device (① End jig monitoring camera, ② Camera on the end of the arm) was not being sent properly to the monitors in the remote operations room for some reason.



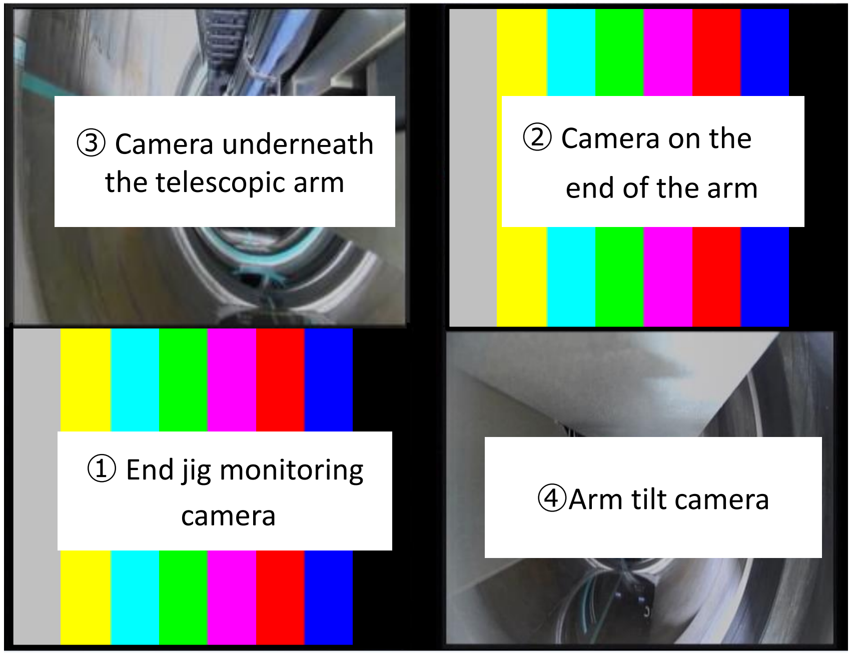

<u>Cameras installed on the telescopic device</u>

# Reference. Field work progress status (Investigation into camera malfunctions)

- On September 17, cameras ① and ② out of the four cameras attached to the telescopic device were not sending video to the monitors in the remote operations room, and only the color bar test pattern was displayed.
- Camera footage is sent from the video converters inside the reactor building to the remote operations room via a fiber-optic cable (hardwired). As part of the investigation, the four pairs of camera cables inside the control panel in the reactor building were rearranged to different video converters.
- When the connections to the four video converters for each of the cameras were switched (changed connections of ①and③), the monitors to which the problematic cameras were connected to displayed the color bar test pattern (refer to the images below) thereby confirming that there are no problems with signal wiring from the control panel in the reactor building to the remote operations room.




Prior to swapping video converter connections (reference photos)



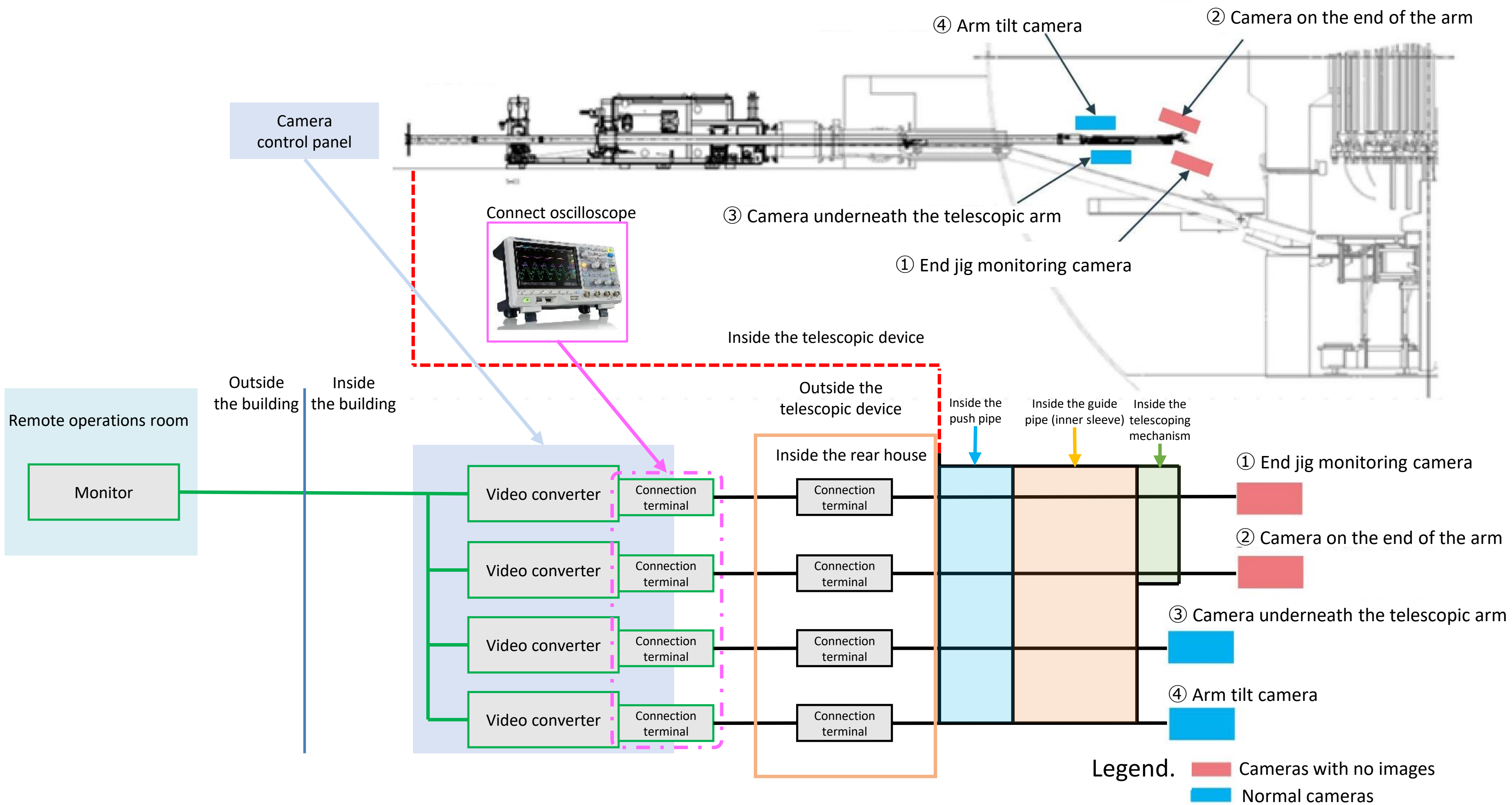

After swapping video converter connections (reference photos)

# 6-2. Field work progress status (Investigation into camera malfunctions)

TEPCO

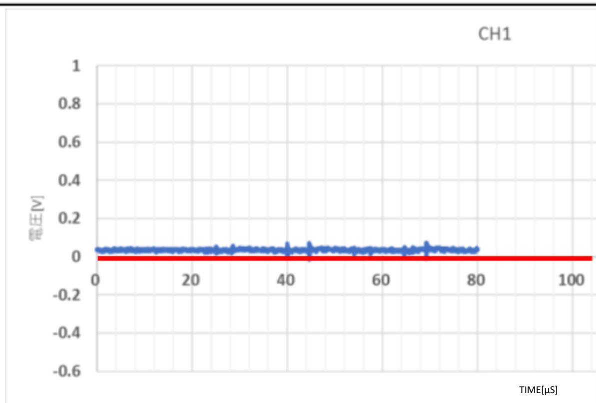
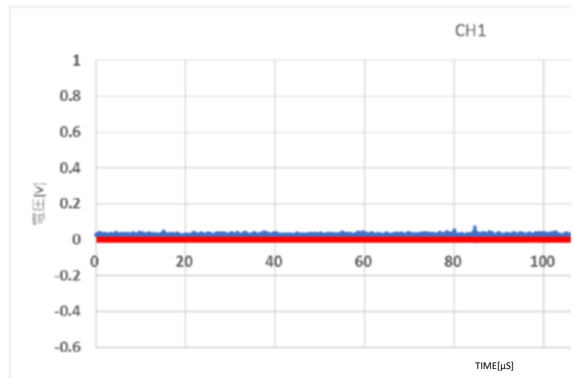
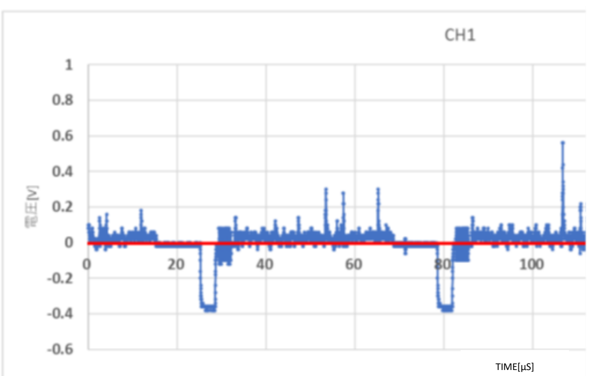
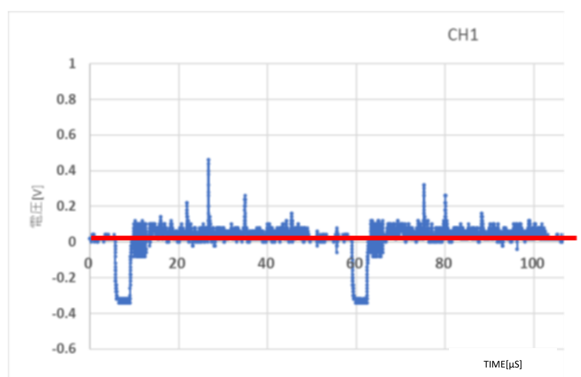
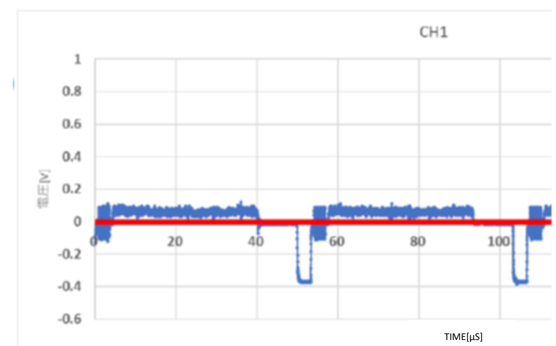
■ In order to investigate the cause of this incident, we have been inspecting all camera cables, connection terminals, and the outside of the video converters by checking their exterior, signals and measuring insulation resistance.

■ The oscilloscope was used to measure the intensity of the camera signal between September 20~21.



# Reference. Field work progress status
## (Results of camera signal intensity measurements taken with instruments)

- When measuring the intensity of the camera signals on the end of the telescopic device (① End jig monitoring camera, ② Camera on the end of the arm) and other cameras', we confirmed a difference in signal behavior between of the cameras on the end of the device and other cameras.

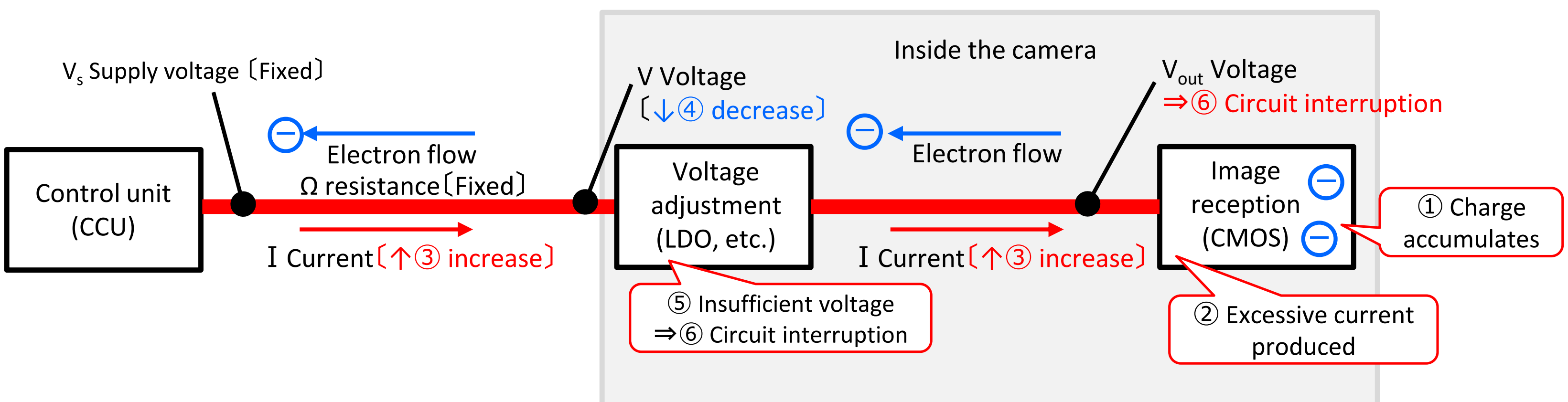
<table>
<tr><td>①End jig monitoring camera</td><td>②Camera on the end of the arm</td><td></td></tr>
<tr><td>
</td><td>
</td><td></td></tr>
<tr><td>③Camera underneath the telescopic arm</td><td>④Arm tilt camera</td><td>Reference: Spare camera</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

# 6-3. Field work progress status (Investigation into camera malfunctions)

TEPCO

- It is hypothesized that as radiation passed through the camera's semiconductor elements a large amount of electrical charge was created due to the ionization effect.
  - ➢ An electrical charge is created when radiation passes through the semiconductor elements, but if the control device is off, this charge will accumulate in the camera circuits.
  - ➢ When the control device is then turned on, excessive current will flow as a result of the accumulated charge the current and causing a drop in voltage to the camera thereby interrupting the camera circuits.
- Considering this mechanism, if the power to the cameras is left on, the accumulated charge can be reduced since it is drained through the power circuit.
- As far as these malfunctions are concerned, the telescopic device has been brought back into the enclosure temporarily in order to inspect the appearance and the status of camera footage. Furthermore, the telescopic device will be left for several days inside the enclosure, which is a lower dose environment, and kept on standby while camera footage status is checked and the effect of the radiation can be examined. This is because the accumulated charge will be drained and the cameras may return to normal if the cameras put in a relatively lower dose environment and left on.
- If the camera footage does not return to normal, the cameras will be replaced.

＜ Electrical charge mechanism ＞




① A charge will accumulate as radiation passes through the semiconductor elements, but the charge will naturally want to dissipate

② When the control device is then turned on, excess current will flow as a result of the accumulated charge and increasing the current then causing a drop in voltage to the camera thereby interrupting the camera circuits

# Reference. Field work progress status
## (Telescopic device investigation status to date)

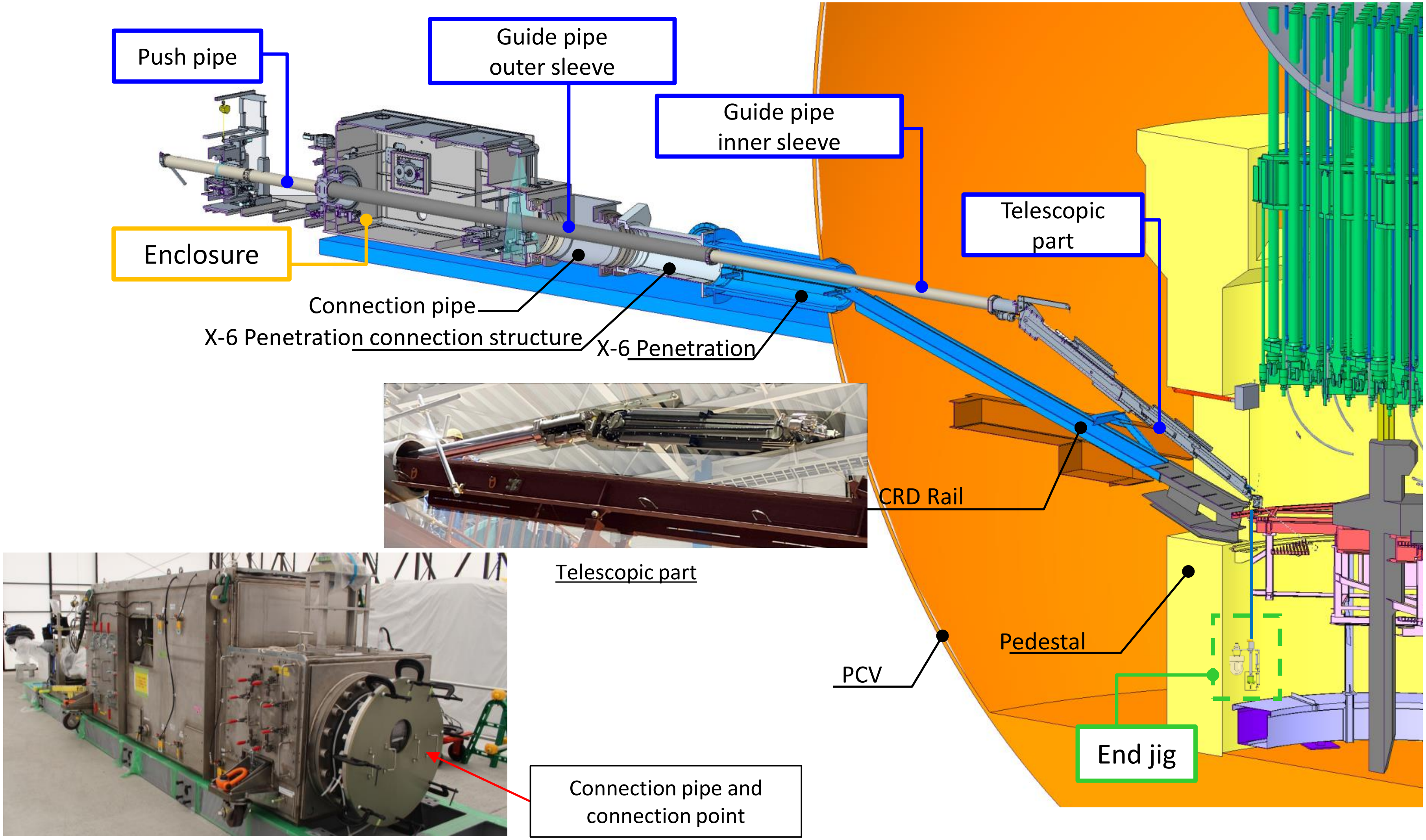
TEPCO

- Investigations of electrical and communications systems have been implemented as shown in the chart below.
- At current time, we have not been able to confirm any cause-effect relationship between the results of each investigation and the malfunctioning cameras, so we will continue our investigation.

| Target system | Investigation results |
|---|---|
| Cables/ connection terminals | ■Severed wires/short circuits, insulation defects<br>Resistance measurements have shown that the resistance for cameras 1~4 are the same (approximately 110Ω~116Ω), and there is little discrepancy with the sum of actual measurements for the spare camera and theoretical cable values (approximately 117Ω~119Ω). Furthermore, electrical current measurements have confirmed that there are no conductor interruptions, short-circuits, or insulation defects. (Electrical systems have not been compromised by water intrusion or condensation) |
| | ■Poor terminal connections<br>Connection terminals were disassembled and visually inspected but no abnormalities were found, and there were no changes in resistance measurements taken before disassembly and after reassembly. Therefore, we have confirmed that the cause is not poor terminal connections. |
| | ■Poor terminal/cable connections<br>No changes were seen in the footage or resistance measurements after moving the cables by actuating the telescopic portion of the device, thus we have confirmed that the cause is not poor terminal/cable connections. |
| Video converters | ■Low input signal levels into video converters<br>There was no change to the conditions was seen when each video converter power was left on in order to check the signals from other cameras on different video converters, thus we have confirmed that the cause is not low signal levels. |
| | ■Hardware/software malfunctions<br>Since the video feeds displayed properly when the feeds from normal cameras were fed through the video converters used for the malfunctioning cameras, we confirm that there are no hardware/software malfunctions. |
| Miscellaneous | ■Noise interference<br>There is no change to the video feeds even when noise from other construction was eliminated, thus this was ruled out as the cause. |

# Reference. Sampling debris with the telescopic fuel debris trial retrieval device

- The telescopic device will be used for the trial retrieval of fuel debris by accessing the inside of the PCV from the X-6 penetration
- Since it will be connected to the connection pipe, the enclosure will serve as a PCV boundary during the trial retrieval of fuel debris.

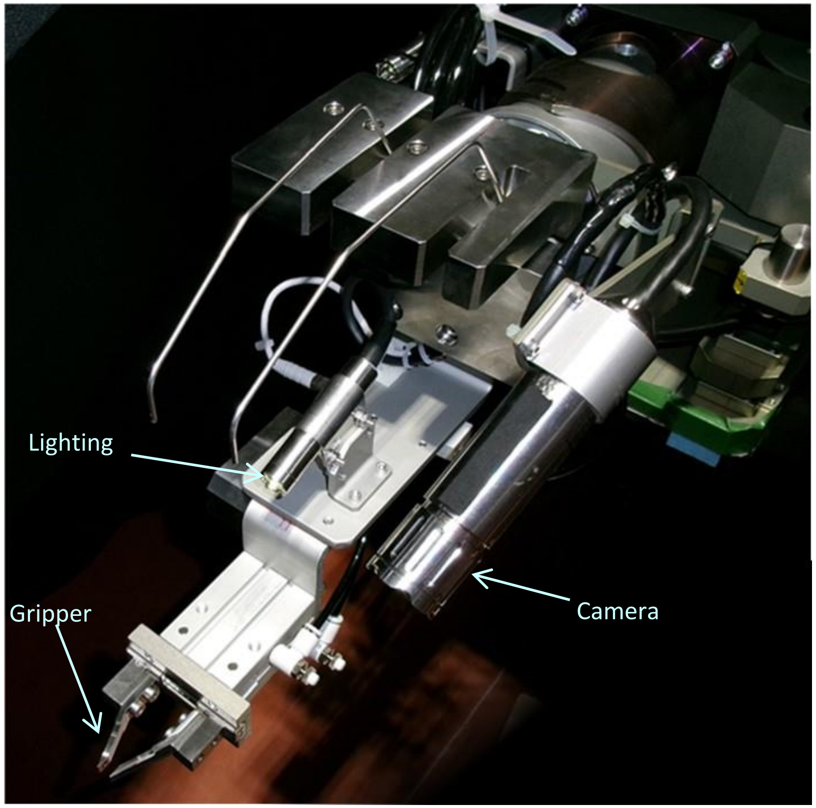



Telescopic part

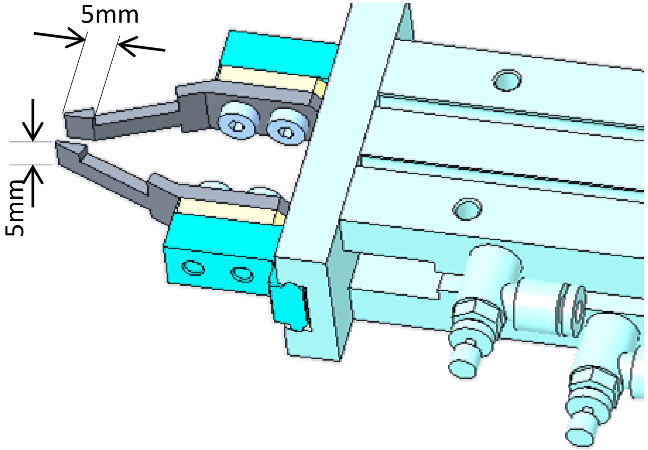
Telescopic device

# 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

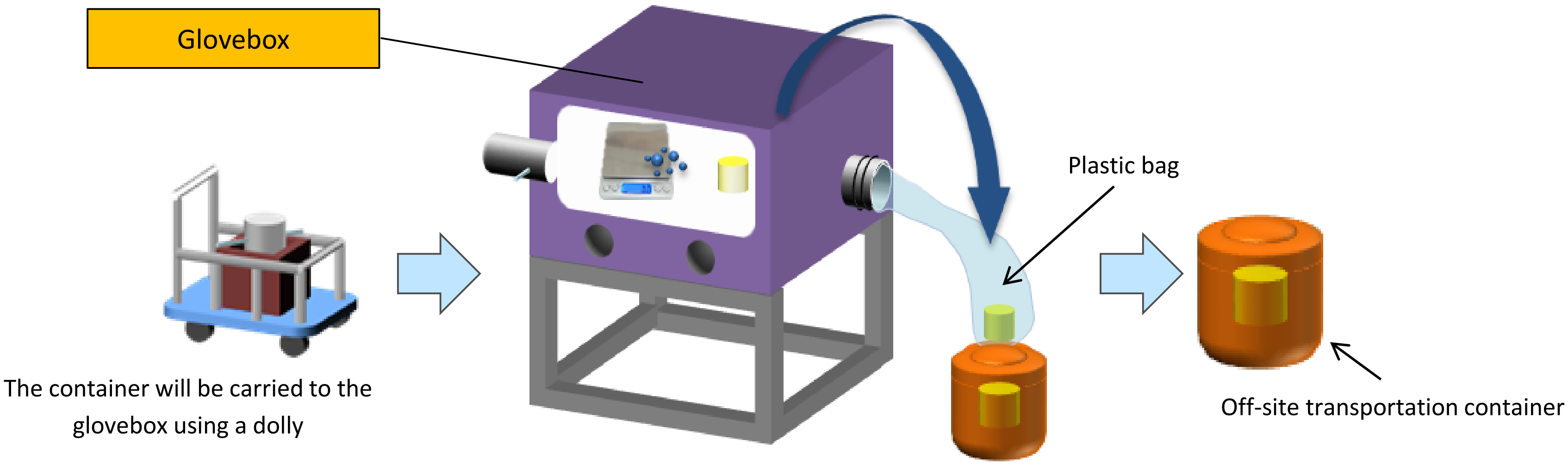



Gripper claws will be used to determine the size (gripper tool)

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

# 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

TEPCO

- 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. $3.7\times10^{10}$ Bq) |
| Dose equivalent rate | Surface of transported item: below 2mSv/h<br>1m from surface of transported item: 100μSv/h |
| Surface contamination density | Alpha nuclide: 0.4Bq/cm$^2$<br>All other nuclides: 4Bq/cm$^2$ |
| Transport container test conditions | Freefall test, compression test, penetration test, etc. |

A-type transport container

# 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

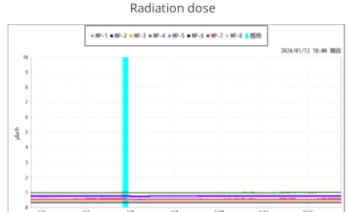
**Radiation Dose measured at Monitoring Post of Fukushima Daiichi Nuclear Power Station**

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 | 風向 | 風速 | 感雨 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.517 | 0.783 | 0.490 | 0.987 | 0.703 | 0.315 | 0.566 | 0.530 | 北北西 | 1.4 | 無 |

**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 : $Bq/cm^3$ 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

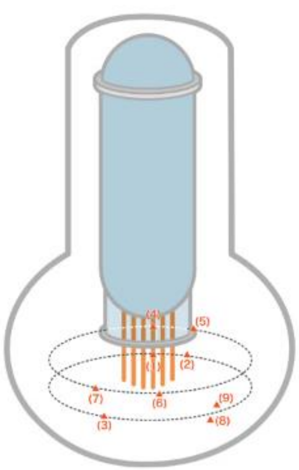
[Reference] Screen image of our website

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

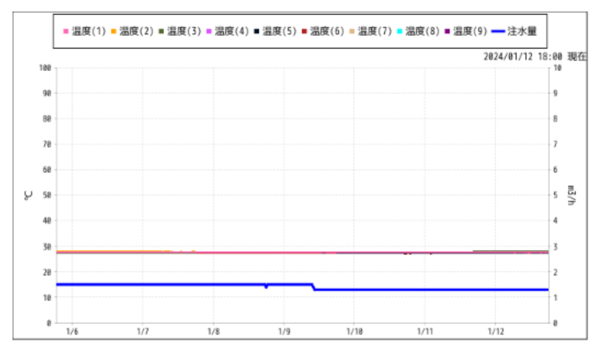
Here are the measurement results of temperatures inside the Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station.

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 |