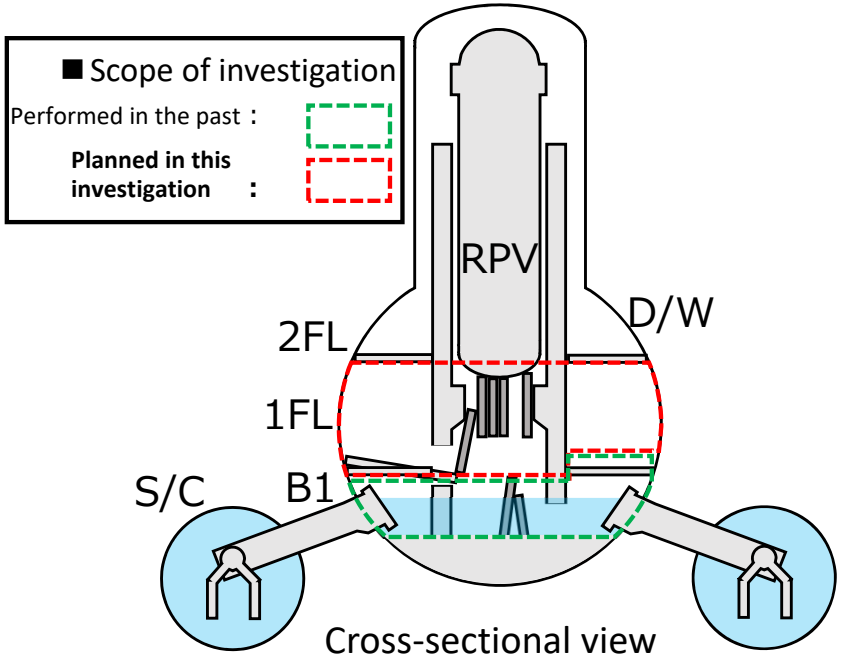
Unit 1 PCV Internal Investigation (Non-submerged area)

March 28, 2024

Tokyo Electric Power Company Holdings, Inc.

1. Overview

- Internal investigations of the Unit 1 primary containment vessel (hereinafter referred to as, "PCV") to ascertain the condition of fuel debris have mainly been carried out in the subfloors.
- In preparation to retrieve fuel debris, we need information about not only the subfloors, but about the entire PCV. Therefore, we are planning to conduct an non-submerged internal investigation of the Unit 1 PCV that will focus on the first floor.
- During this investigation, we plan to get videos of outside the pedestal (the first floor) and inside the pedestal, using small drones (four in total) and snake-like robot that relay wireless communications.

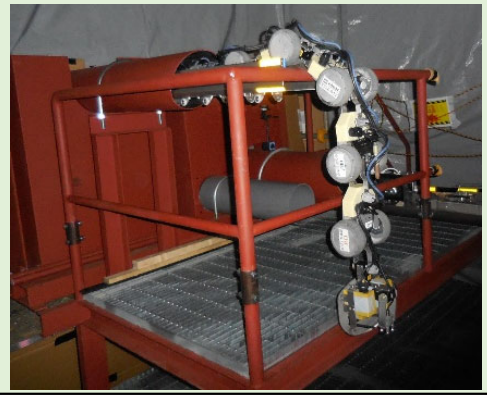


Scope of Unit 1 PCV internal investigations

Small drone

Use: Photography
Dimensions: 191×179×54[mm]
Weight: 185[g](Including battery)
Flight time: Approx. 8 min. (Investigation will consist of four 5-min. flights.)
Installed equipment: lights (90lm(45lm×2)), ultra-high-sensitivity camera (front only)

Wireless communications relay snake-like robot



Use: Carry wireless communications relays and take dose measurements
Dimensions: 2,900×180×165[mm]
Weight: Approx. 25[kg]
Installed equipment: Drone wireless communications relays, CMOS cameras (2), dosimeter

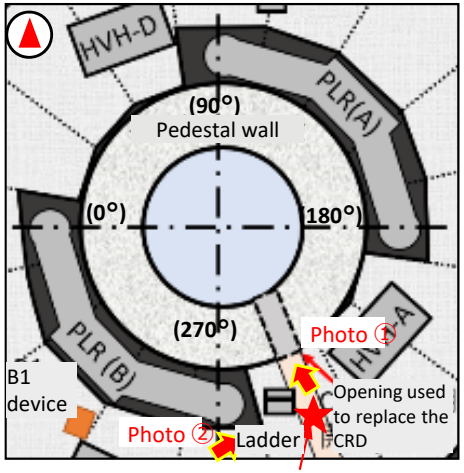
Investigation devices for Unit 1 PCV internal investigation of non-submerged area

2-1. Investigation results on March 14 (In the vicinity of the opening outside the pedestal)

Announced by TEPCO HD on March 18, 2024

TEPCO

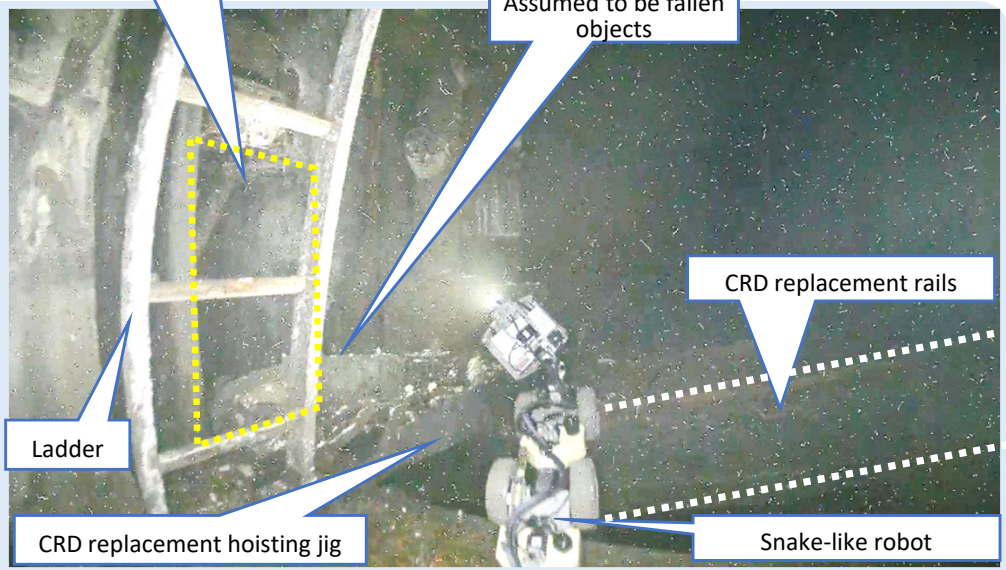
- Photo ①: This is a picture of the opening used to replace the CRD taken from outside the pedestal. Although there are fallen objects in front of the opening, there is no substantial damage to the pedestal walls. The existing structures have experienced some discoloration due to aging, but they retain their original form for the most part.

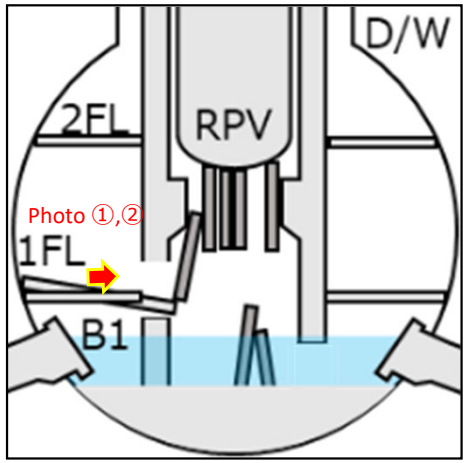


Snake-like robot standby position

Enlarged diagram of the first floor inside the Unit 1 PCV (schematic)

- Photo ②: This photo gives a birds-eye view of the snake-like robot in front of the opening used to replace the CRD. Since no major obstructions were found in the vicinity of the CRD replacement rails during the February 28 investigation, the snake-like robot relayed radio signals from the location of the CRD replacement rails as planned.





Cross-section of the inside of the Unit 1 PCV (schematic)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

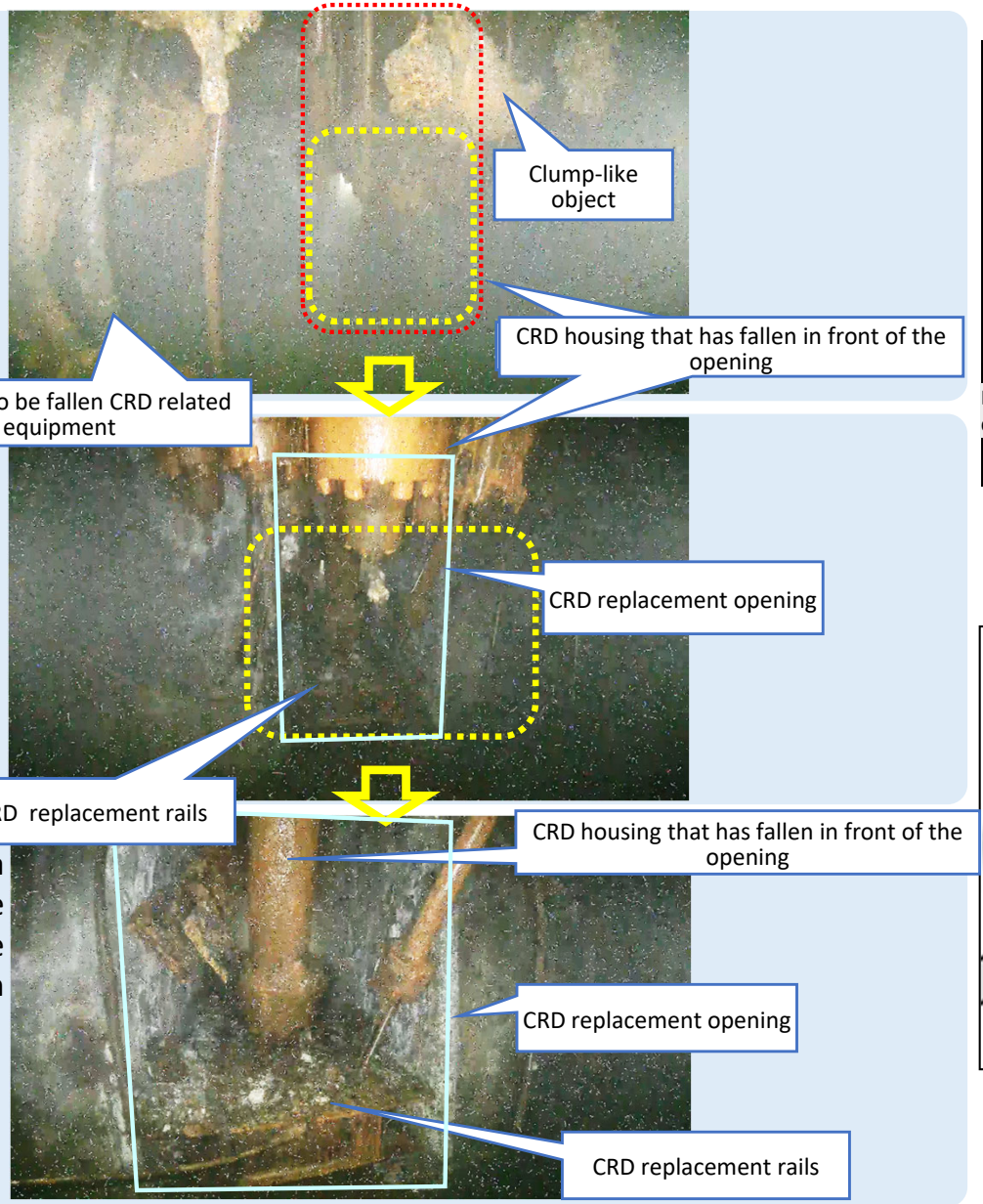
Image processing: Tokyo Electric Power Company Holdings, Inc.

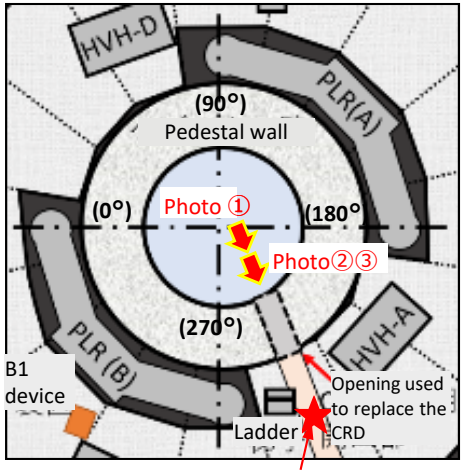
2-2. Investigation results on March 14
(CRD housing in the vicinity of the CRD opening inside the pedestal)

Announced by TEPCO HD on March 18, 2024 (partially revised)

TEPCO

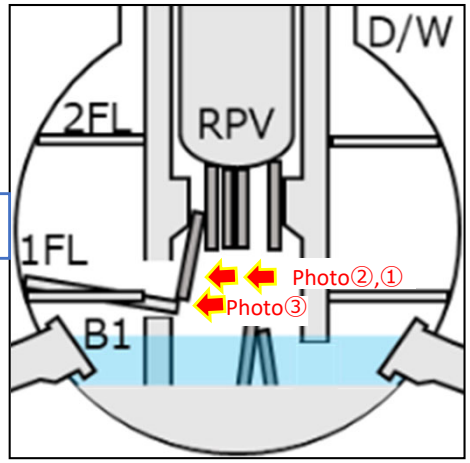
- Photo ①: This is a photo near the opening used to replace the CRD, taken from inside the pedestal. The area surrounded by red dotted line is the fallen CRD housing that has obstructed the opening.
- Photo ②: This is a photo of the area surrounded by the yellow dotted line in photo ①. The CRD housing fell with multiple pieces of CRD related equipment.
- Photo ③: This is a photo of the area surrounded by the yellow dotted line in photo ②. It appears that the bottom of the CRD housing fell on top of the CRD replacement rails.





Snake-like robot standby position

Enlarged diagram of the first floor inside the Unit 1 PCV (schematic)



Cross-section of the inside of the Unit 1 PCV (schematic)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

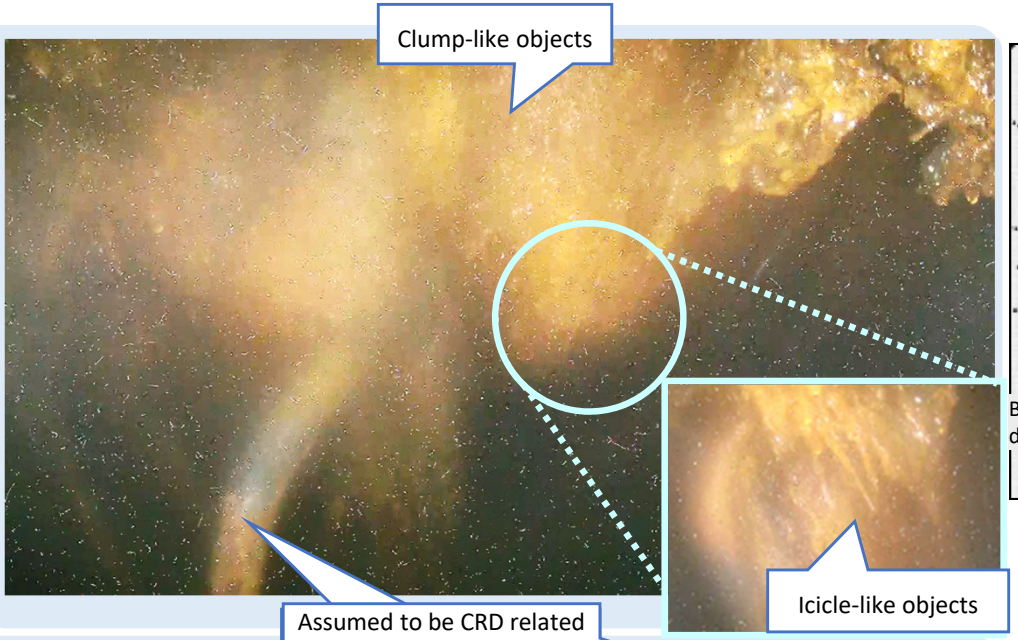
Image processing: Tokyo Electric Power Company Holdings, Inc.

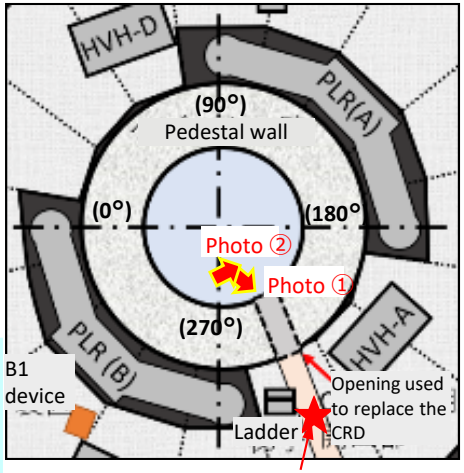
2-3. Investigation results on March 14

Announced by TEPCO HD on March 18, 2024

(Clump-like objects in the vicinity of the CRD opening inside the pedestal)

- Photo ①: There are clump-like objects on top of the CRD housing that has fallen in the vicinity of the opening used to replace the CRD. Icicle-like objects are seen partly on the clump-like objects. Since they concentrate around the top, it is assumed that these objects migrated downward from above.

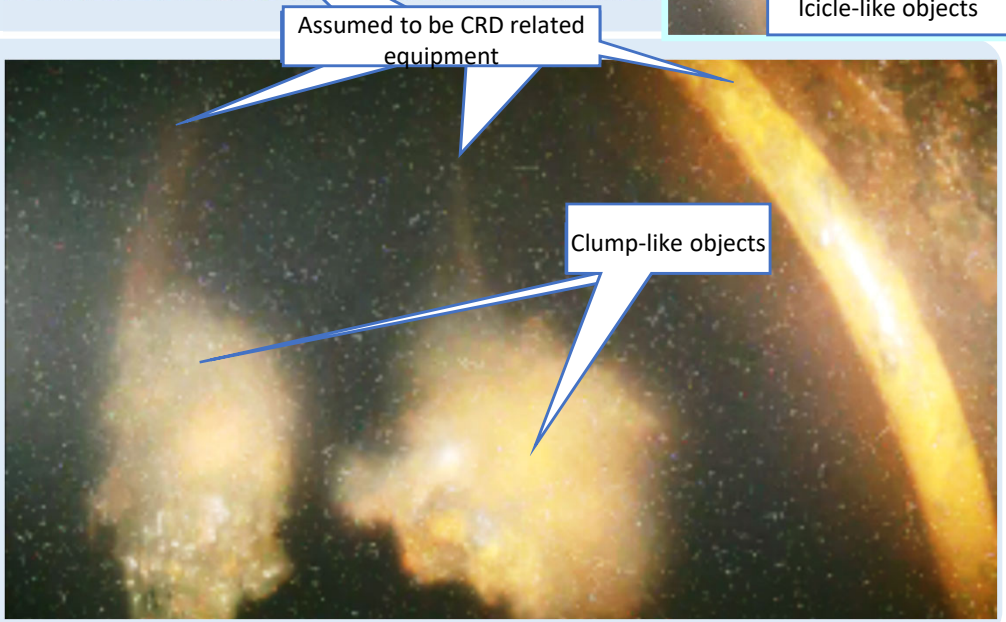


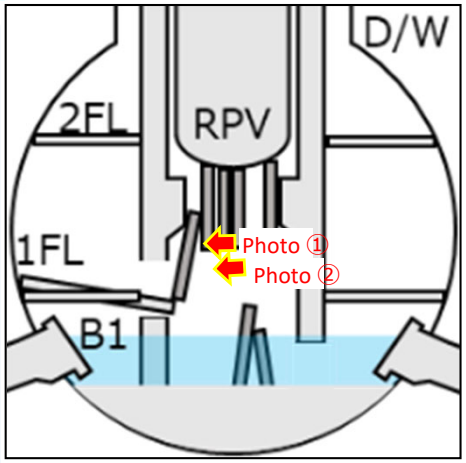


Snake-like robot standby position

Enlarged diagram of the first floor inside the Unit 1 PCV (schematic)

- Photo ②: These are clump-like objects that are further inside the pedestal than the CRD housing that has fallen in the vicinity of the opening used to replace the CRD. They are hanging off of the CRD related equipment. As with photo ①, it is assumed that these objects migrated downward from above.





Cross-section of the inside of the Unit 1 PCV (schematic)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

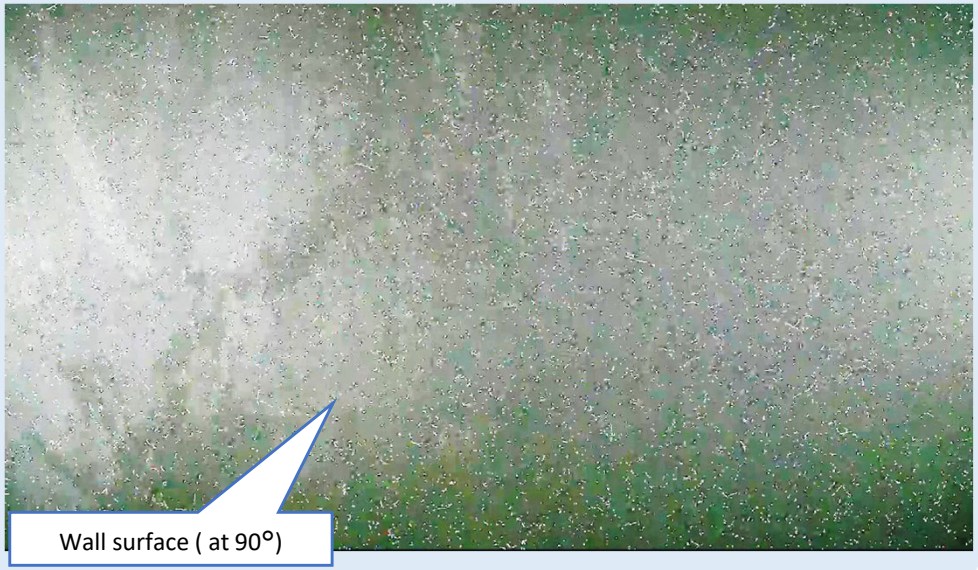
Image processing: Tokyo Electric Power Company Holdings, Inc.

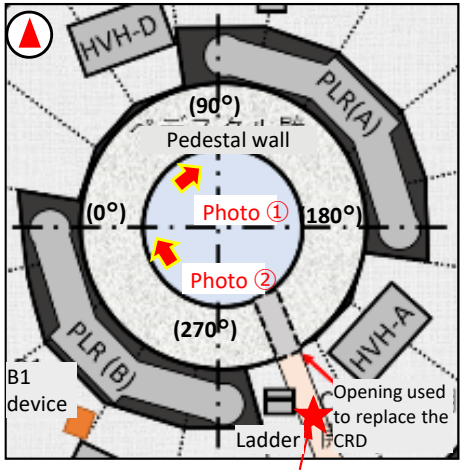
2-4. Investigation results on March 14 (Pedestal wall inside the pedestal)

Announced by TEPCO HD on March 18, 2024

TEPCO

- Photo ①: This is a photo of the pedestal wall at 90° inside the pedestal. Although there is some discoloration, but no significant damage is observed, and the concrete is still present. No equipment is found since there had been no equipment installed on this wall prior to the disaster.

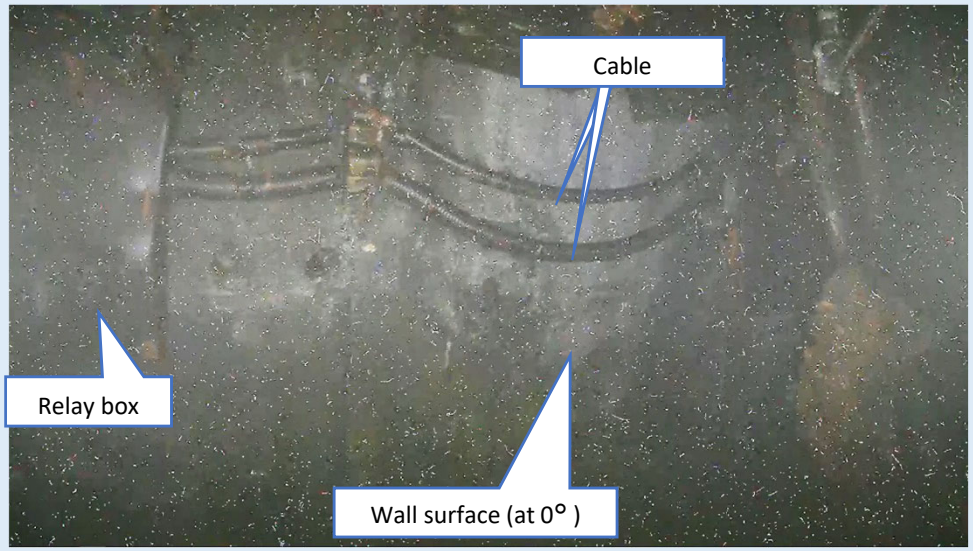


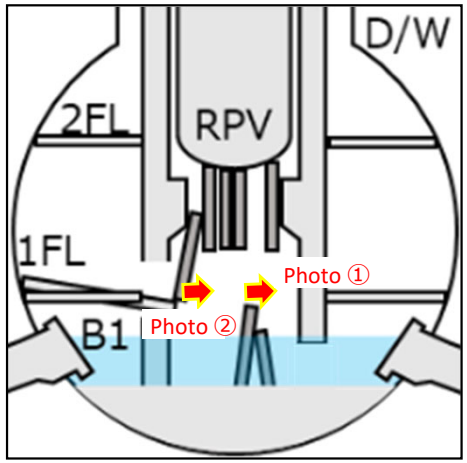


Snake-like robot standby position

Enlarged diagram of the first floor inside the Unit 1 PCV (schematic)

- Photo ②: This is a photo of the pedestal wall at 0° inside the pedestal. As with photo ①, there is some discoloration but no significant damage is observed, and the concrete is still present. Cable relay box, which is assumed to be discolored and deformed, are observed.





Cross-section of the inside of the Unit 1 PCV (schematic)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

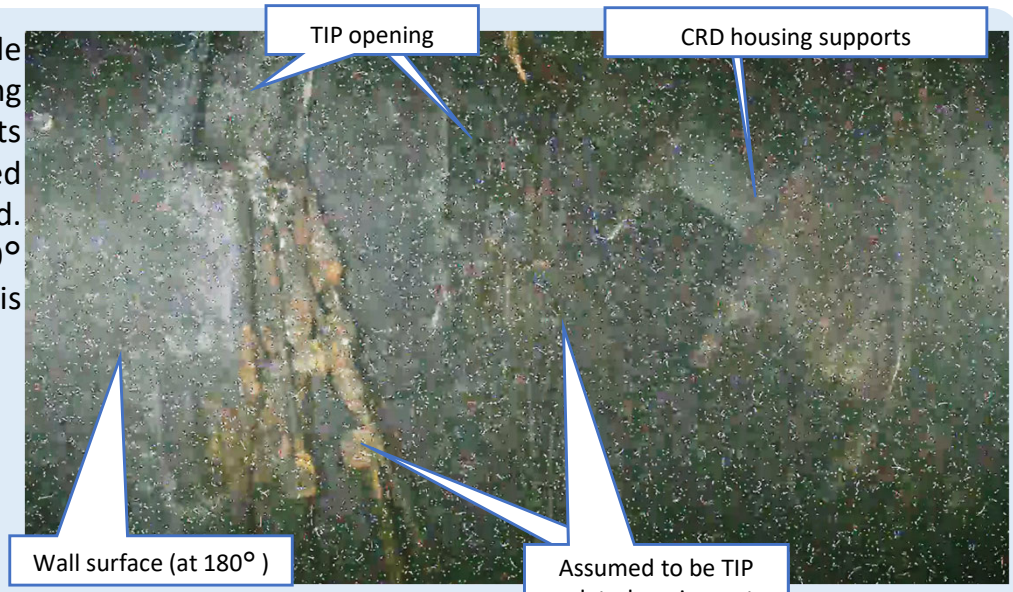
Image processing: Tokyo Electric Power Company Holdings, Inc.

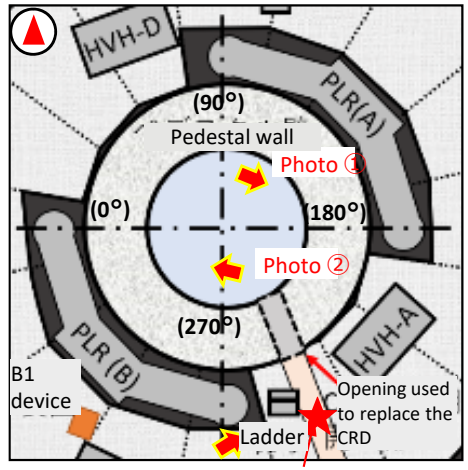
2-5. Investigation results on March 14 (Structures inside the pedestal)

Announced by TEPCO HD on March 18, 2024

TEPCO

- Photo ①: This is a photo of inside the pedestal at 180°. The existing TIP opening can be seen, and objects assumed to be TIP related equipment are hanging downward. Similarly with the pedestal wall at 0° and 90°, no significant damage is observed.

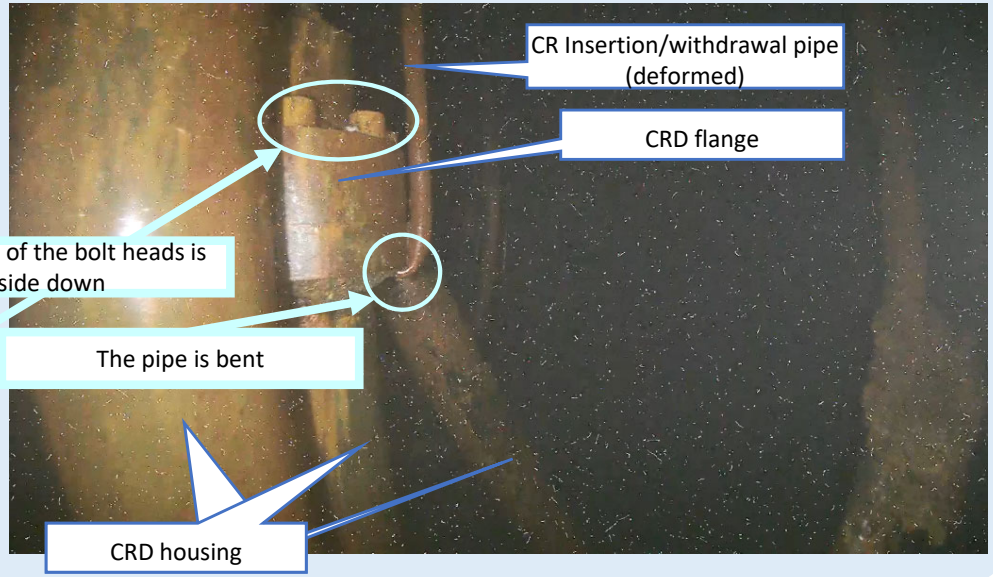


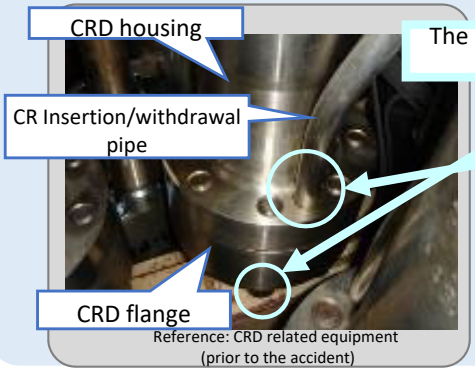


Snake-like robot standby position

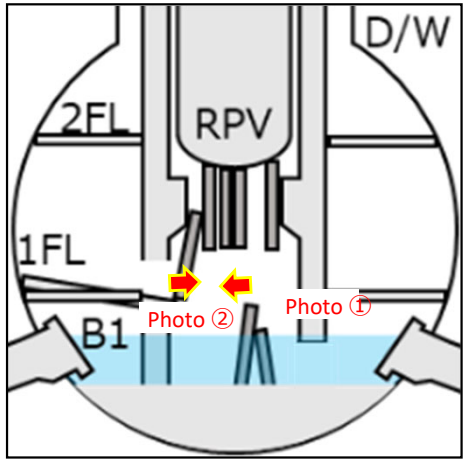
Enlarged diagram of the first floor inside the Unit 1 PCV (schematic)

- Photo ②: This photo shows the CRD housing that has been reversed from its original position. The insertion/withdrawal pipe is deformed.





Reference: CRD related equipment (prior to the accident)



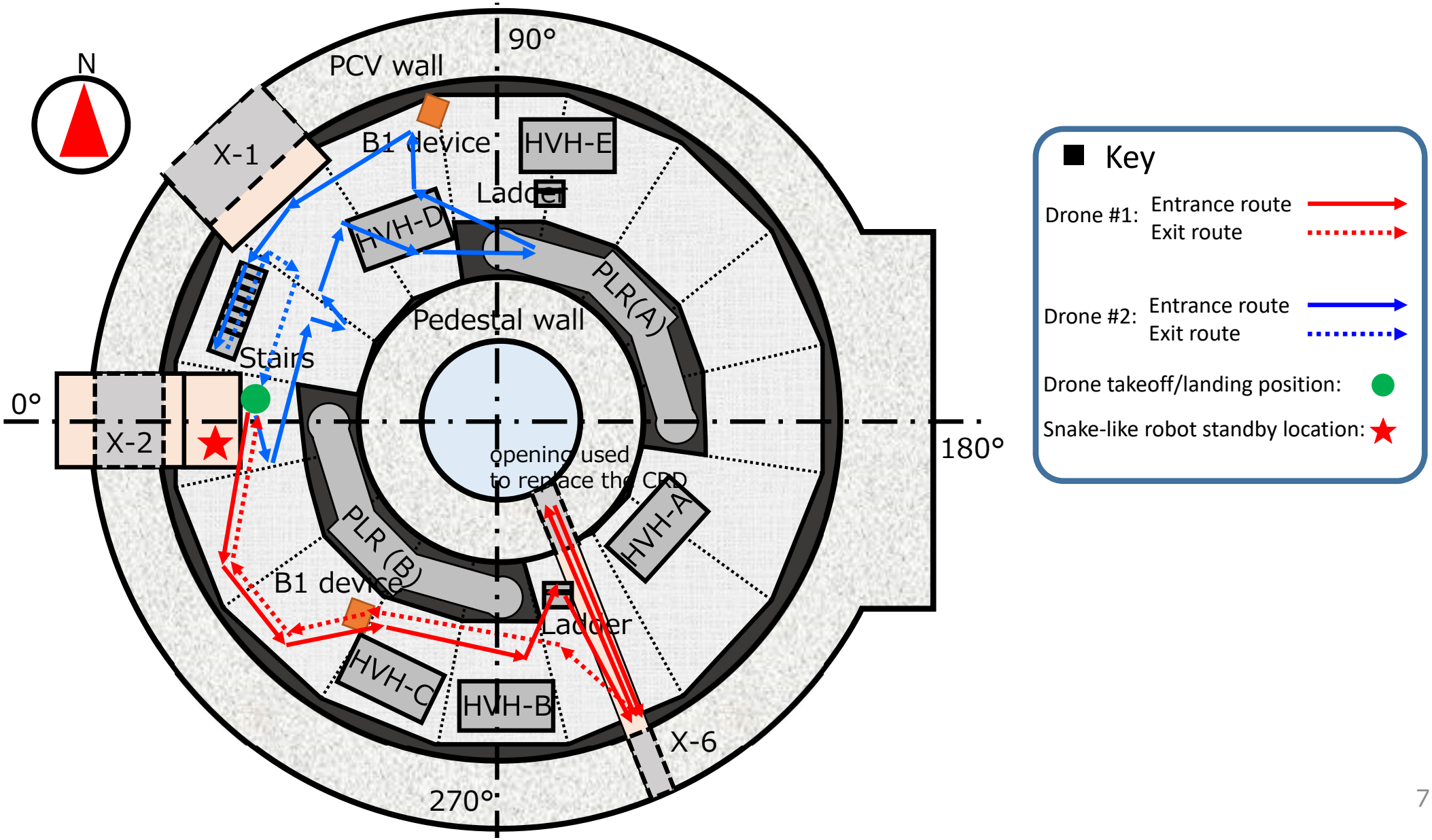
Cross-section of the inside of the Unit 1 PCV (schematic)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: Tokyo Electric Power Company Holdings, Inc.

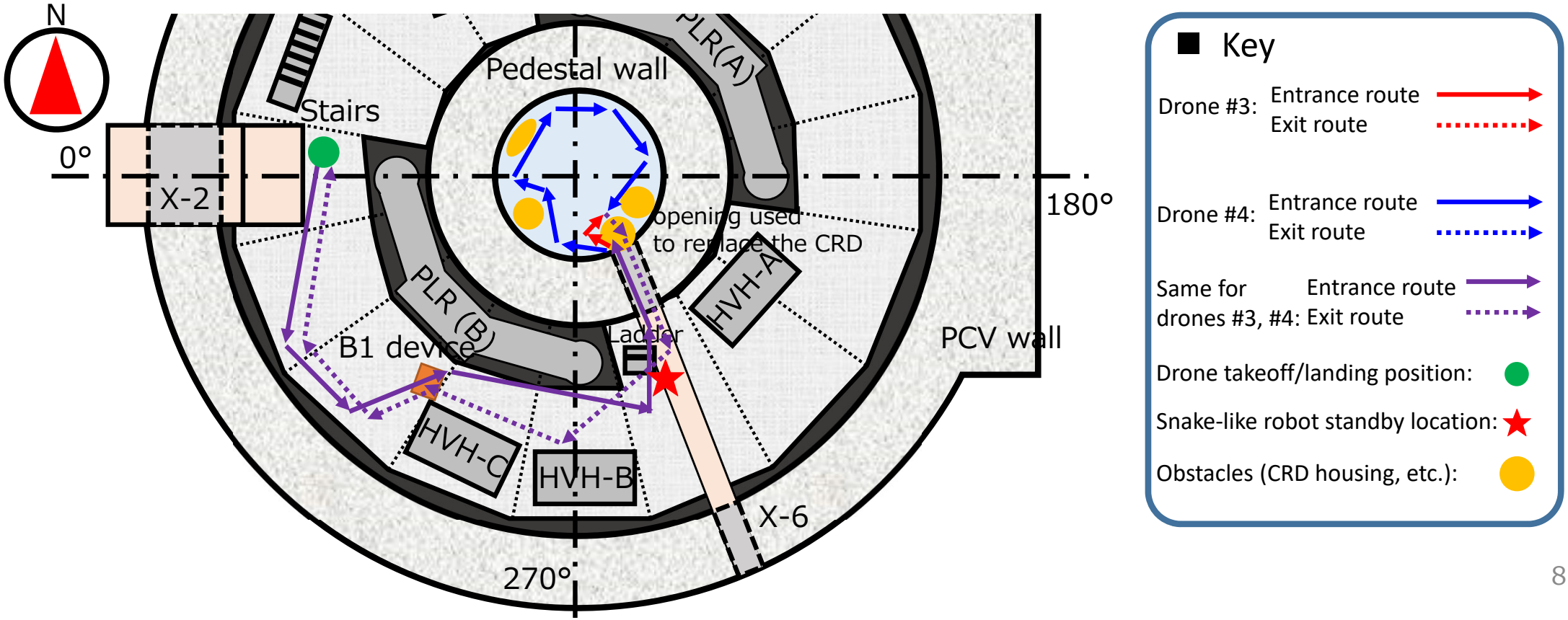
3-1. Flight route record (Outside the pedestal)

- Drones #1 and #2 had been flown outside the pedestal and had been able to take the planned flight routes for the most part.
- Since visibility was poor due to the fog, the drones were being flown carefully while keeping landmark structures in frame.



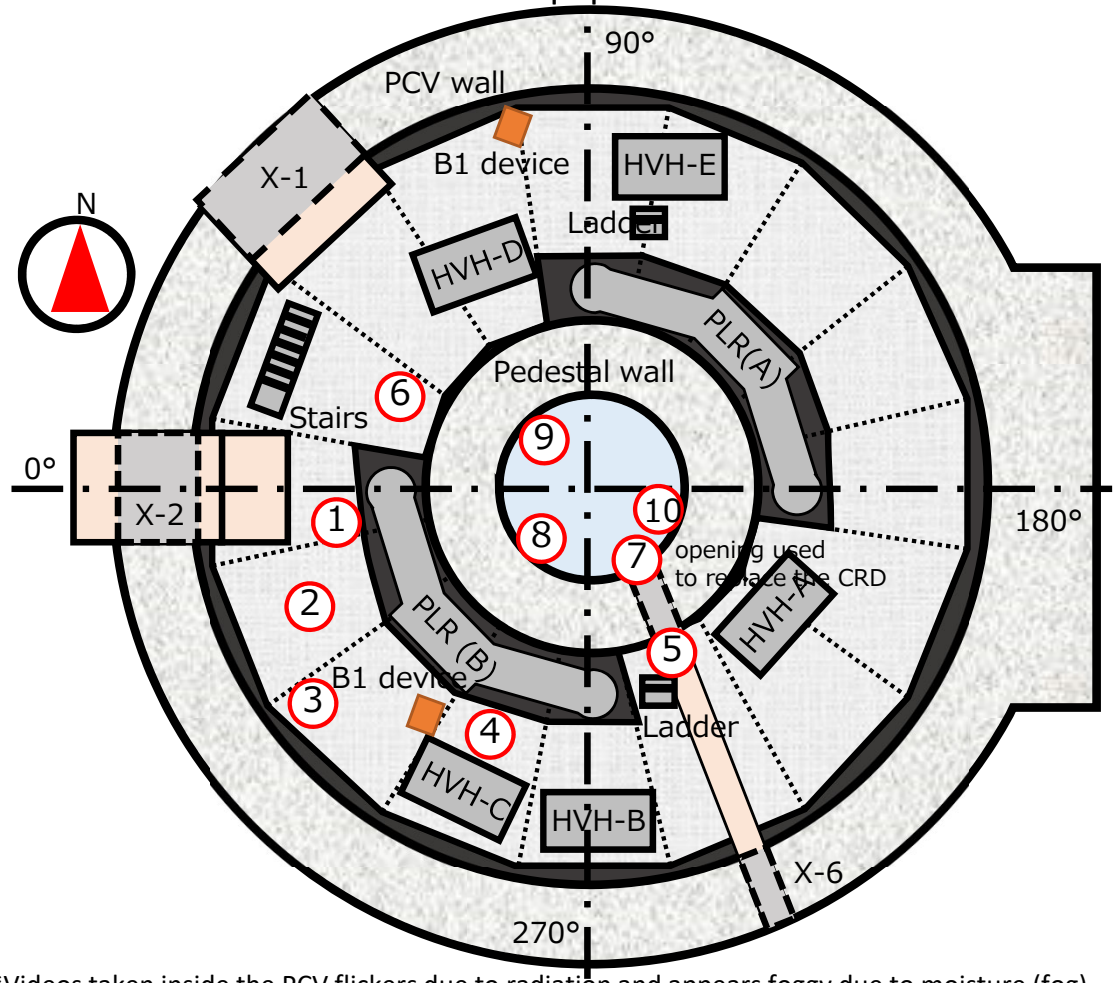
3-2. Flight route record (Inside the pedestal)

- Drones #3 and #4 had been flown inside the pedestal. During the flight of drone #3, which was originally planned to be flown the entire inner circumference of the pedestal, we discovered several structures that have fallen in the vicinity of the opening used to replace the CRD, so we changed the flight plan.
- Drone #3 was used to carefully examine the area around the opening used to replace the CRD. Once the flight route had been recalculated, drone #4 was flown in a clockwise direction around the inner circumference of the pedestal.
- As with outside the pedestal, visibility was poor due to the fog, so the drones were being flown very carefully while keeping the pedestal walls in frame and avoiding obstacles.
- In principle, the altitude of the drones was kept at approximately 4m from the bottom of the pedestal (2m from the surface of the water)



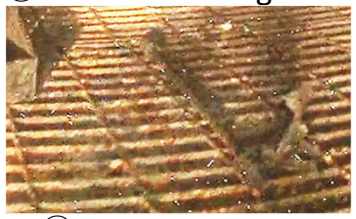
4. Major objects that have fallen inside the PCV

- We have observed fallen objects on the grating outside the pedestal, such as lead shielding mats, etc., that were seen in past investigations.
- There is a fallen object in front of the opening used to replace the CRD which is assumed to be the chain block used to hoist the CRD rails.
- Inside the pedestal, in addition to the vicinity of the opening used to replace the CRD, there are fallen structures on the wall side, which are assumed to be the CRD related equipment.




① : Lead shielding mats


② : Fallen object A


③ : Fallen object B


④ : Fallen object C


⑤ : Chain block (assumed)


⑥ : Light cover


⑦ : Fallen structure A


⑧ : Fallen structure B


⑨ : Fallen structure C

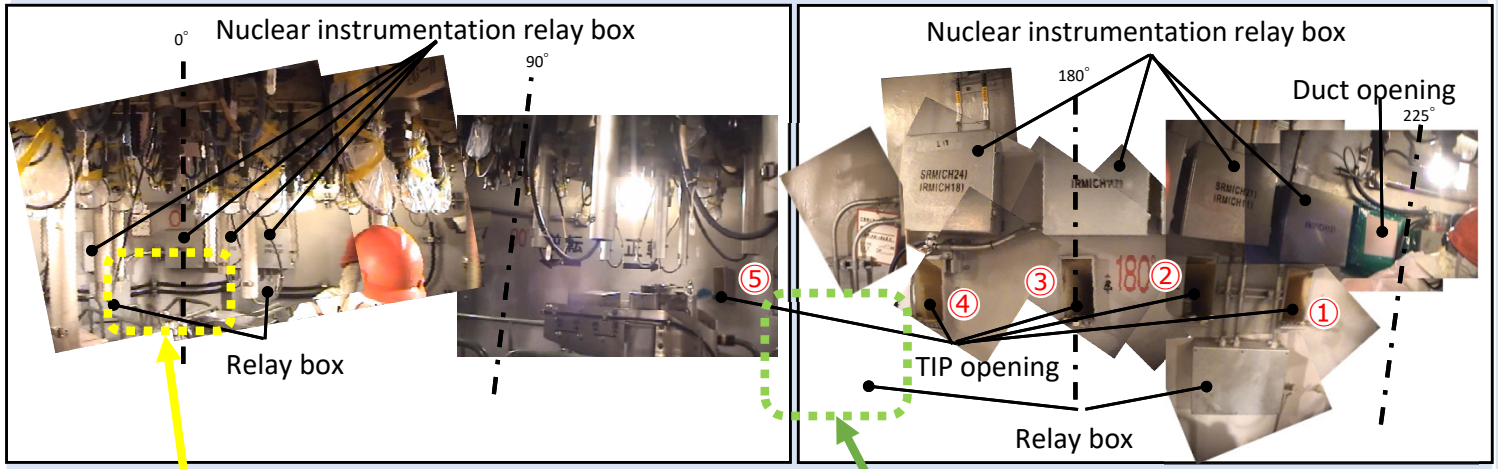

⑩ : Fallen structure D

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

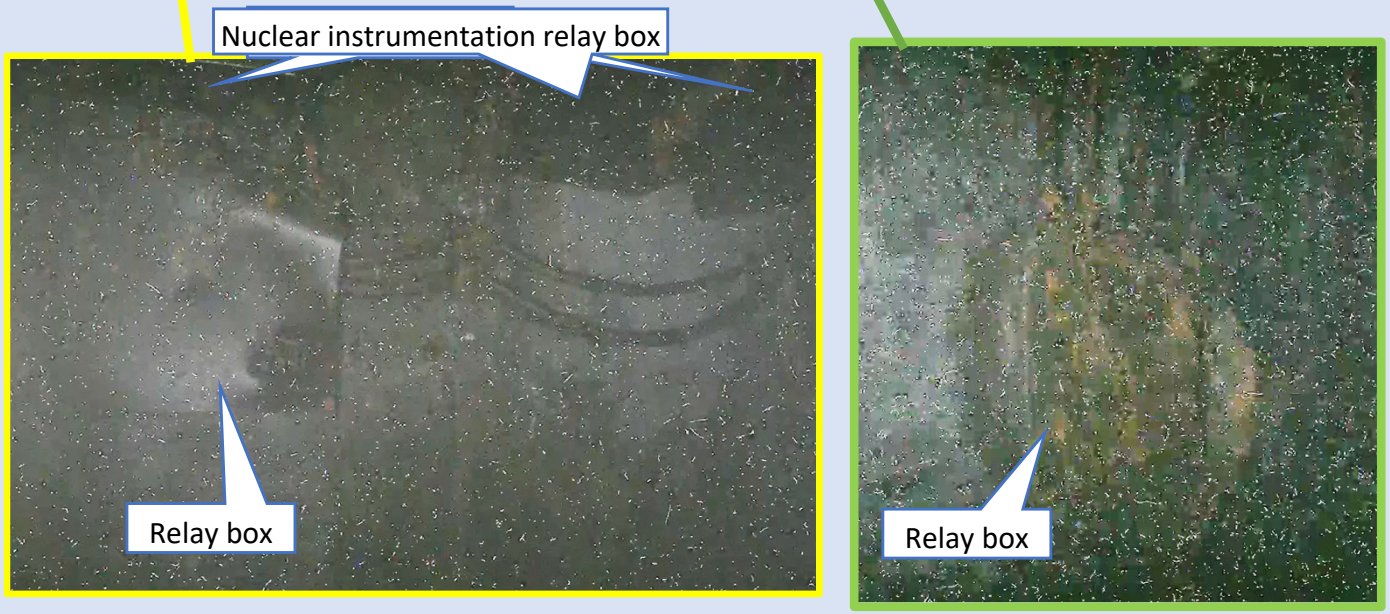
Image processing: Tokyo Electric Power Company Holdings, Inc.

5-1. Comparison with Conditions prior to the accident (Relay box inside the pedestal, TIP opening)

Relay box on the pedestal wall

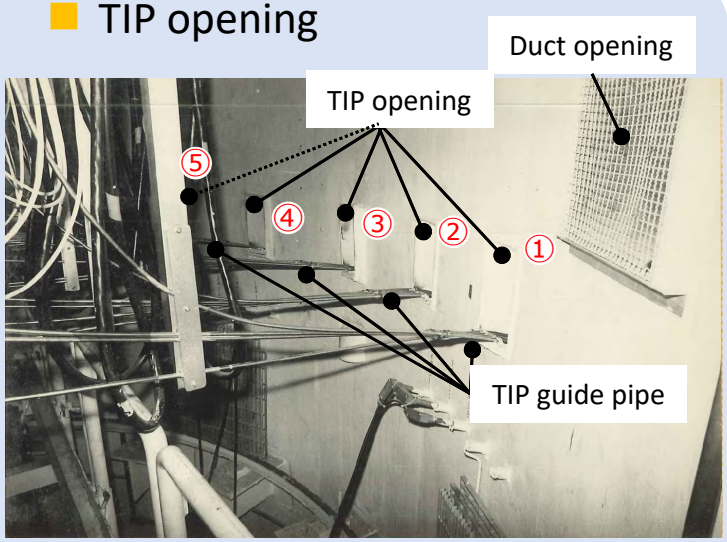


[Prior to the accident: during the periodic inspection] Inner pedestal wall (left: around 0°~90°, right: around 180°～225°)

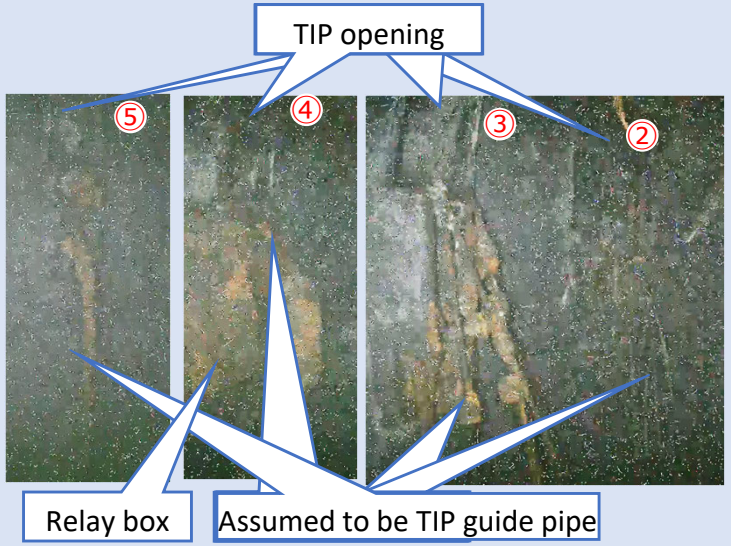


Condition of relay box inside the pedestal (left: around 0°, right: around 180°)

TIP opening



[Prior to the accident: during the construction] TIP opening (around 180°)



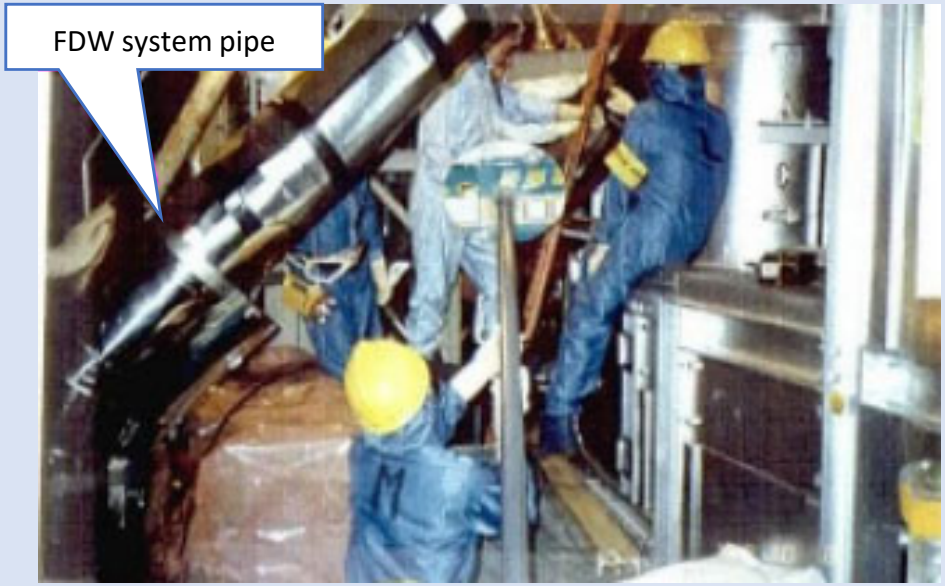
Condition of TIP opening (around 180°)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

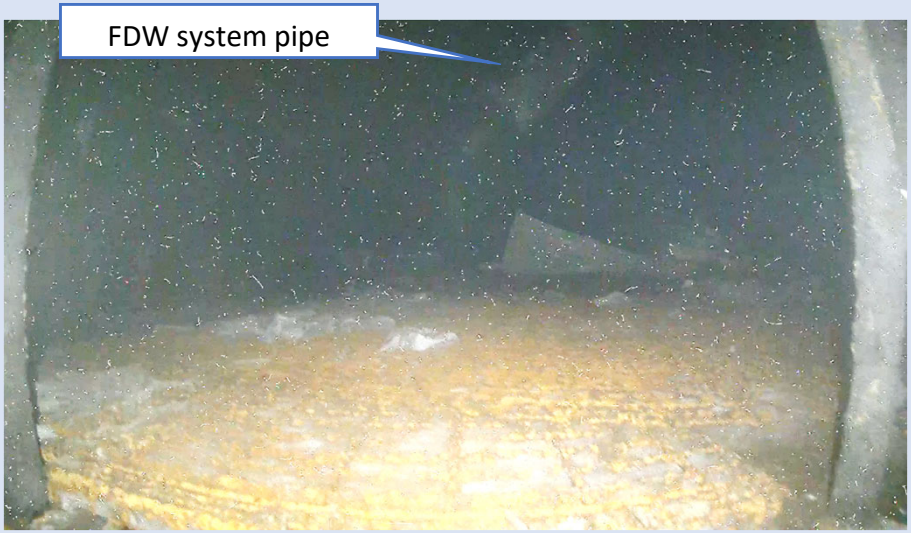
Image processing: Tokyo Electric Power Company Holdings, Inc.

5-2. Comparison with conditions prior to the accident (FDW system pipes, CRD related equipment)

- FDW system pipes outside the pedestal on the second floor

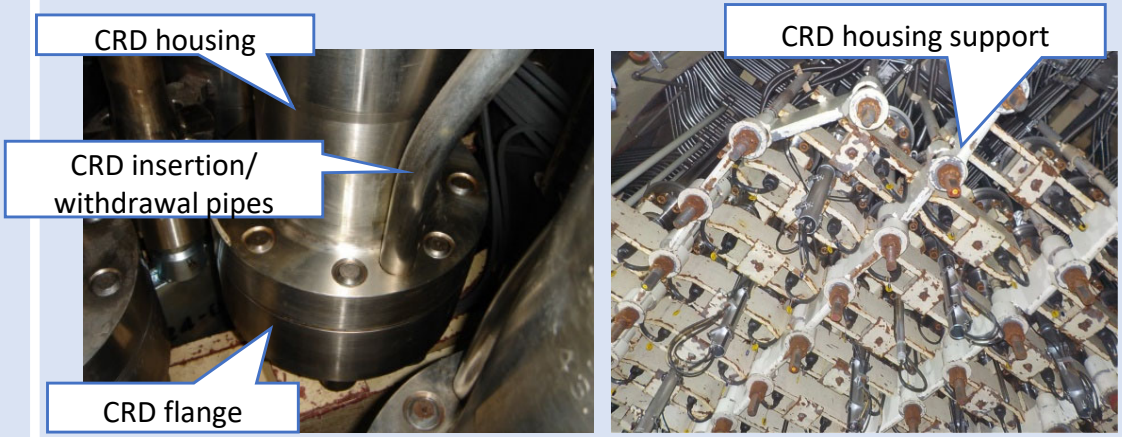


[Prior to the accident: during the periodic inspection] FDW system pipe

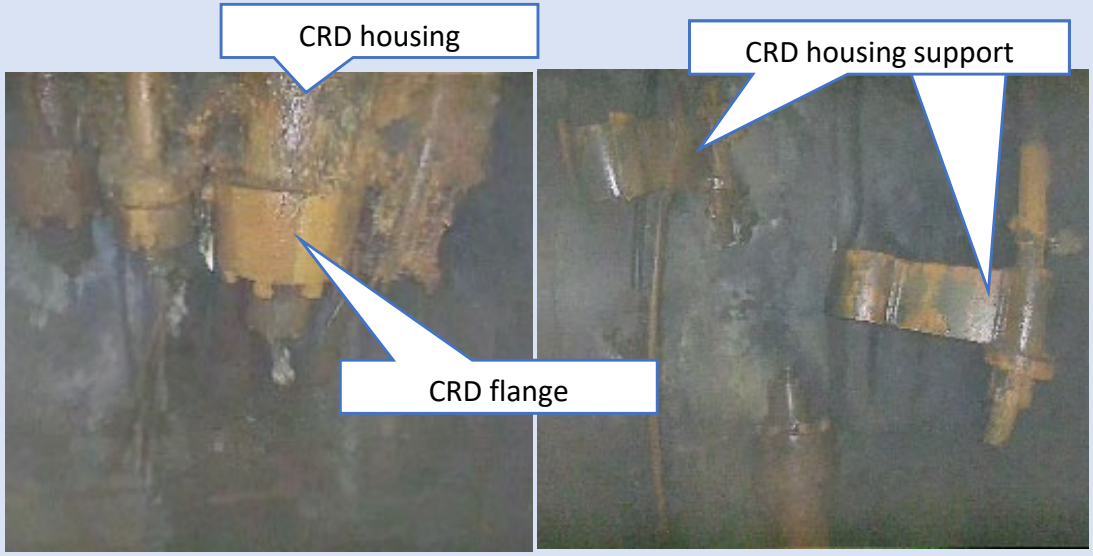


Condition of second floor

- CRD equipment inside the pedestal



CRD related equipment
(left: during the periodic inspection prior to the accident, right: unit 5)



Conditions of the CRD related equipment
(left: housing, right: support)

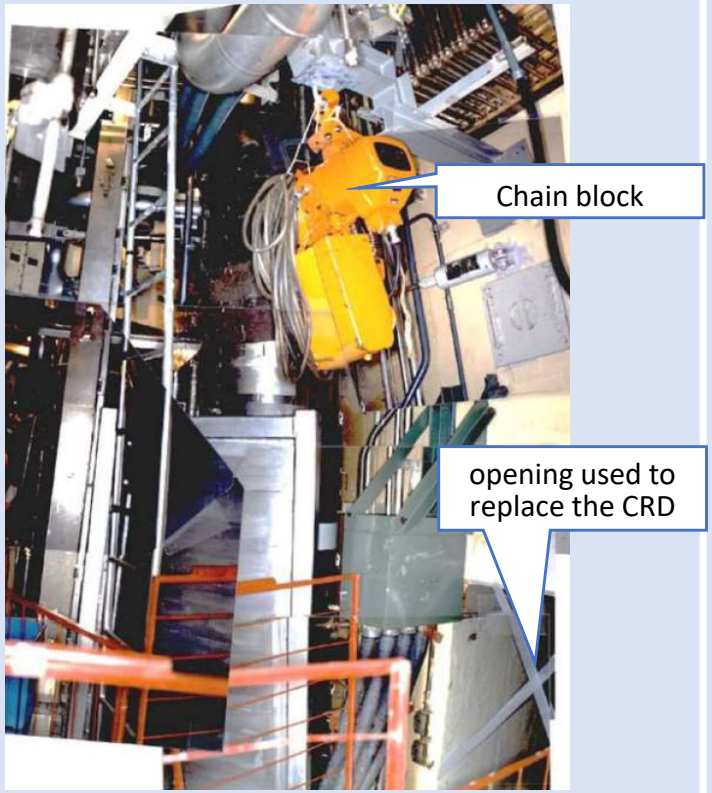
*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: Tokyo Electric Power Company Holdings, Inc.

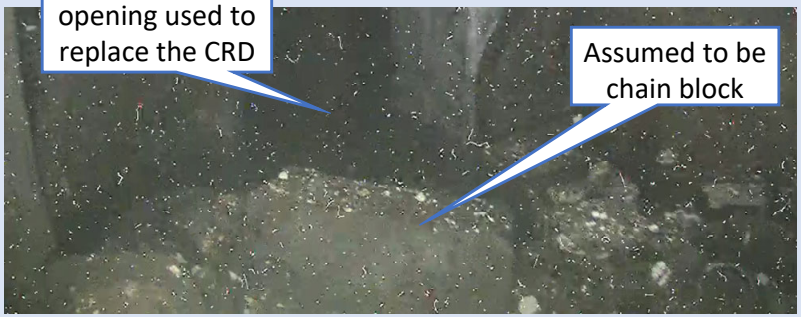
5-3. Comparison with conditions prior to the accident
(Outside the pedestal around the opening used to replace the CRD)

TEPCO

Chain block

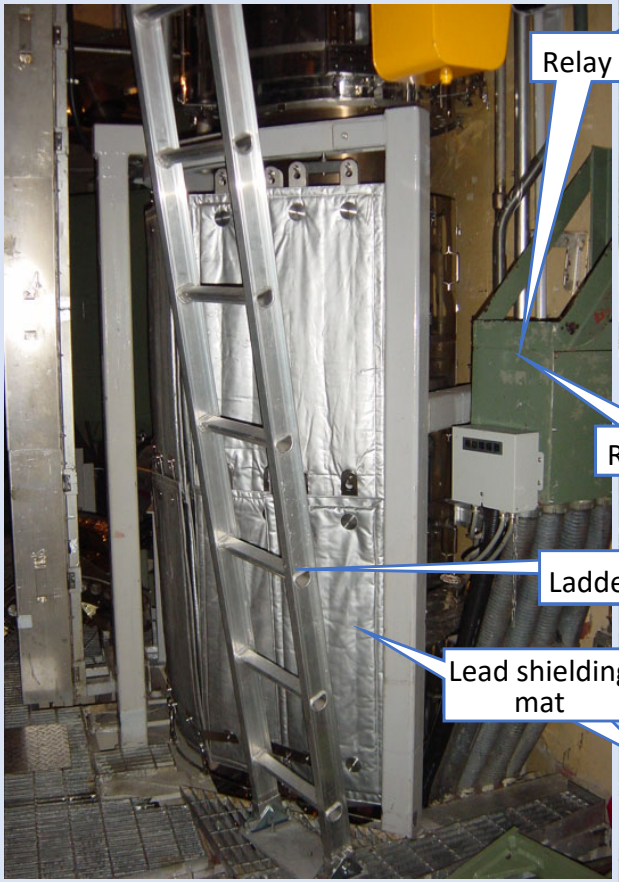


【Prior to the accident: during the periodic inspection】
Chain block in front of opening used to replace the CRD

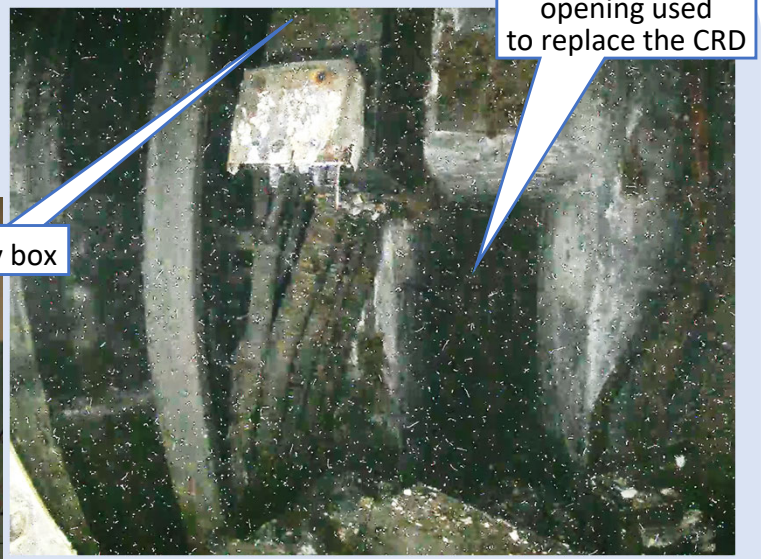


In front of the opening used to replace the CRD (fallen chain block)

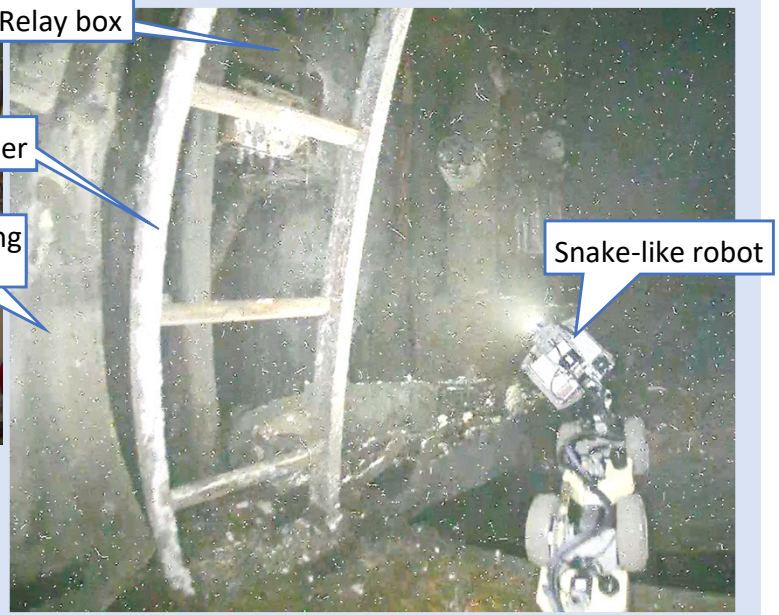
Ladder and relay box



【Prior to the accident: during the periodic inspection】
Ladder and relay box



Condition in front of the opening used to replace the CRD (relay box)



Condition in front of the opening used to replace the CRD (ladder)

*Videos taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

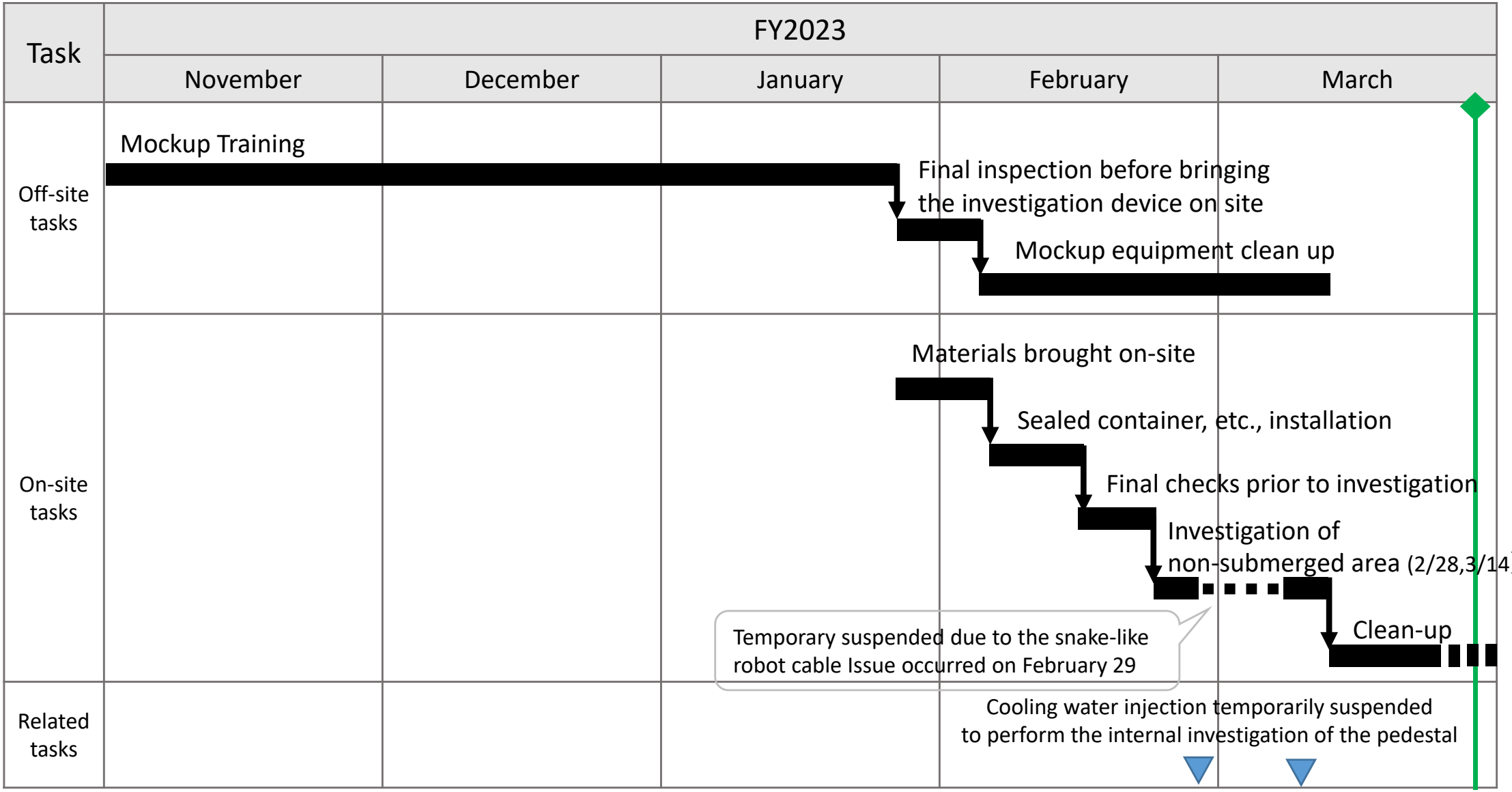
Image processing: Tokyo Electric Power Company Holdings, Inc.

6. Knowledge to be leveraged for future investigations

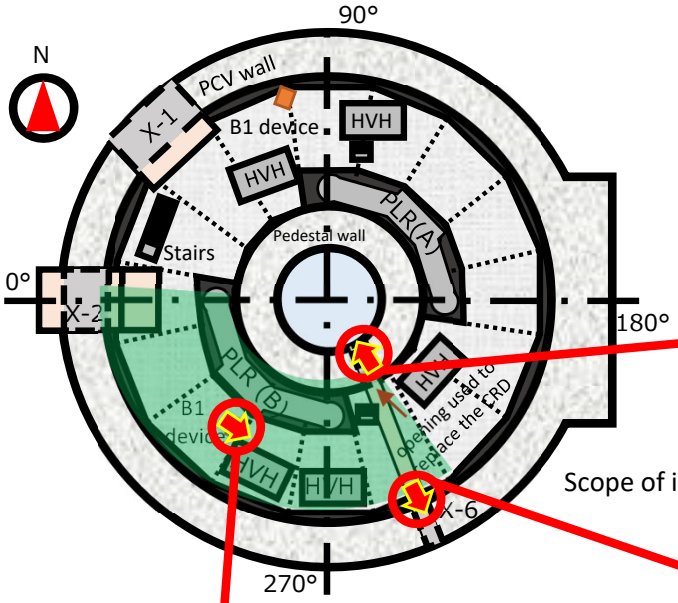
- Since no significant increases were seen in PCV gas management system or operating floor dust monitors during drone flights, we have deemed **the small drones to have a minimal impact on dust dispersion**.
- Since we have found that multiple upper structures assumed to be the CRD related equipment have fallen inside the pedestal, **a method for observing the upper portion will be required in order to use drones in the same way to investigate the area around the bottom of the RPV**.
- We have confirmed that **the stairs near the X-1 penetration can be used to access the area above the second floor**. And, we have confirmed that **the access opening in front of the X-2 penetration that was opened for the submersible ROV investigation, and the ladder leading down to the subfloors, can be used to access the subfloors**.
- The temperature gauge that the drones were equipped with showed **no significant temperature changes within the flightpath during the investigation**.
- We have confirmed that **the drone control signal can be maintained as far as the X-6 penetration if there is a radio relay at the X-2 penetration**. However, communications become unstable when entering the opening used to replace the CRD, so, **as with this investigation, future investigation inside the pedestal will require a radio relay to be positioned in an effective location, such as opening used to replace the CRD.**
- **When performing investigations of non-submerged area, countermeasures need to be implemented for fog** encountered inside the PCV since the fog greatly reduces the performance of the lights, **shortens the visibility distance, and also causes the cameras to fog up.**
- Since the cameras installed on the small drones were not designed to be resistant to radiation**, the image was affected by radiation noise as the drones got closer to the inside of the pedestal. However the drones were not impacted to a degree that prevented flight.**

7. Schedule

- We are examining if field data can be generated from the videos obtained from this internal investigation to make 3-D maps.
- Future PCV internal investigation will be planned in light of the effectiveness of small drone.



[Reference] Investigation results from the south side outside the pedestal (Drone #1)



Unit 1 PCV interior first-floor schematic

Scope of investigation:

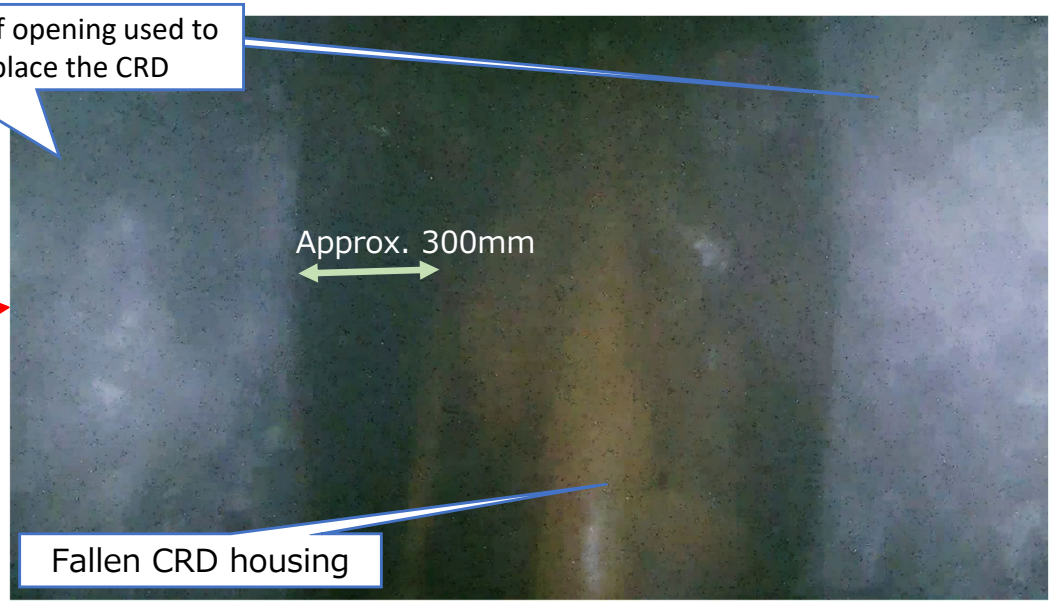


Photo 1. Condition of opening used to replace the CRD (after compensating for the flickering)

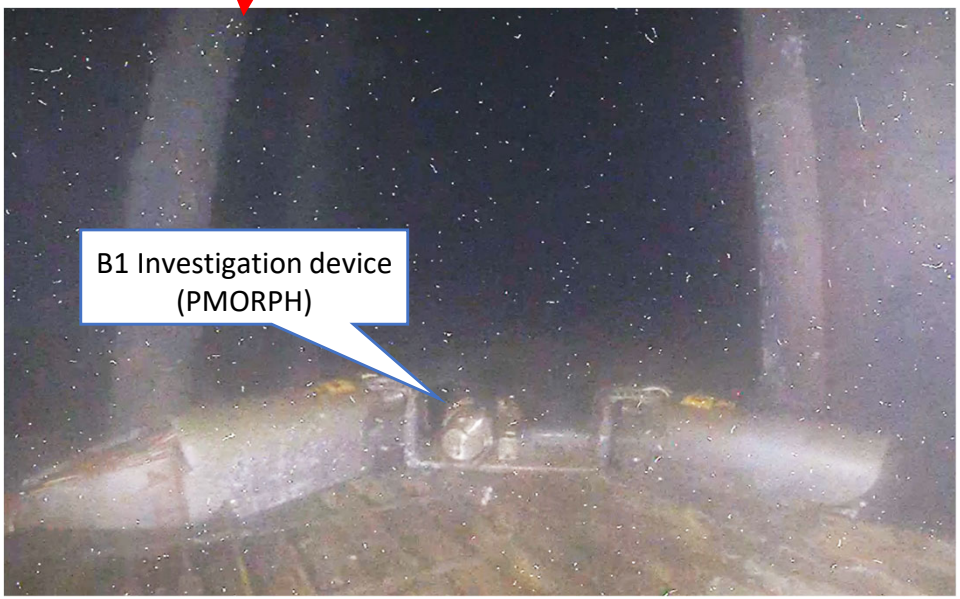


Photo 2. remains of B1 investigation device (PMORPH) on south side

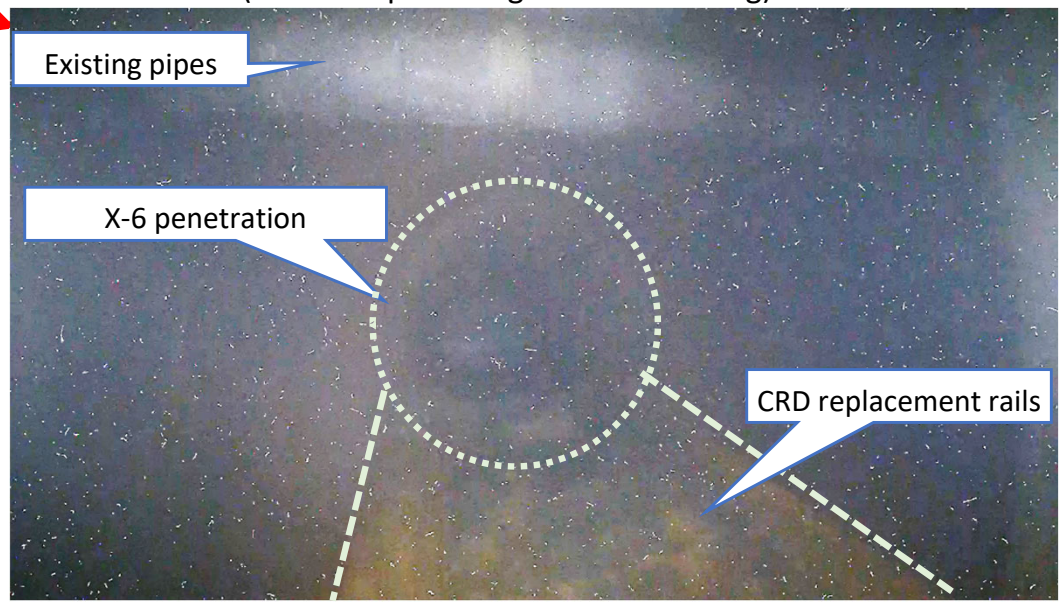
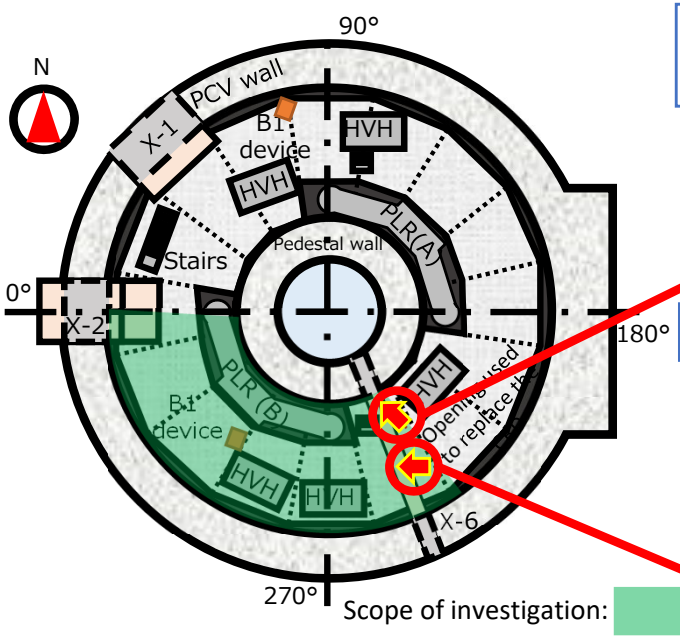


Photo 3. X-6 penetration condition

※ Video taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: TEPCO Holdings, Inc.

[Reference] Investigation results from the south side outside the pedestal (Drone #1)



Unit 1 PCV interior first-floor schematic

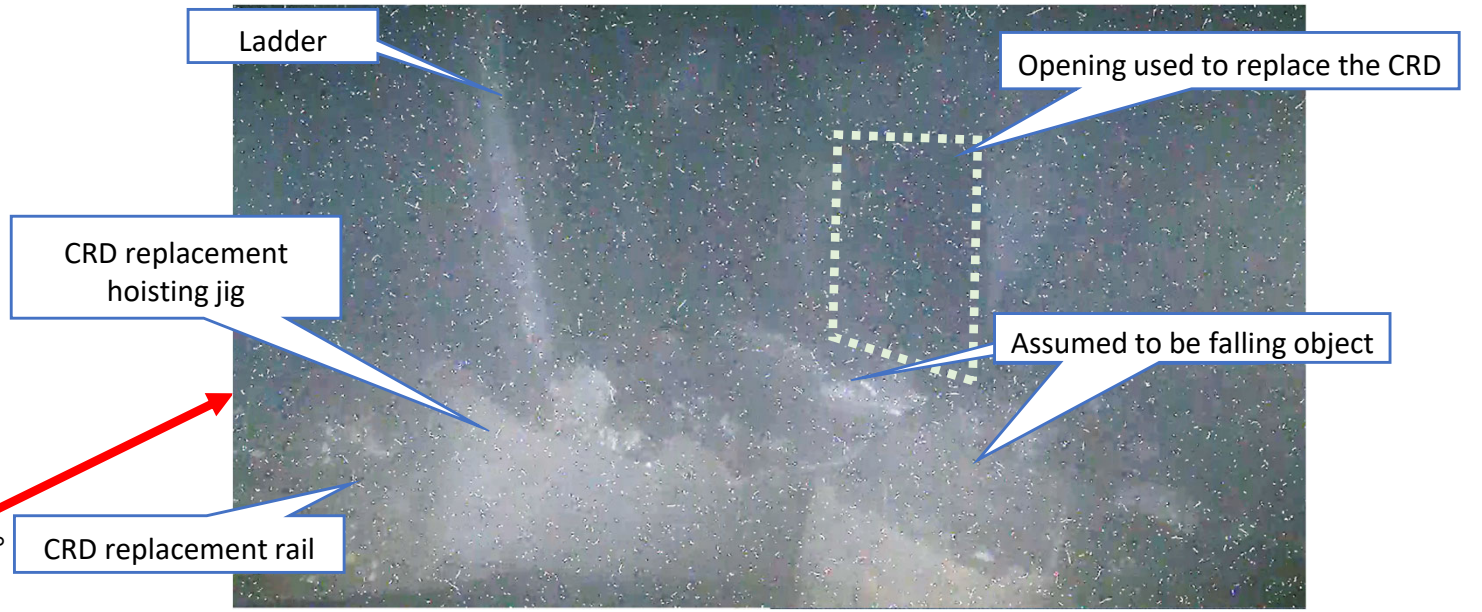


Photo 1. CRD replacement rails condition ①

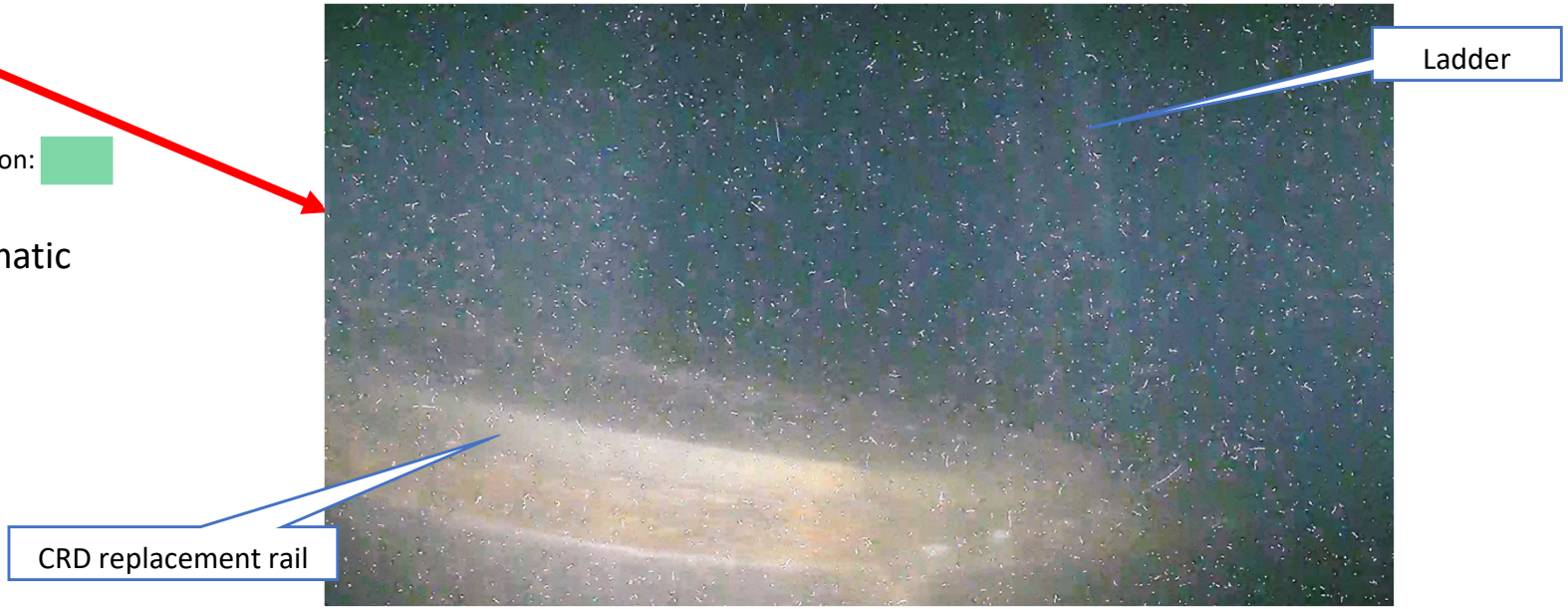
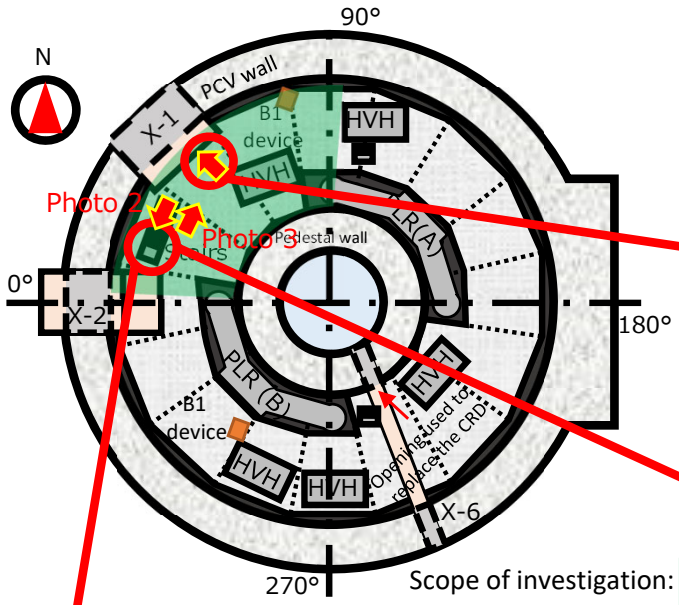


Photo 2. CRD replacement rail condition ②

※ Video taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: TEPCO Holdings, Inc.

[Reference] Investigation results from the north side outside the pedestal (Drone #2)



Unit 1 PCV interior first-floor schematic

Photo 1. X-1 penetration condition

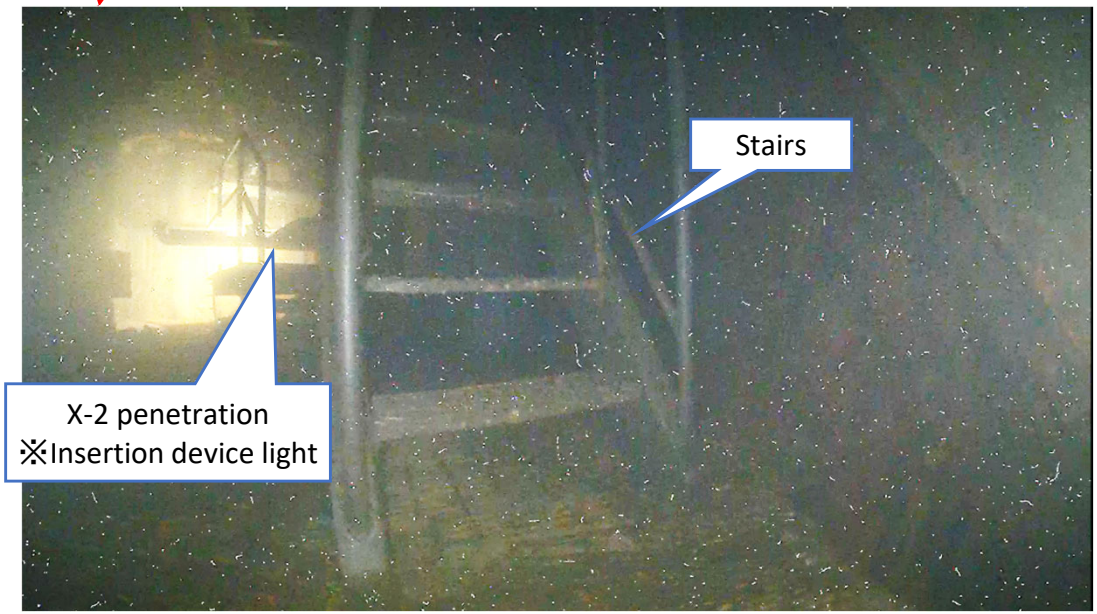


Photo 2. Condition of stairs

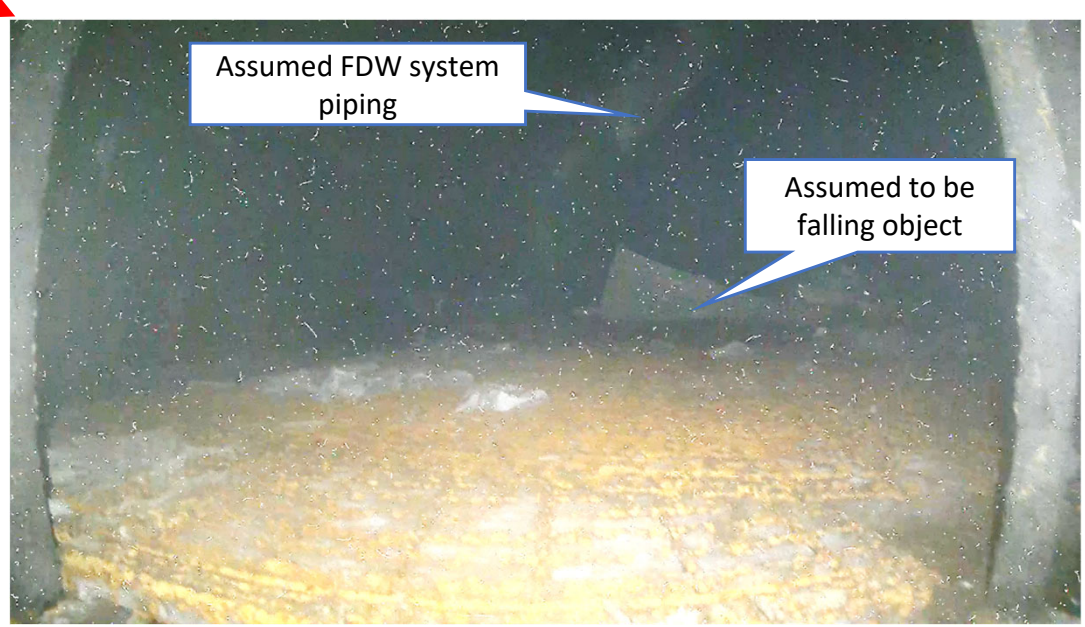
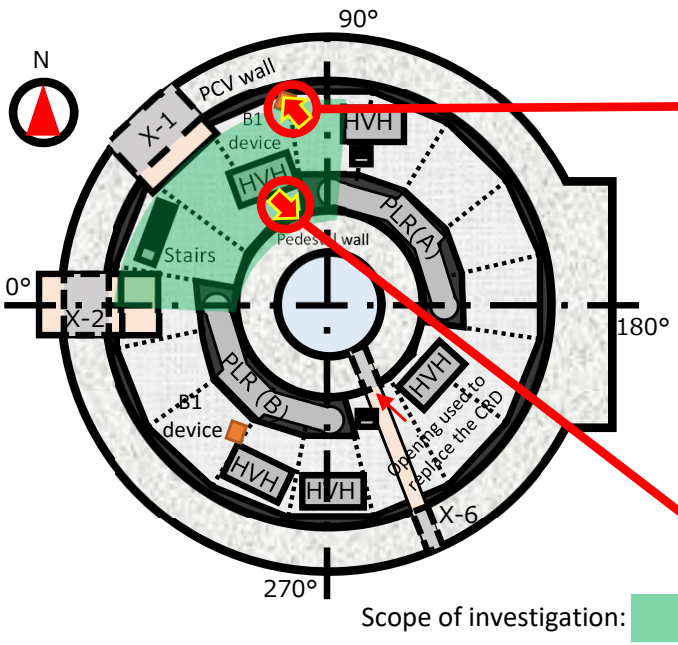


Photo 3. 2FL condition

※ Video taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: TEPCO Holdings, Inc.

[Reference] Investigation results from the north side outside the pedestal (Drone #2)



Unit 1 PCV interior first-floor schematic

Photo 1. Remains of B1 investigation device (PMORPH) on north side

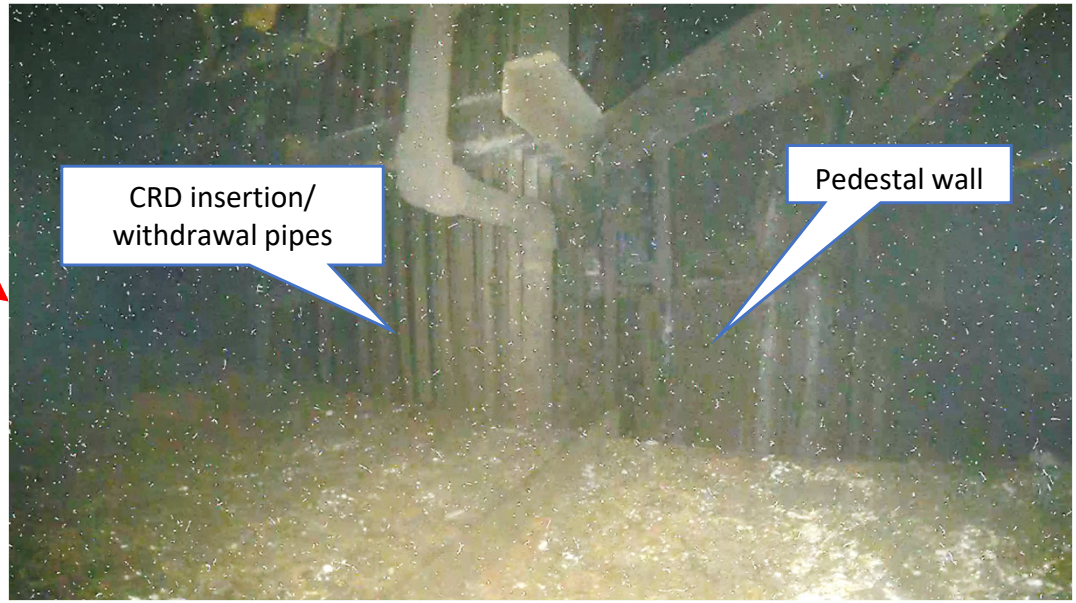


Photo 2. condition of CRD insertion/withdrawal pipes

※ Video taken inside the PCV flickers due to radiation and appears foggy due to moisture (fog)

Image processing: TEPCO Holdings, Inc.

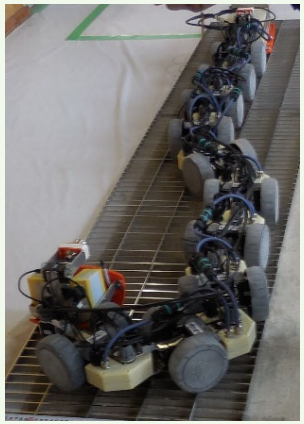
[Reference] Investigation devices

- Since the space inside the PCV is dark and cramped, **small drones** like the ones shown below that are tiny, maneuverable, and can take excellent photographs/videos are employed.
- Since high resolution photographs/videos can be taken, field data can be generated from these videos to make 3-D maps of the inside of the PCV (structure from motion technology).
- **A snake-like robot with wireless communications relays** is employed in order to cover the entire wireless communications area of the small drones
- As with the submersible ROV investigation**, an isolation chamber is connected to the X-2 penetration** thereby allowing the small drones and snake-like robot to be employed into the PCV while keeping the PCV isolated.

Small drone

Use: Photography
Dimensions: 191×179×54[mm]
Weight: 185[g](Including battery)
Communication method: wireless
Flight time: Approx. 8 min. (Investigation will consist of four 5-min. flights.)
Installed equipment: lights (90lm(45lm×2)),
ultra-high-sensitivity camera (front only)
Camera specifications
・Resolution: Full HD
・Vie angle: Horizontal: 131° Vertical: 80° Diagonal: 144°
・Range: Approx. 3m
・Frame rate: 60fps
Radiation resistance: Approx. 150Gy
Reasons for selection: Small, highly maneuverable in cramped spaces and can take highly detailed photographs/video

Wireless communications relay snake-like robot

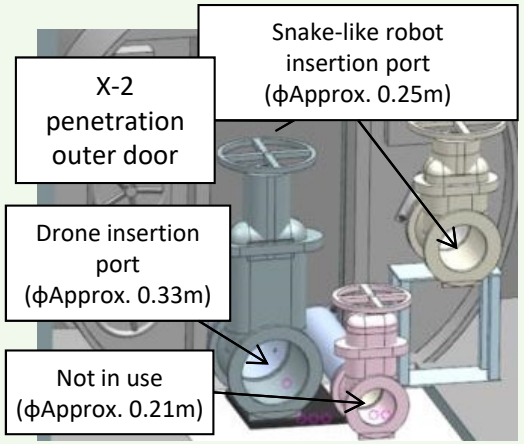


Snake-like robot

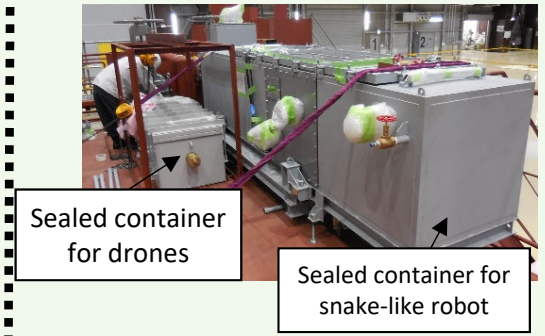
Testing to see how it climbs through from the X-2 penetration

Use: Carry wireless communications relays and take dose measurements
Dimensions: 2,900×180×165[mm]
Weight: Approx. 25[kg]
Communication method: wired
Installed equipment: Drone wireless communications relays, CMOS cameras (2), dosimeter
Radiation resistance: Approx. 249Gy
Reasons for selection: Can climb over the X-2 penetration railing and up the grating

Sealed container



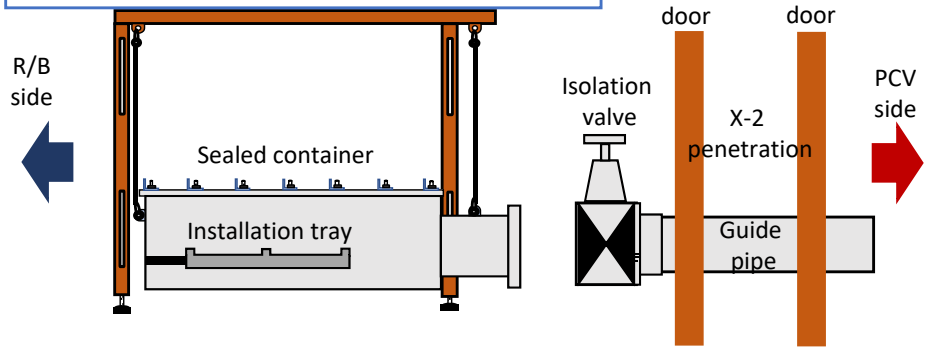
X-2 Penetration isolation valve usage diagram



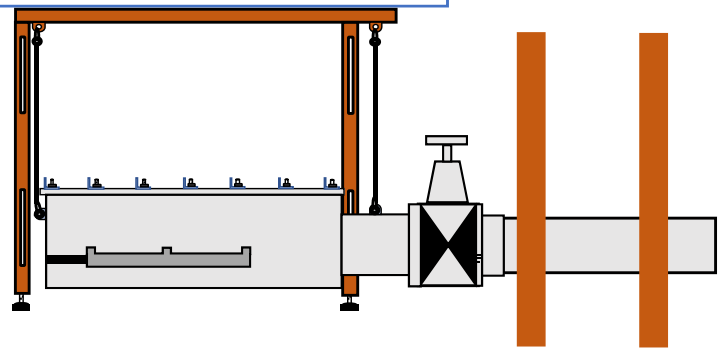
Sealed container installation mock-up

[Reference] Primary work steps

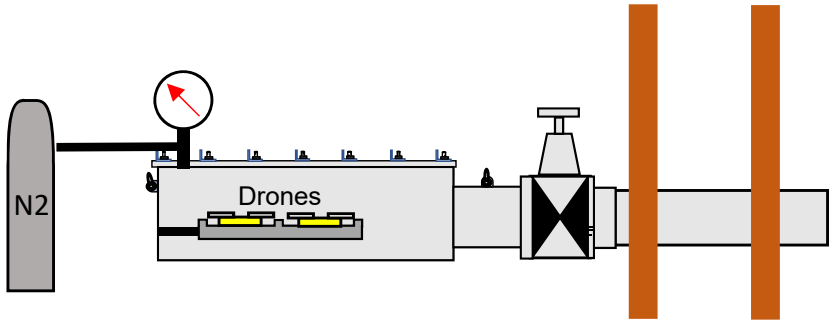
① Sealed container positioning



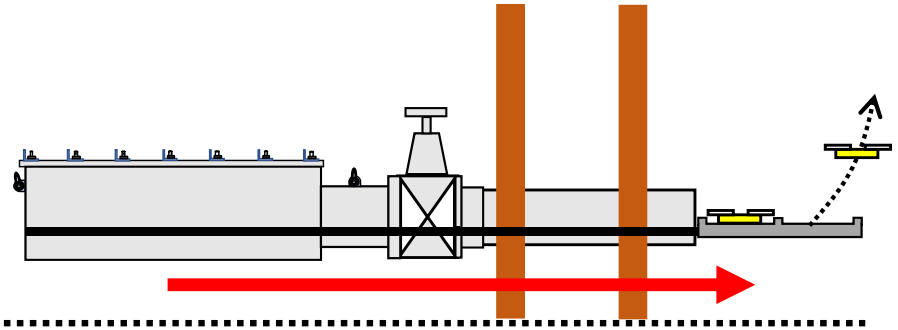
② Sealed container coupling



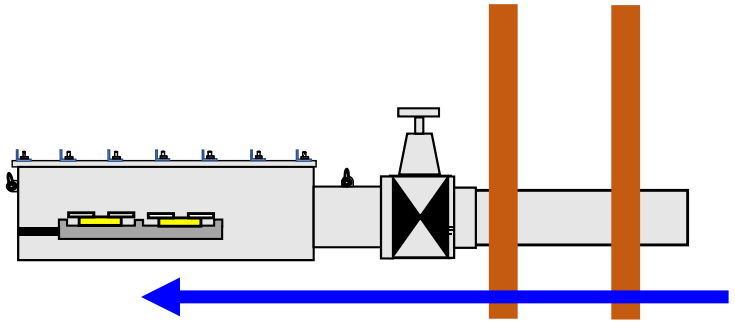
③ Investigation devices put in sealed container, leak check



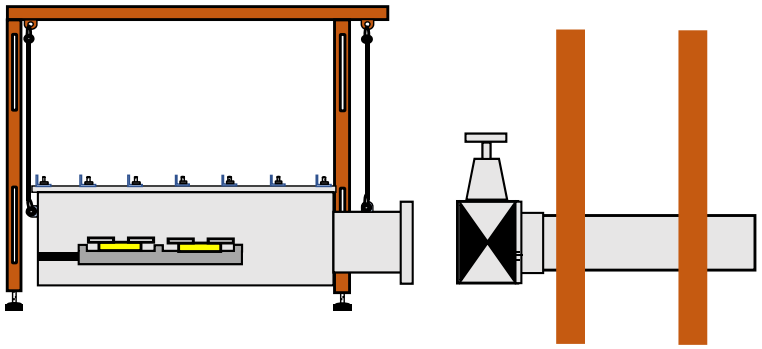
④ Investigation device insertion ⇒ Snake-like robot relocation ⇒ Drone flight



⑤ Investigation device recovery



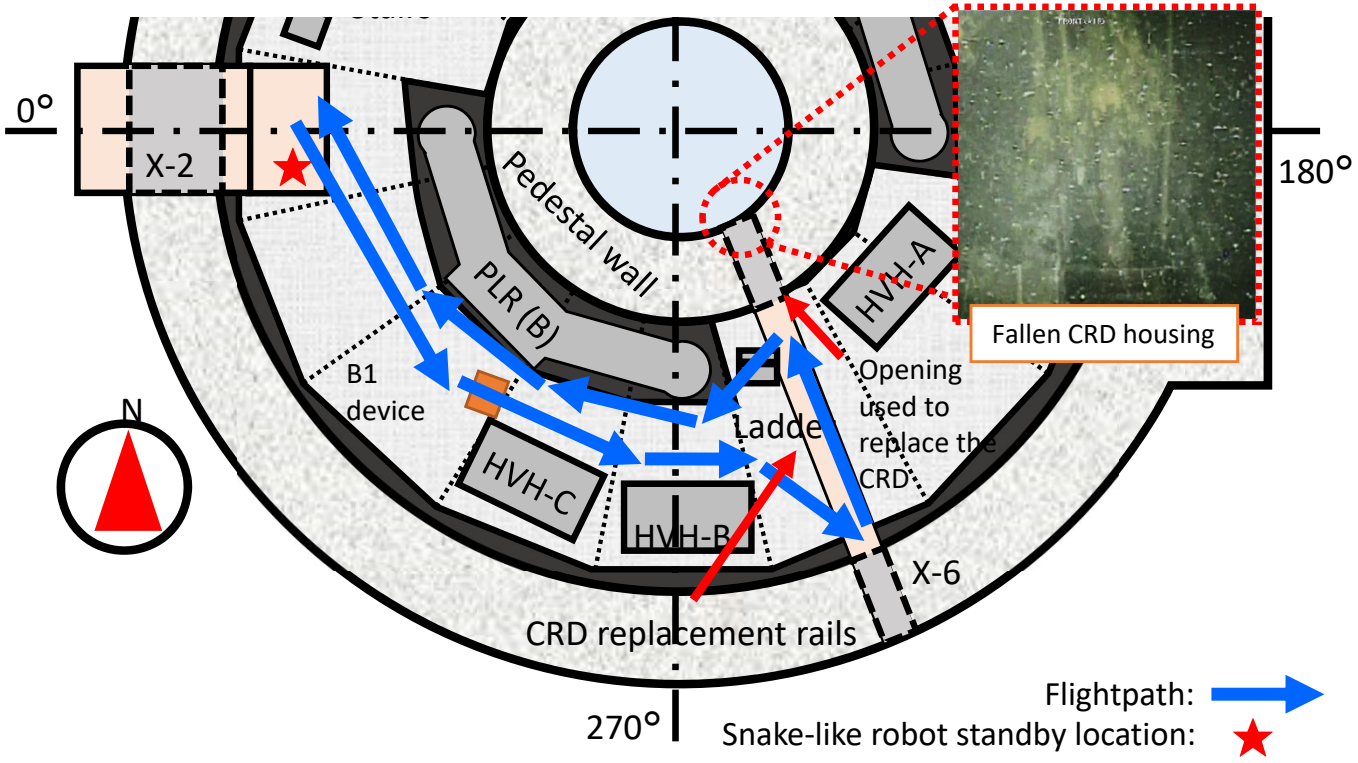
⑥ Sealed container decoupling



＊2 sealed containers are used for this work, but both of the configuration are similar so the diagram of the sealed container for snake-like robot has been omitted in this concept diagram.
Furthermore, whereas the snake-like robot is housed inside the sealed container when it is positioned, the drones are put in on the day of the investigation after they have been fully charged.

[Reference] Planned investigation route (Outside the pedestal on the south side)

- The south side of the outside of the pedestal will be investigated using the drone #1.
  - Investigation target: X-6 penetration, opening used to replace the CRD, CRD replacement rails, other existing equipment.
  - Snake-like robot relays radio signals from in front of the X-2 penetration.
  - Since the snake-like robot will move to the position of the CRD replacement rails during the internal investigation of the pedestal, we must confirm that there are no obstructions along its route of movement (such as objects that have fallen onto the grating, leftover device from the B1 investigation, etc.)
  - Since the CRD housing that fell around the opening used to replace the CRD (discovered during the submersible ROV investigation) is on the flight path of the pedestal internal investigation, we must check the position of the housing to determine whether it is possible to implement the pedestal internal investigation.



Enlarged view of the south side of the Unit 1 PCV first floor diagram

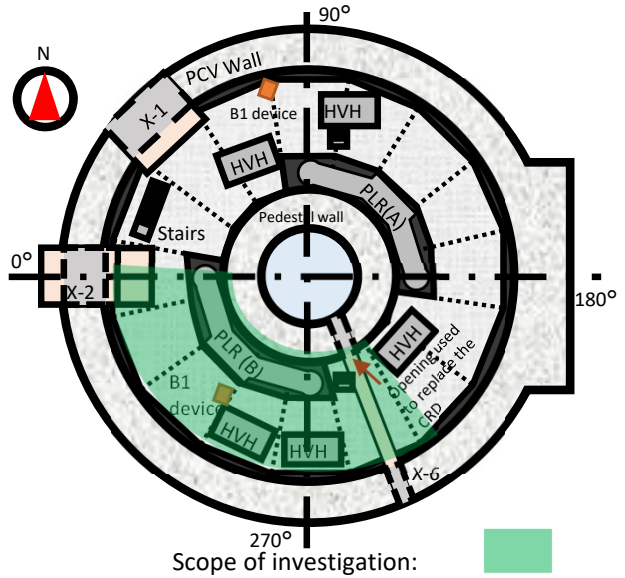
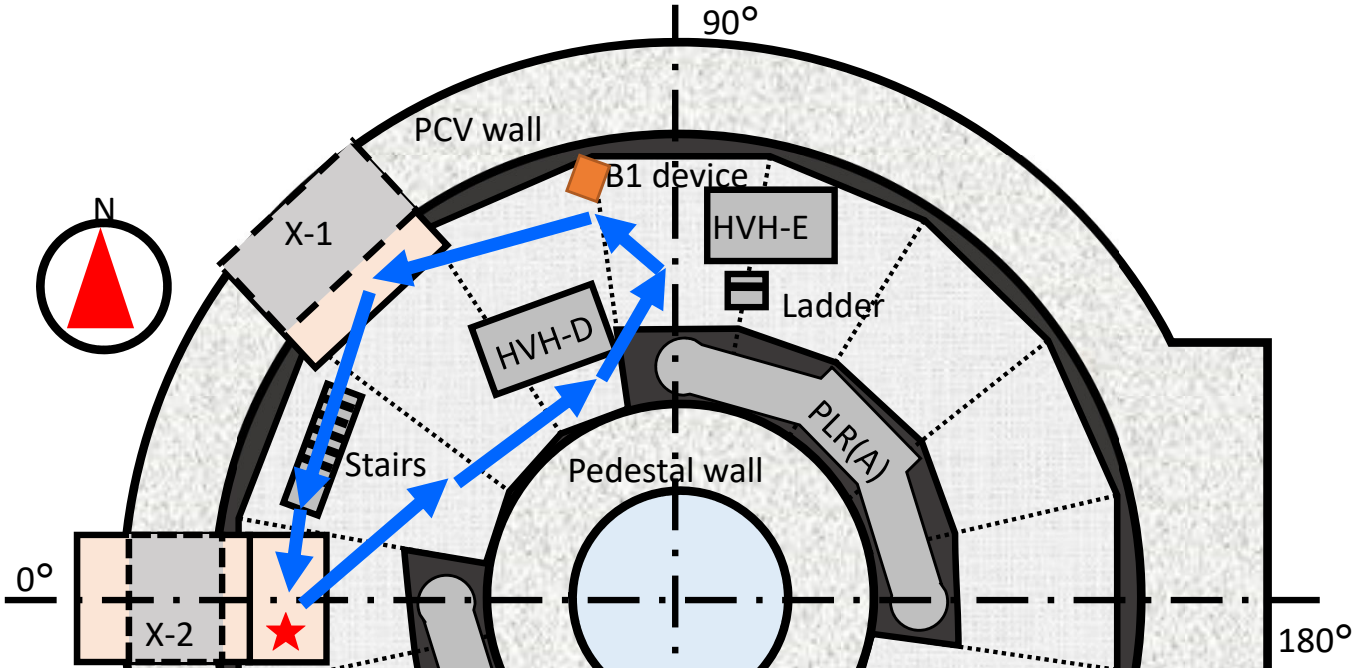


Diagram of the entire first floor inside the Unit 1 PCV

＊Flightpath and investigation targets may be changed depending on field conditions

[Reference] Planned investigation route (Outside the pedestal on the north side)

- The north side of the outside of the pedestal will be investigated using the drone #2.
  - Investigation target: X-1 penetration, stairs, other existing equipment.
  - Snake-like robot relays radio signals from in front of the X-2 penetration.
  - When investigating the stairs, the drone will be flown up as high as possible to see if the second floor is accessible .
  - If the opening used to replace the CRD was not fully investigated using the first drone, this drone will investigate the south side of the pedestal again (to enable the internal investigation of the pedestal to be conducted by the drones #3 and #4).



Snake-like robot standby location: ★ Flightpath: →

Enlarged view of the north side of the Unit 1 PCV first floor diagram

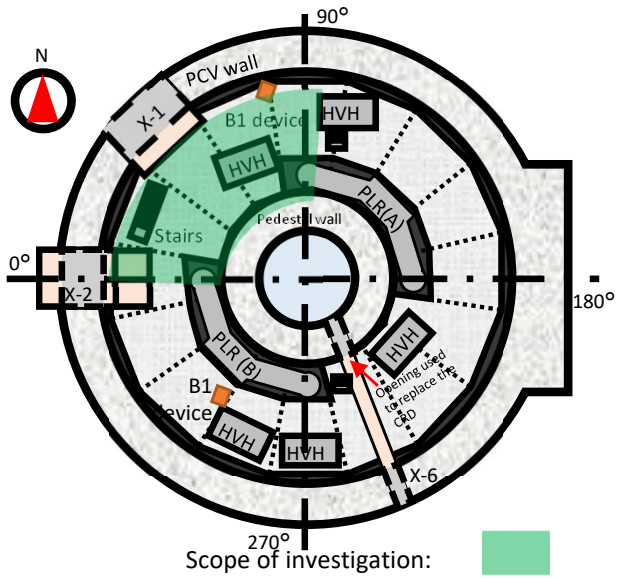


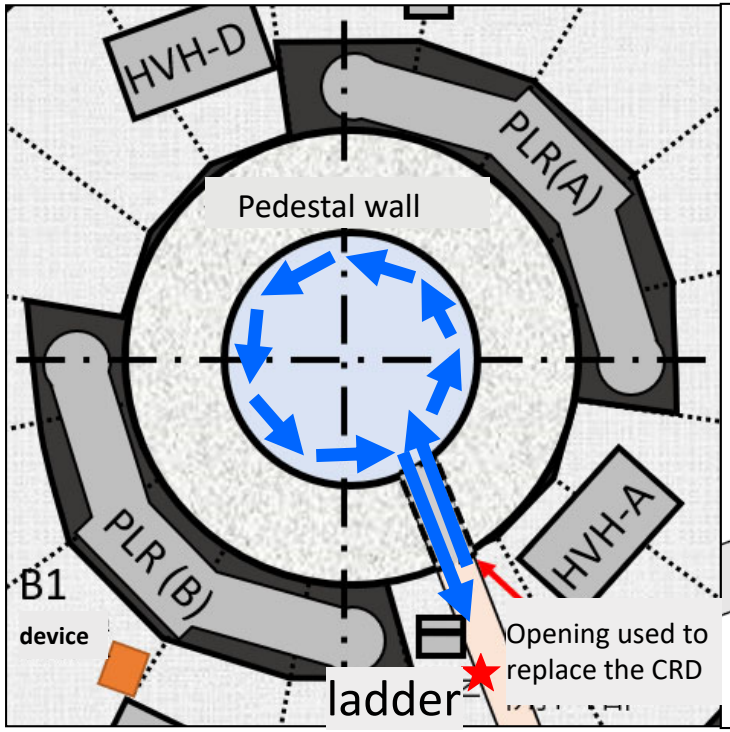
Diagram of the entire first floor inside the Unit 1 PCV

＊Flightpath and investigation targets may be changed depending on field conditions

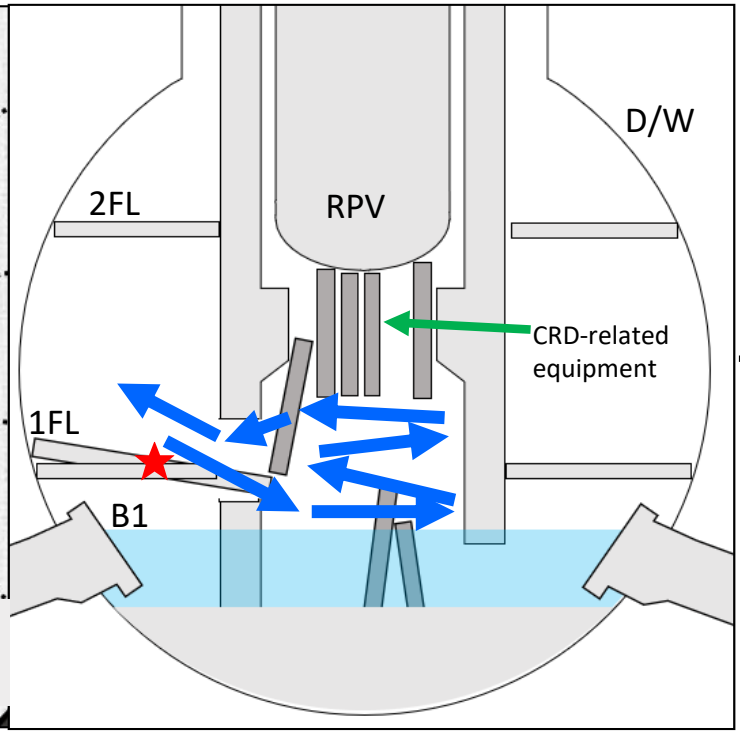
[Reference] Planned investigation route (Inside the pedestal)

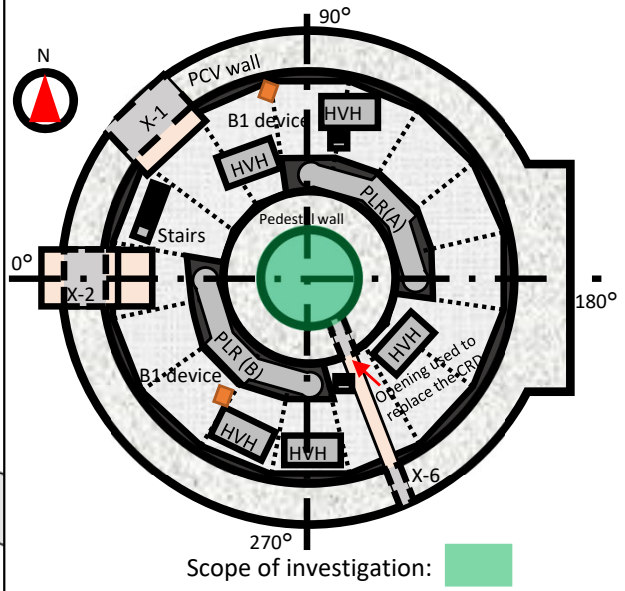
- The investigation of the inside of the pedestal will be conducted using the drones #3 and #4.
  - Investigation target: Inner walls of the pedestal, internal structures of the pedestal, and condition of the fallen CRD housing.
  - Snake-like robot relays radio signals from around the CRD replacement rails.
  - The drone #3 will be used to take as much footage of the inside of the pedestal as possible, and the drone #4 will be used to photograph places of interest found with the drone #3.
  - Upper structures will be photographed as much as possible, but since the camera is attached to the front of the drone, it will not be able to take pictures directly above it.

Horizontal cross-section



Vertical cross-section





Scope of investigation:

Diagram of the entire first floor inside the Unit 1 PCV

Snake-like robot standby location: ★ Flightpath: →

Enlarged view of the inside of the pedestal in the Unit 1 PCV first floor diagram

＊Flightpath and investigation targets may be changed depending on field conditions

Partially revised document from the meeting of the Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water (April 30, 2015)

[Reference] Location of the remains of the B1 investigation device

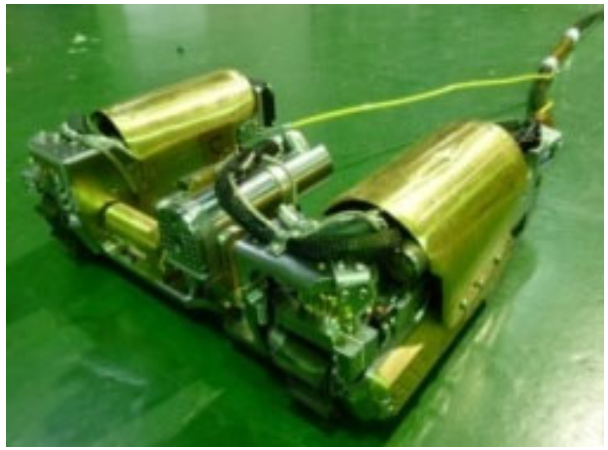
TEPCO

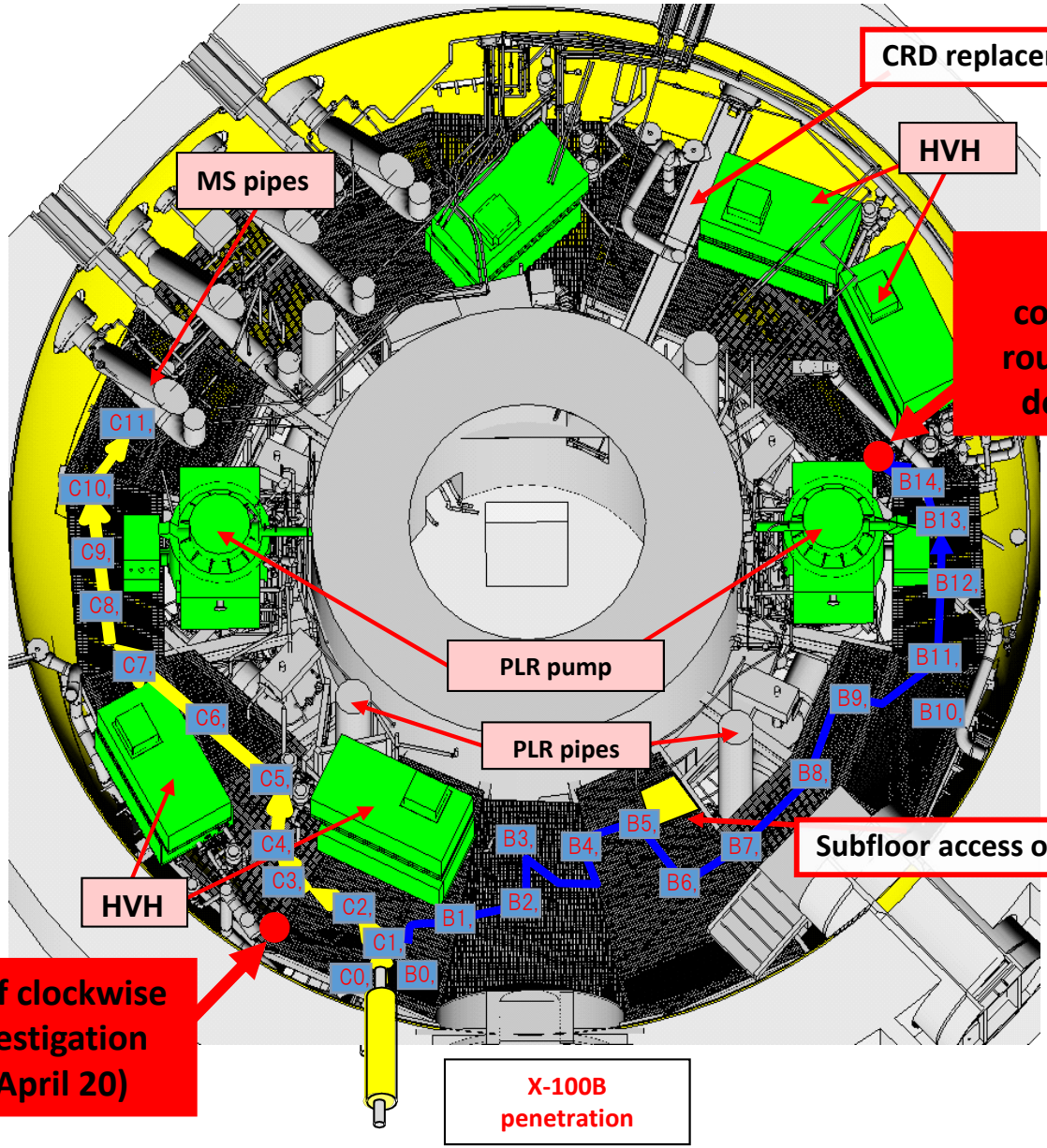
- During the investigation of the grating on the first floor outside the pedestal implemented in April 2015 (B1 investigation), two investigation devices were remained.

→ : Verified access route (counterclockwise route)

→ : Verified access route (clockwise route)

Investigation device





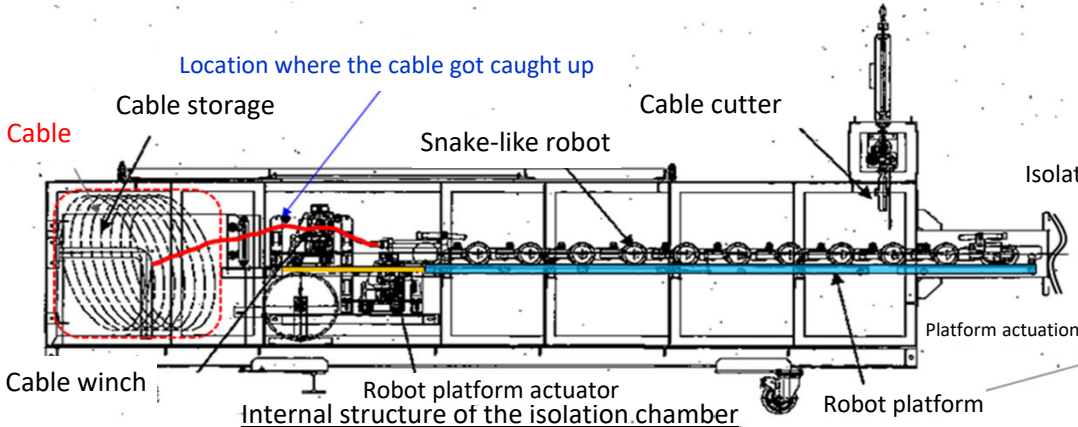
[Reference] Fukushima Daiichi Nuclear Power Station
Unit 1 Primary Containment Vessel Internal Investigation (Non-submerged area)
Causes and Countermeasures for Snake-like Robot Cable Issues

- On February 28, a small drone was used to perform an investigation of non-submerged area outside the pedestal of the Unit 1 primary containment vessel (hereinafter referred to as, "PCV") (first day of the investigation). During this investigation, we observed the condition of the PCV penetration (X-6 penetration), and the opening used to replace the control rod drive (CRD) and rails, etc. We have yet to see any substantial damage to equipment or structures within the scope that the investigation was conducted.
- During the internal investigation planned on February 29 (second day of the investigation), the snake-like robot was unable to reach the CRD replacement rails as intended due to issues with paying out the cable.
- As a result, the small drone investigation of the pedestal that was originally planned for February 29 will be performed after implementing countermeasures.

＜Announced as of March 7＞

- After investigating the reason why we were not able to pay out the cable for the snake-like robot it was found that when the cable was being paid out, part of it wrapped around the installation bracket for the guide roller※ inside the sealed container thereby preventing the cable from being paid out to the PCV.
- Now that we have confirmed by March 8 that recurrence prevention measures are effective, we will implement the pedestal internal investigation using the small drones on March 14.
- We will move forward safely and carefully with these tasks so as to not impact the surrounding environment

※ Guide roller ：A roller that secures and guides the route from the cable storage to the cable winch.



Internal structure of the isolation chamber (with the snake-like robot housed inside)

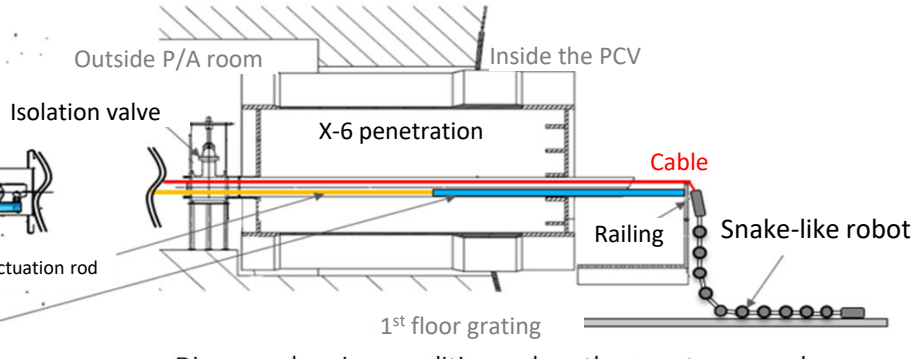
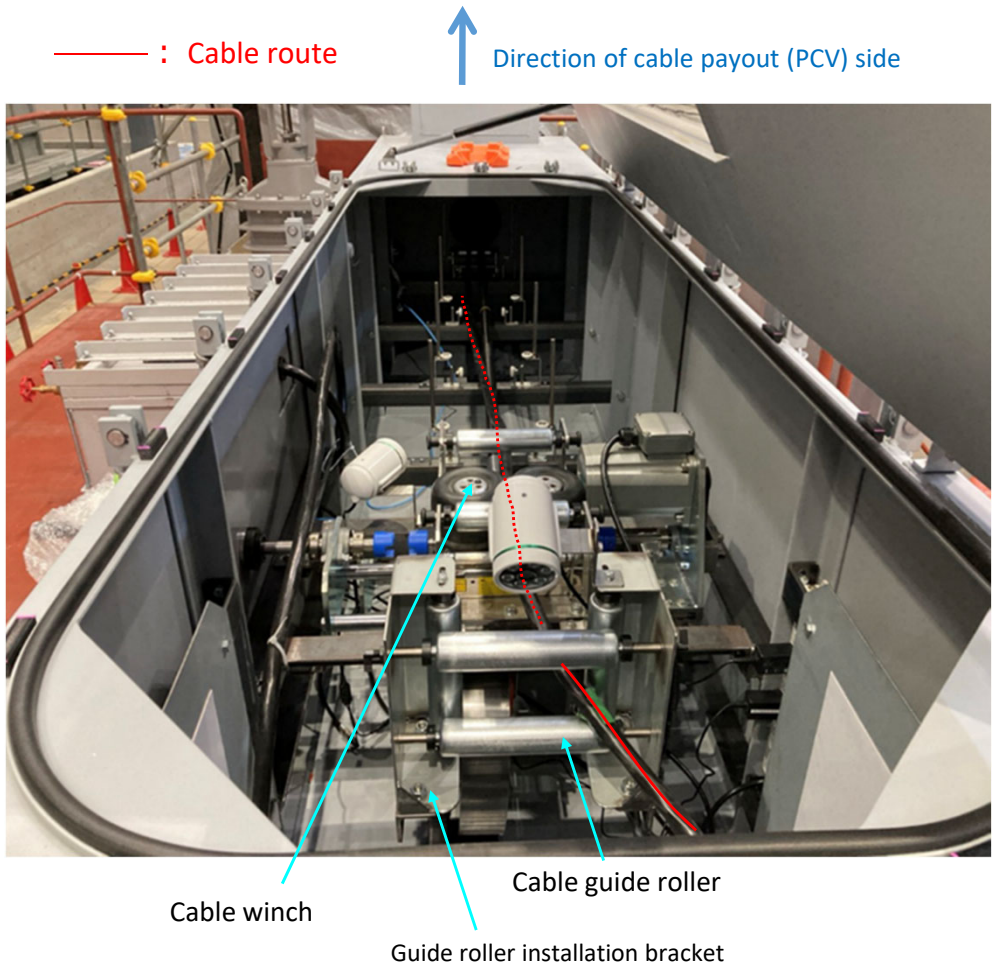


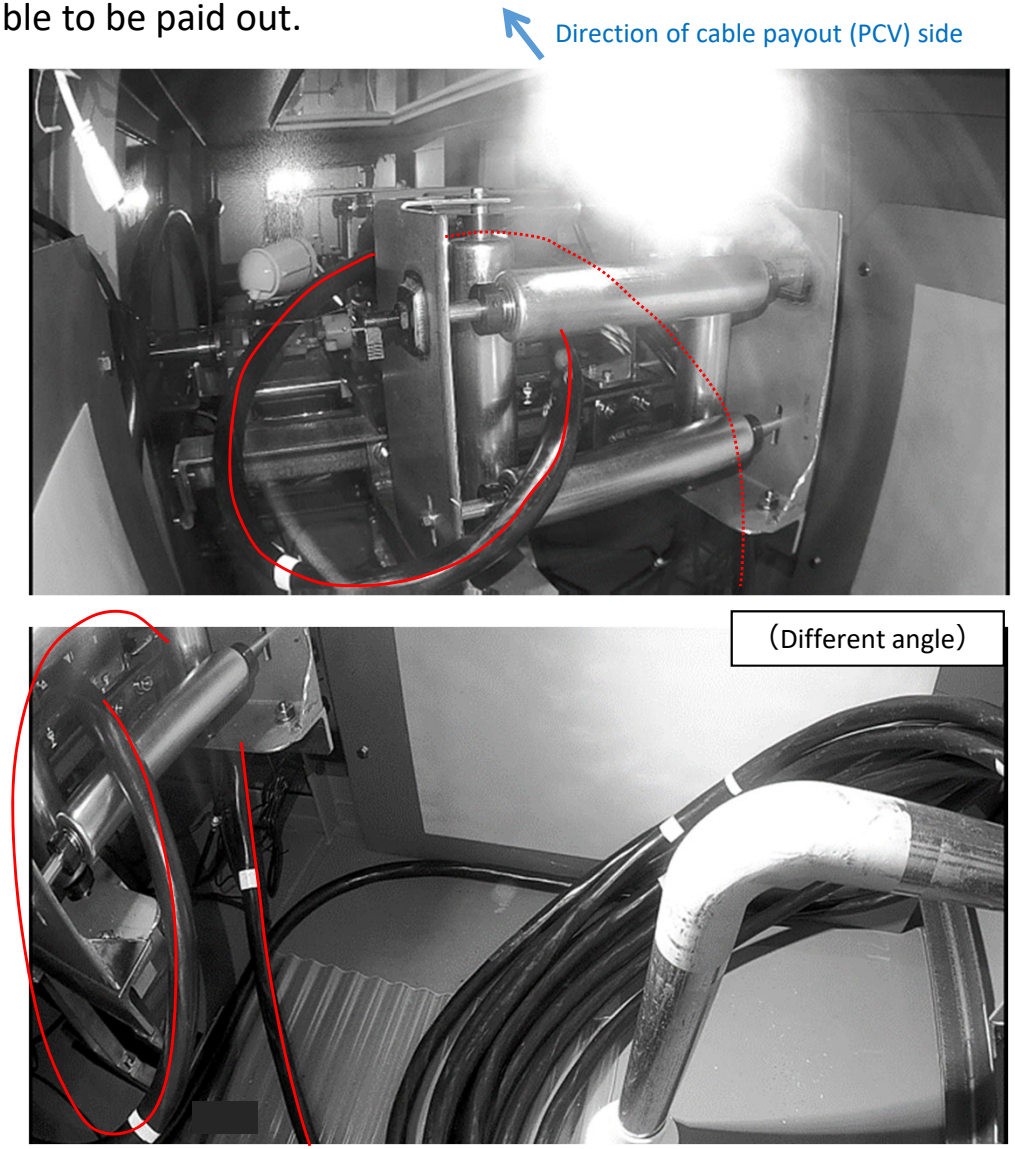
Diagram showing conditions when the event occurred

[Reference] Causes (Cable conditions when the event occurred)

- Usually, cable is routed through guide roller to the cable winch.
- In this case, cable route was different from the normal route due to the flexure in the cable. As a result, cable was caught in the installation bracket for the guide roller, unable to be paid out.



Normal conditions (photo taken during the mockup)



Conditions when event occurred

[Reference] Recurrence prevention measures

■ Although no similar cases have been observed in previous mockups, we will implement following measures to prevent recurrence.

① **Cable recoiling**

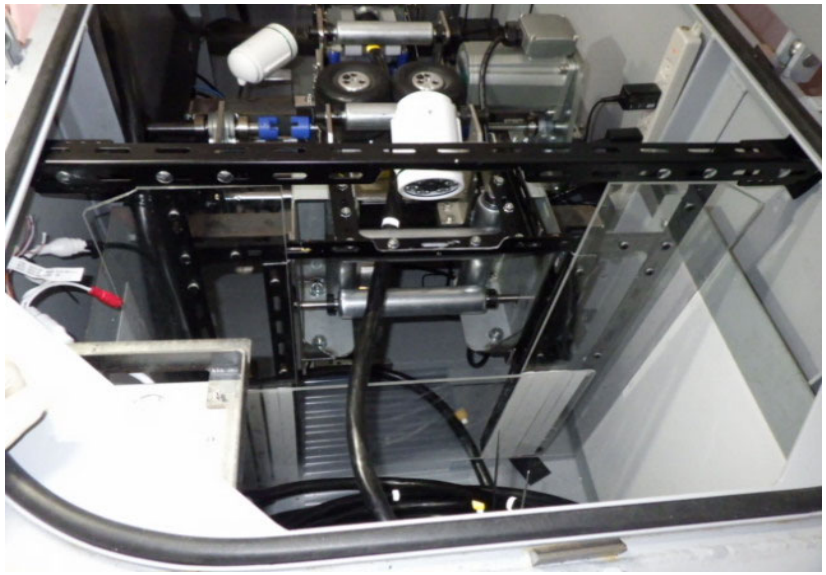
Since it is getting more probable that the cable will take a different route when paid out repeatedly, the cable will be recoiled to reduce the possibility of it taking a different cable route.

② **Restricting the range of mobility of the cable**

A guard panel will be installed to restrict the range of mobility of the cable to prevent it from getting caught up on, or wrapping around, the guide roller installation bracket even if the cable behave differently than normal.

③ **Strengthening monitoring of abnormal behavior and clarifying procedures for handling issues**

While the cable has always been monitored by cameras, we will add additional monitoring personnel who monitor only the cameras in order to strengthen monitoring of cable conditions and quickly detect signs of abnormalities. Furthermore, if signs of abnormalities are noticed, the instruction to halt the operation is given, and the procedures is clarified so that the cable winch is operated in a way that improves the situation.



After the installment of the guard panel

[Reference] Future internal investigation schedule

- **Investigations of non-submerged area**
  - Investigation of non-submerged area using small drones. Future investigations will be expanded to other units in light of the investigation results during FY2023.
- **Deposit sampling investigation**
  - Plan that samples and analyzes the various types of deposits found during the submersible ROV investigations
- **Vent pipe and S/C investigation**
  - Investigation based on the submersible ROV investigation results to see whether vent pipes and the suppression chamber have been covered with deposits

Investigation	FY2023	After FY2024
Investigations of non-submerged area	Investigation	Improve/review → Investigation (second time) → Schedule adjusted based on investigation results, review and mockup tests
Deposit sampling investigation	Review, design and manufacturing, mockup, training	Sampling investigation → Analysis
Vent pipe and suppression chamber investigation	Review, design and manufacturing, mockup, training	Suppression chamber and vent pipe internal investigation