Unit 1 PCV Internal Investigation (Non-submerged area)

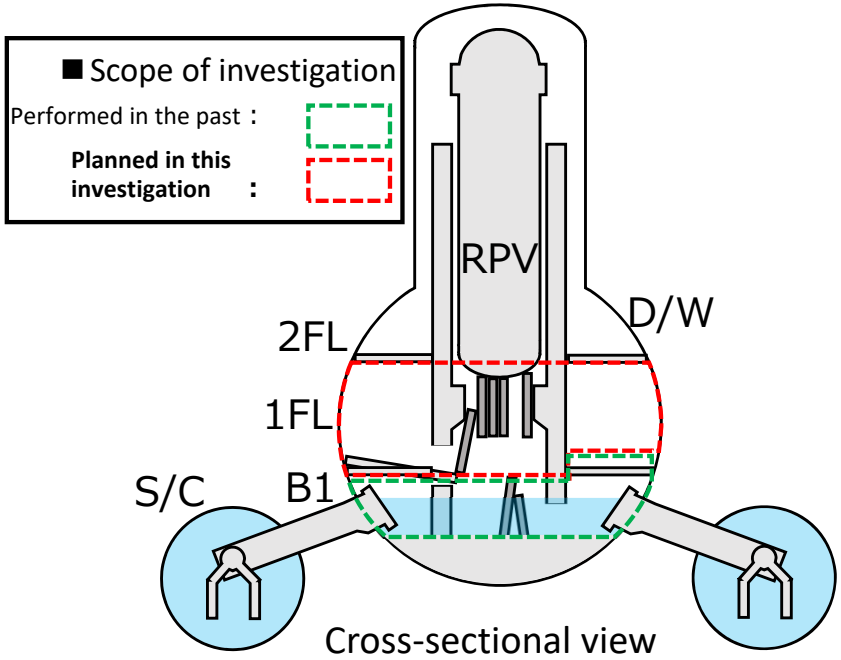
February 29, 2024

TEPCO

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.**

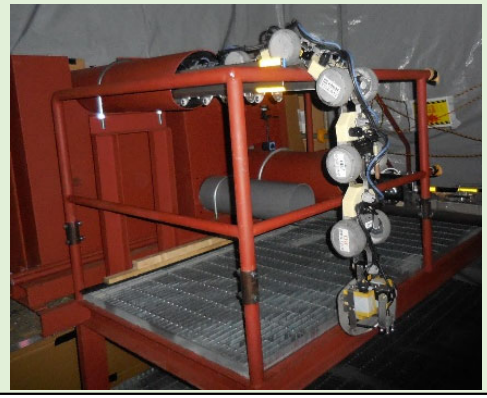


Scope of Unit 1 PCV internal investigations

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)

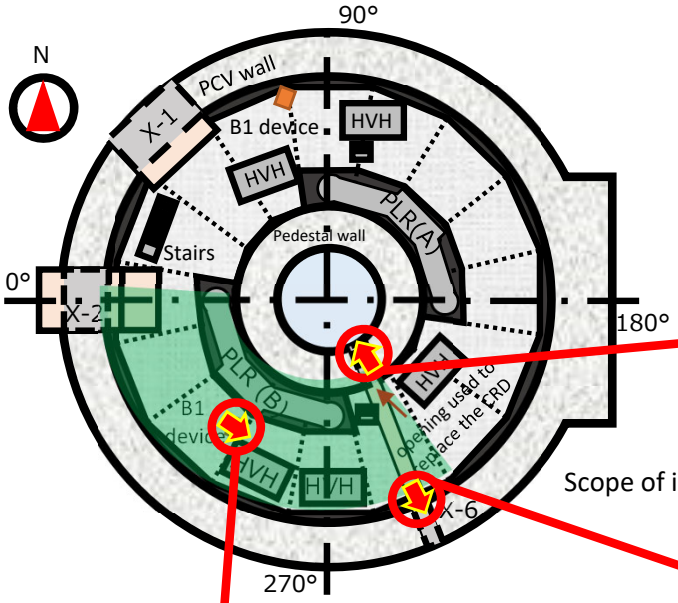
Wireless communications relay snake-like robot



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. Investigation results from the south side outside the pedestal (Drone #1)



Scope of investigation:

Unit 1 PCV interior first-floor schematic

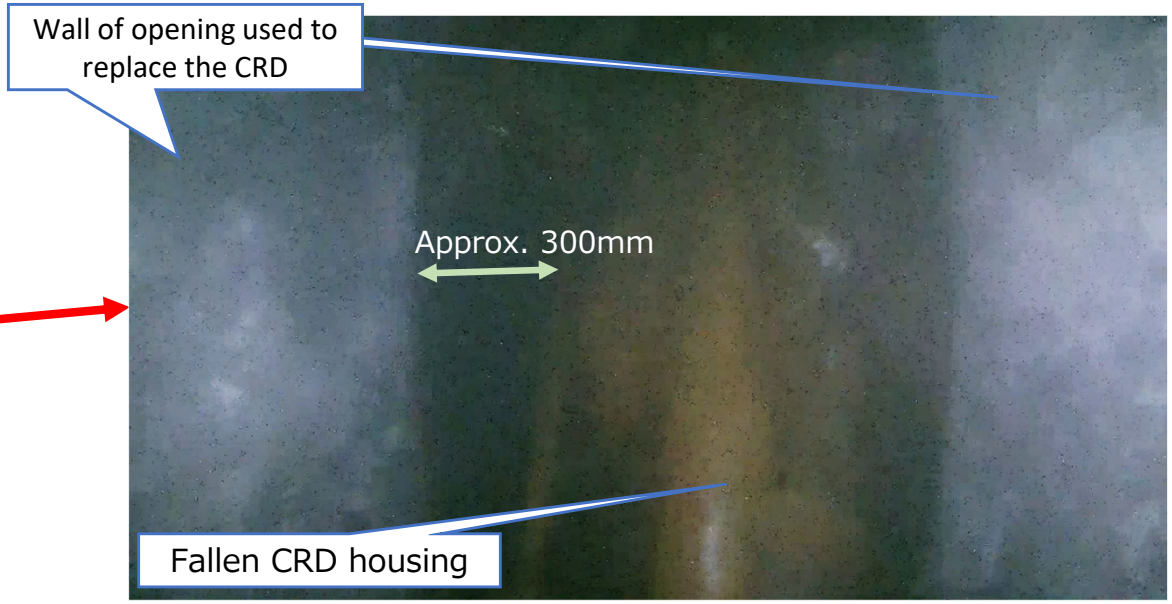


Photo 1. Condition of opening used to replace the CRD (after compensating for the flickering)

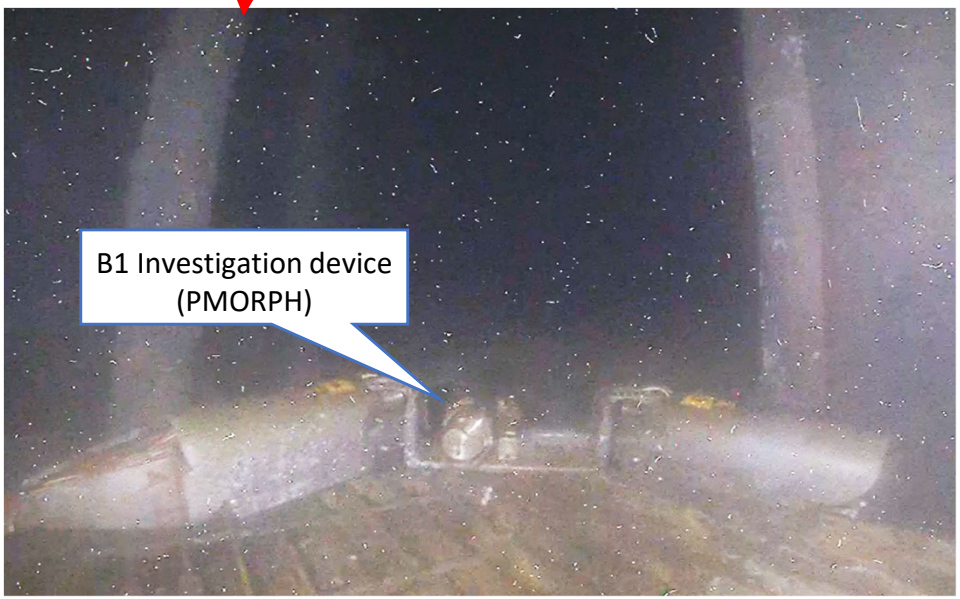


Photo 2. remains of B1 investigation device (PMORPH) on south side

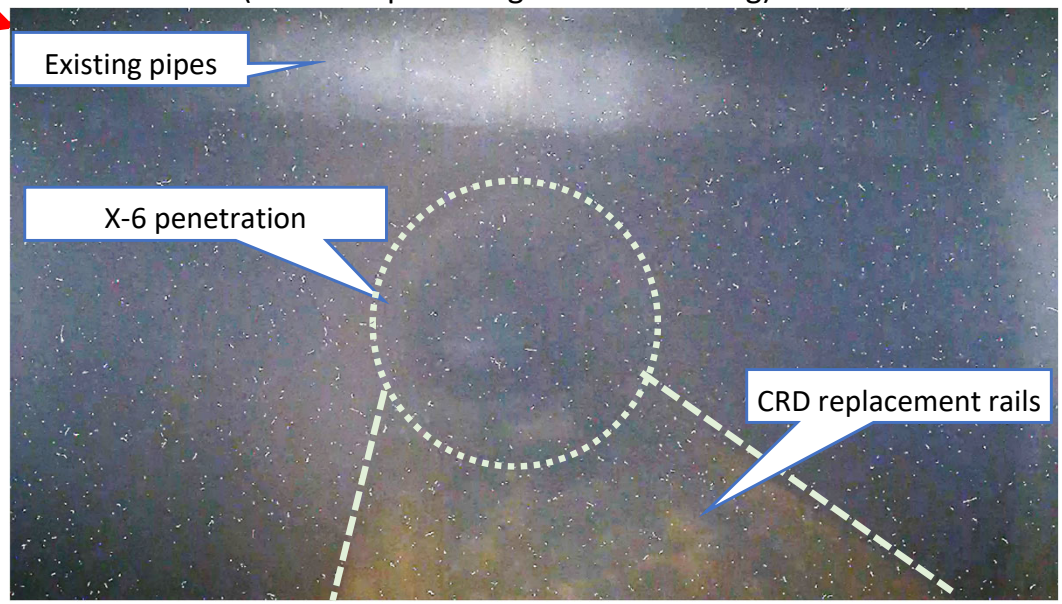
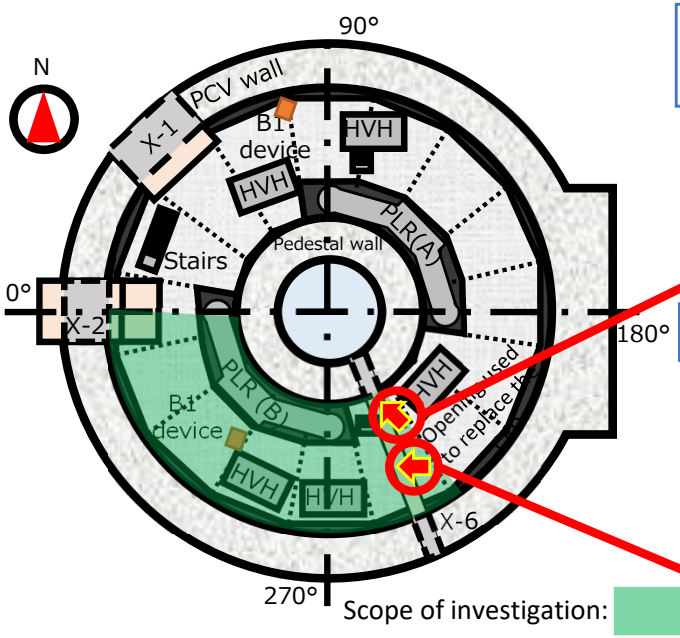


Photo 3. X-6 penetration condition

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

Image processing: TEPCO Holdings, Inc.

2. Investigation results from the south side outside the pedestal (Drone #1)



Unit 1 PCV interior first-floor schematic

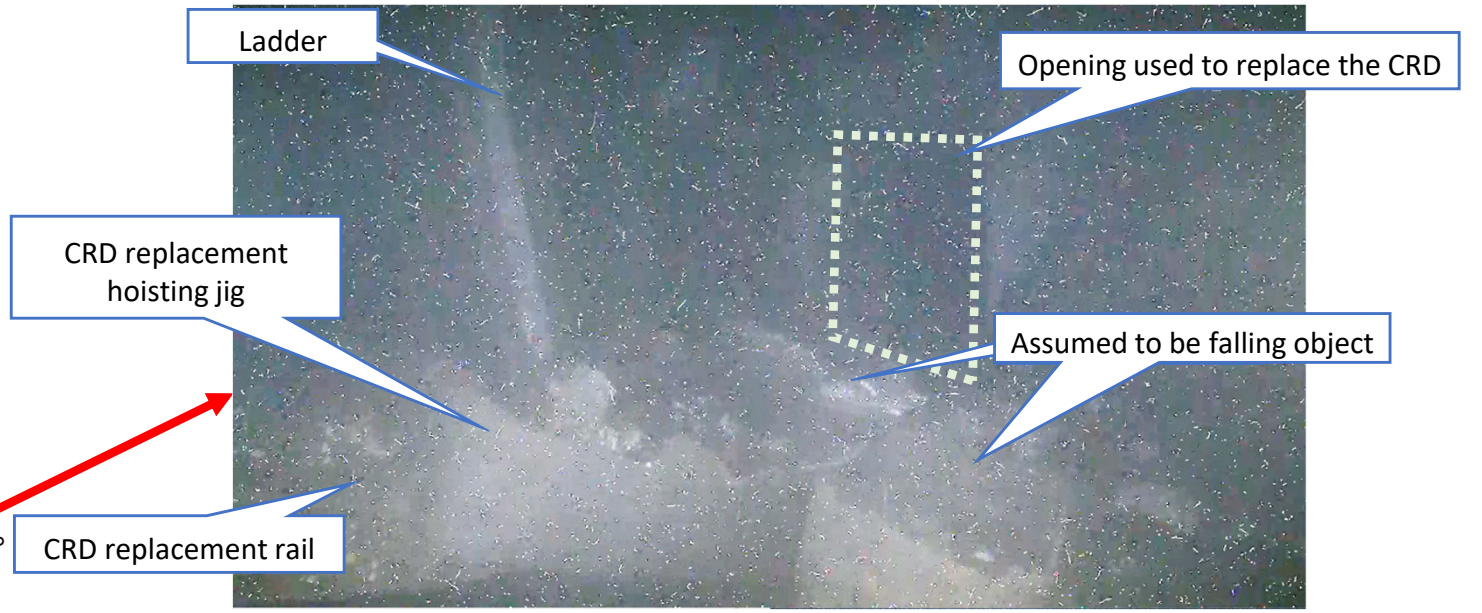


Photo 1. CRD replacement rails condition ①

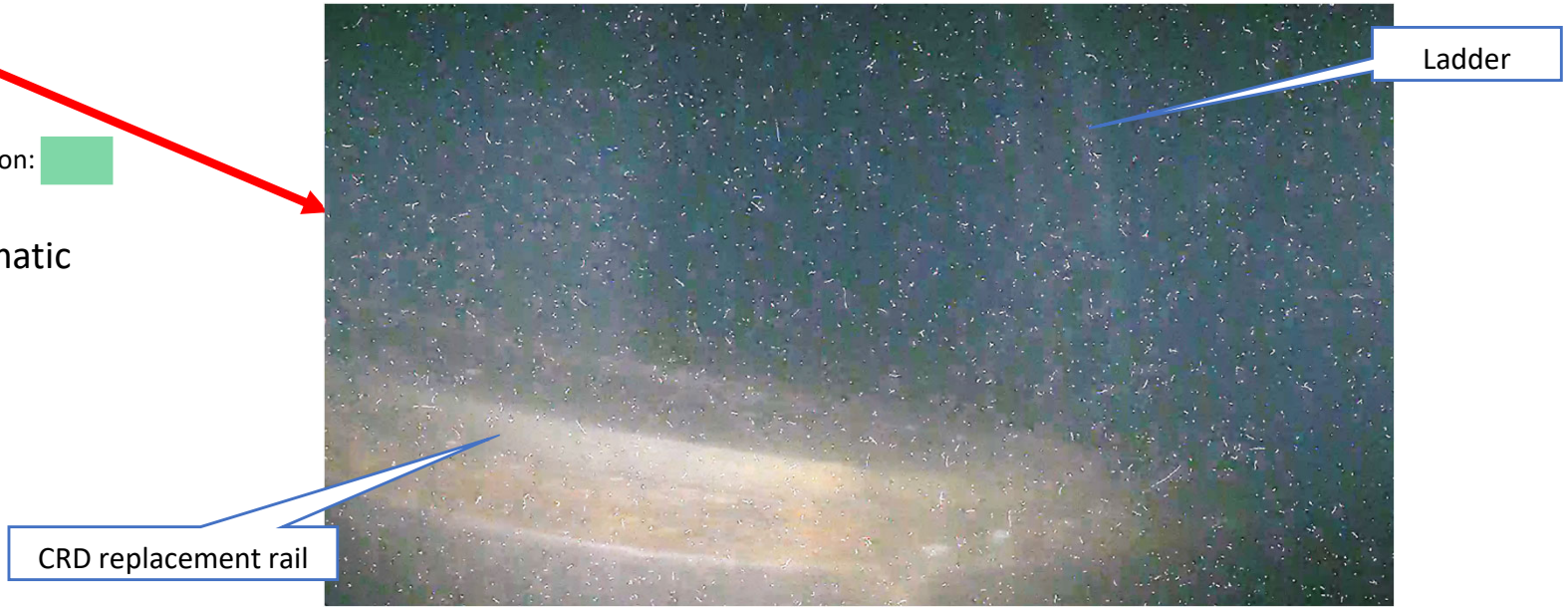
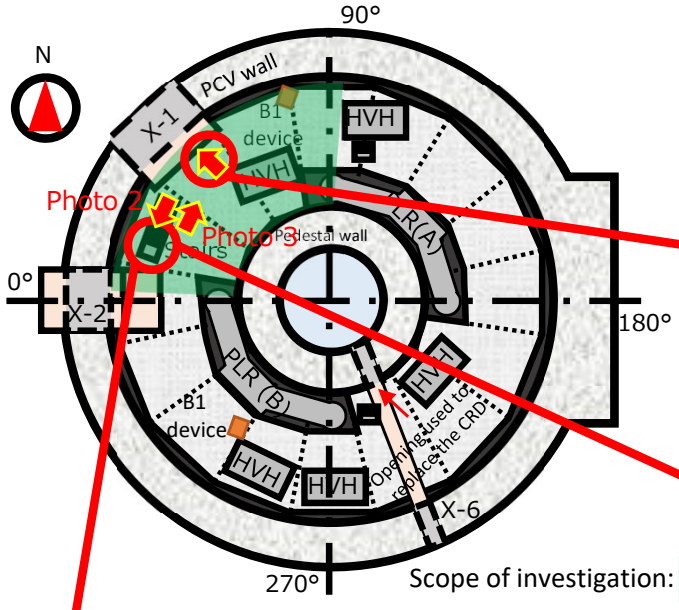


Photo 2. CRD replacement rail condition ②

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

Image processing: TEPCO Holdings, Inc.

3. Investigation results from the north side outside the pedestal (Drone #2)



Unit 1 PCV interior first-floor schematic

Photo 1. X-1 penetration condition

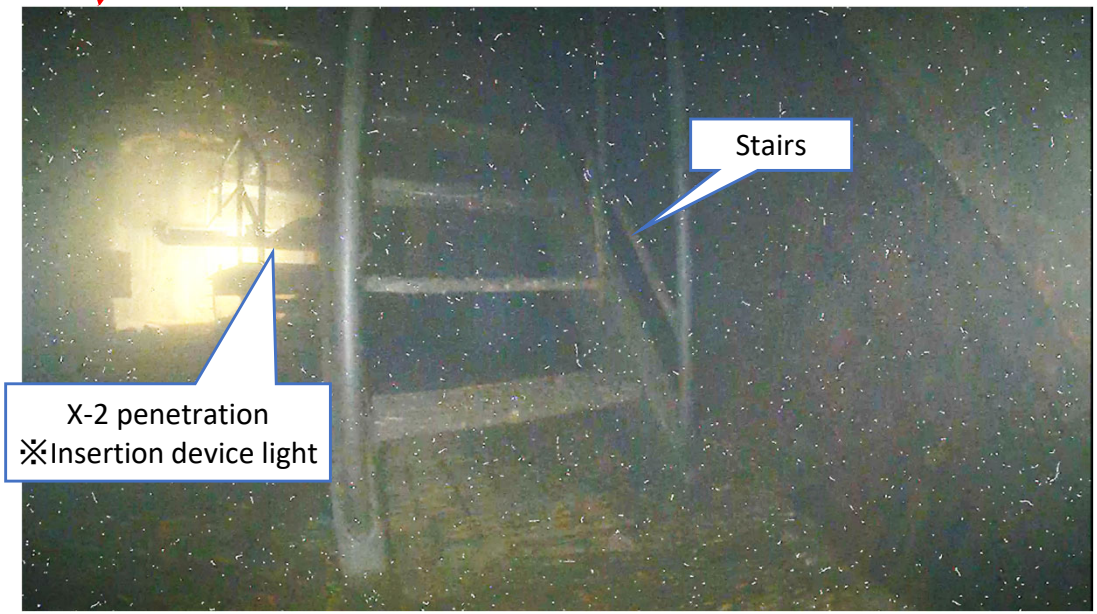


Photo 2. Condition of stairs

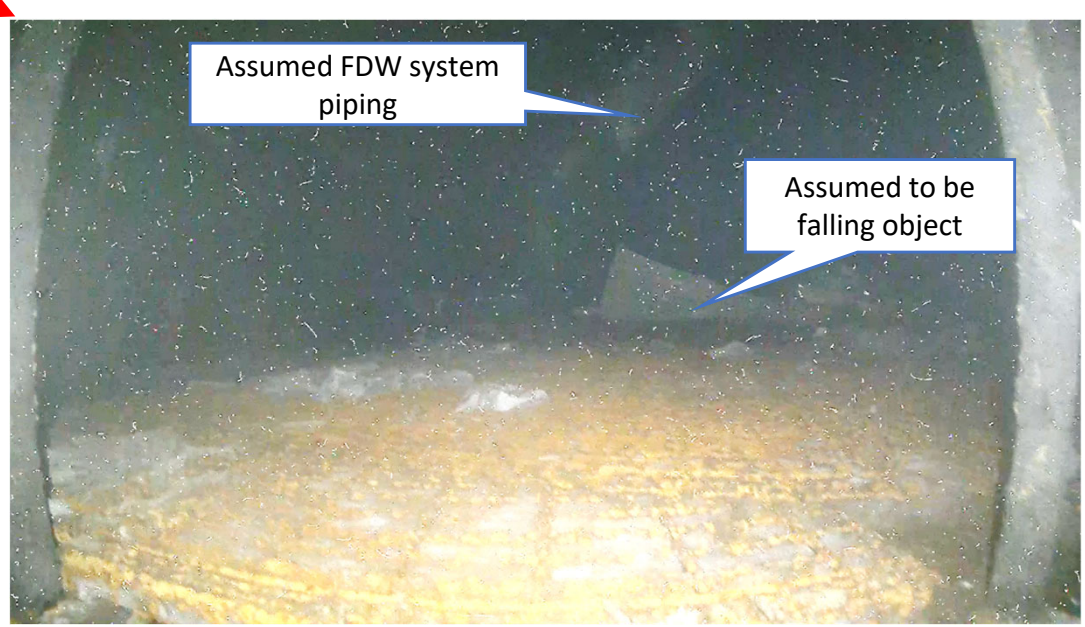
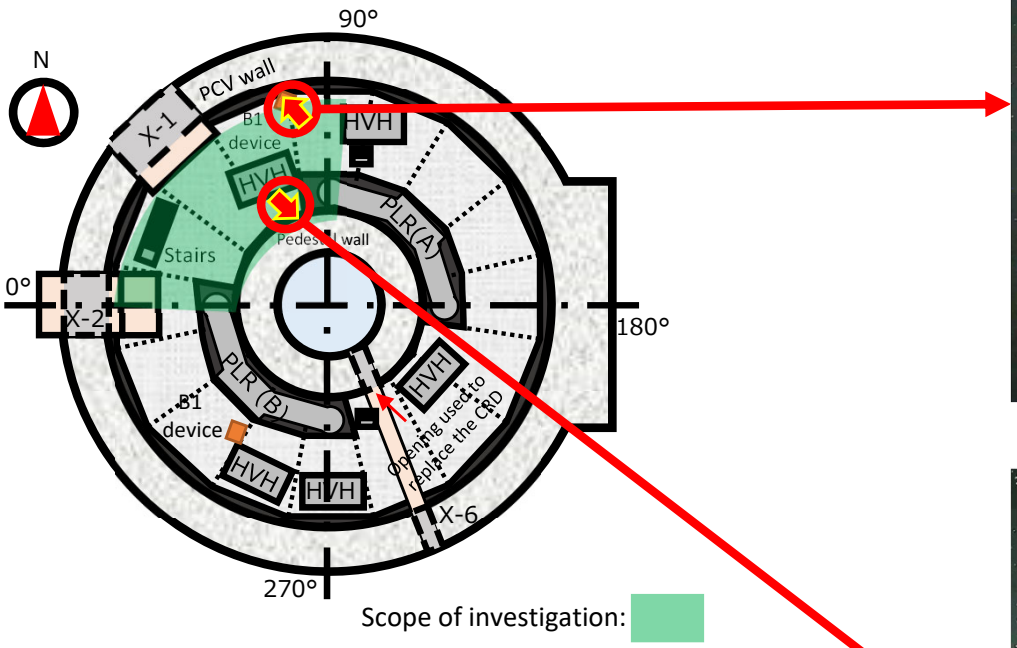


Photo 3. 2FL condition

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

Image processing: TEPCO Holdings, Inc.

3. Investigation results from the north side outside the pedestal (Drone #2)



Unit 1 PCV interior first-floor schematic

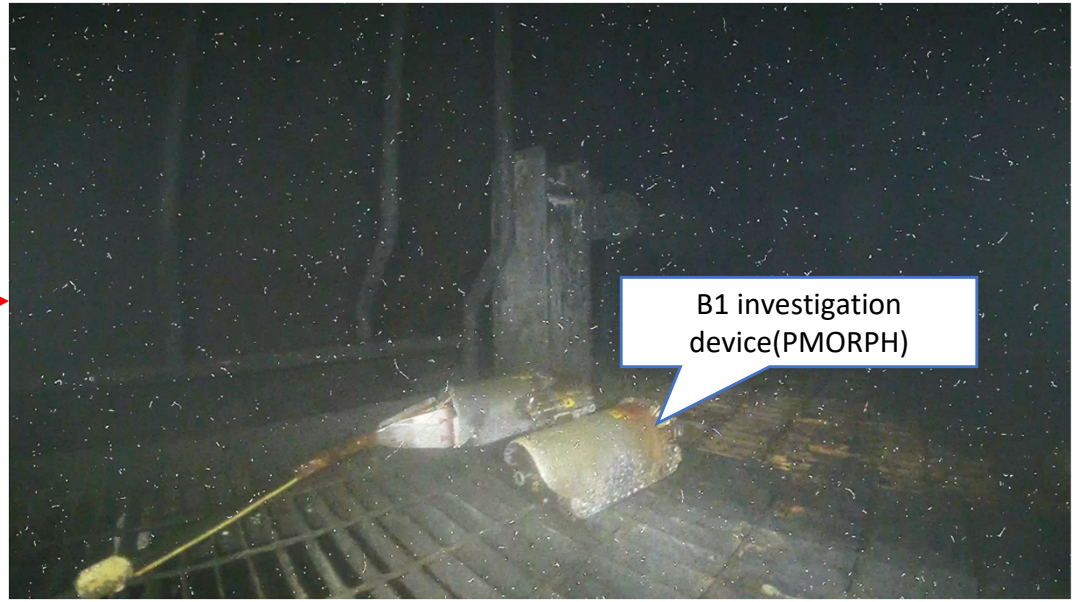


Photo 1. Remains of B1 investigation device (PMORPH) on north side

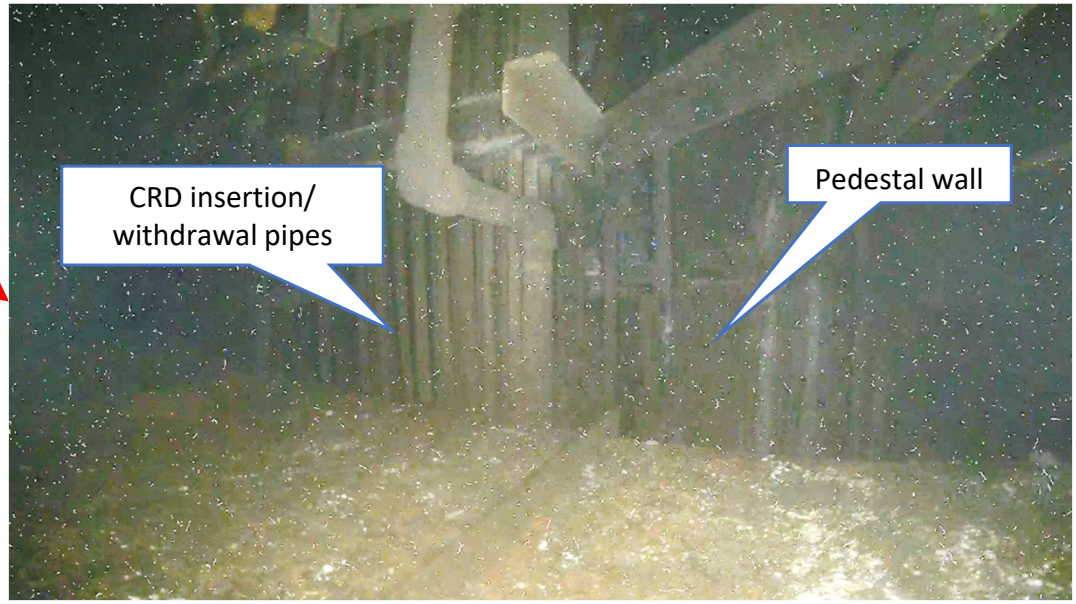
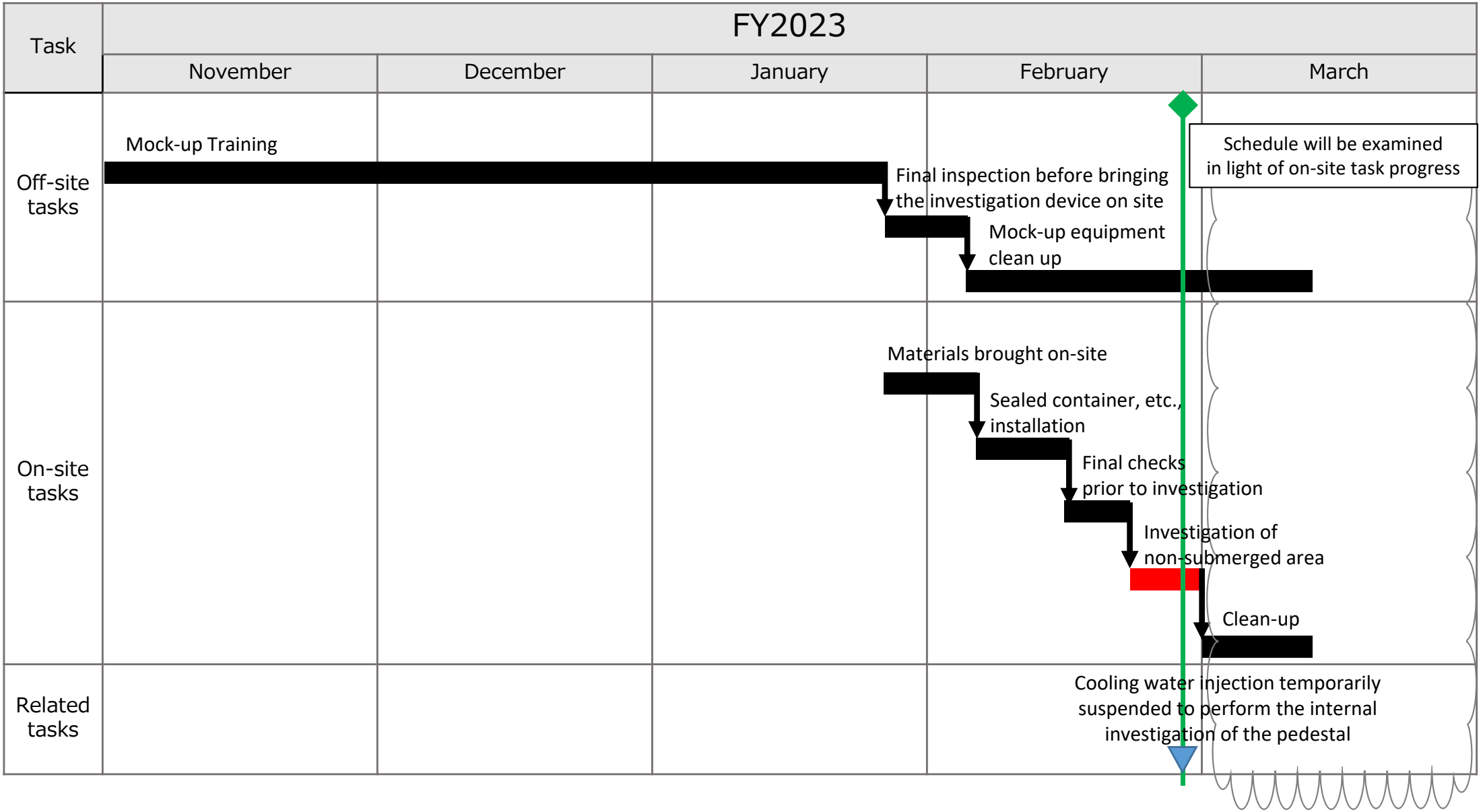


Photo 2. condition of CRD insertion/withdrawal pipes

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

Image processing: TEPCO Holdings, Inc.

4. Schedule


Task
FY2023
November
December
January
February
March
Off-site tasks
On-site tasks
Related tasks
Mock-up Training
Final inspection before bringing the investigation device on site
Mock-up equipment clean up
Schedule will be examined in light of on-site task progress
Materials brought on-site
Sealed container, etc., installation
Final checks prior to investigation
Investigation of non-submerged area
Clean-up
Cooling water injection temporarily suspended to perform the internal investigation of the pedestal

Timeline of the PCV internal investigation of non-submerged area on February 28

Announced on February 28, 2024

TEPCO

11:35 AM Commencement of preparations for the PCV internal investigation of non-submerged area
(Final airtightness check of sealed container for investigation robots)

12:12 PM Employment of small drones into PCV through X-2 penetration (isolation valve opened)

12:51 PM Employment of snake-like robot into PCV through X-2 penetration

1:18 PM **Commencement of PCV internal investigation of non-submerged area**
(small drone (Drone #1) lifts off from install tray)

2:13 PM **Completion of PCV internal investigation of non-submerged area** (isolation valve closed)

[Reference: Small drone flight time]
Drone #1: Approximately 5 minutes from 1:22 PM
Drone #2: Approximately 5 minutes from 1:34 PM

PCV internal investigation of non-submerged area on February 28

Photo 1: Remote operation center

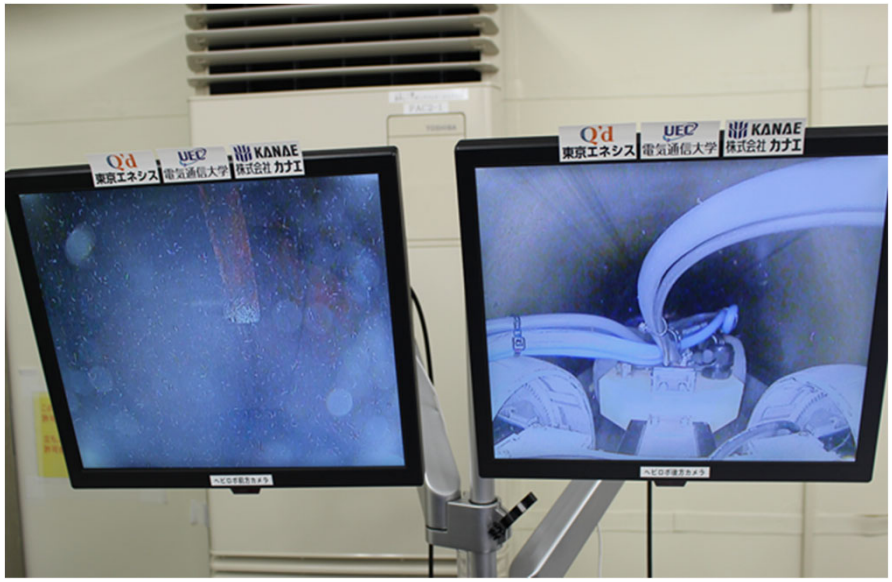


Photo 2: Installment of the snake-like robot
(left: front side right: back side)

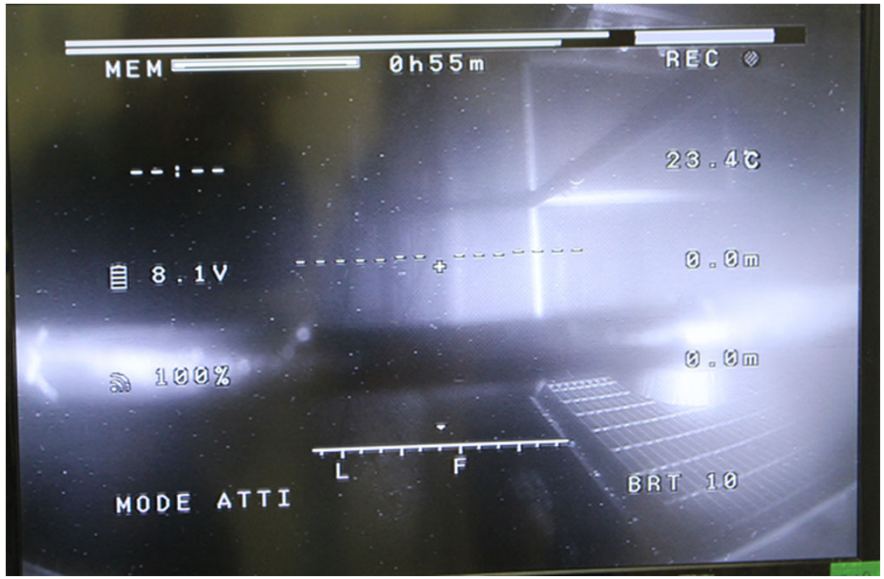


Photo 3: Installment of the small drone (drone #1)

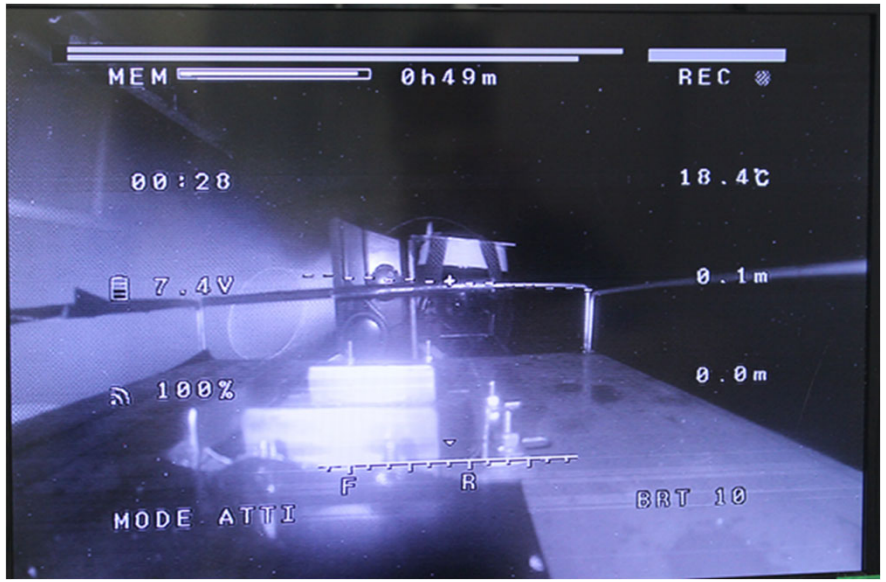


Photo 4: Landing the drone (drone #2)

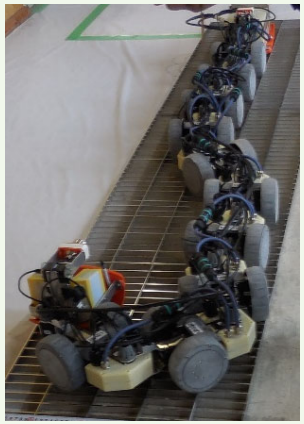
(Reference) Investigation devices

- 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

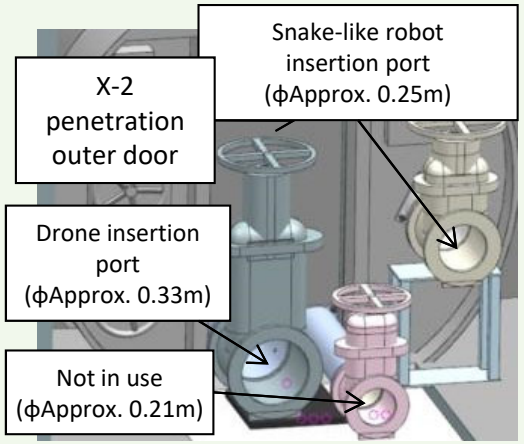


Snake-like robot

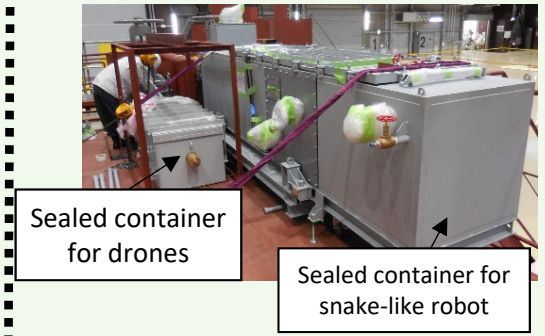
Testing to see how it climbs through from the X-2 penetration

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



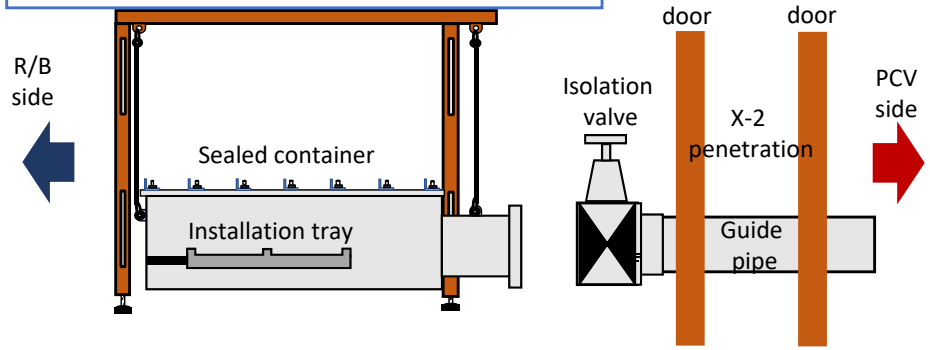
X-2 Penetration isolation valve usage diagram



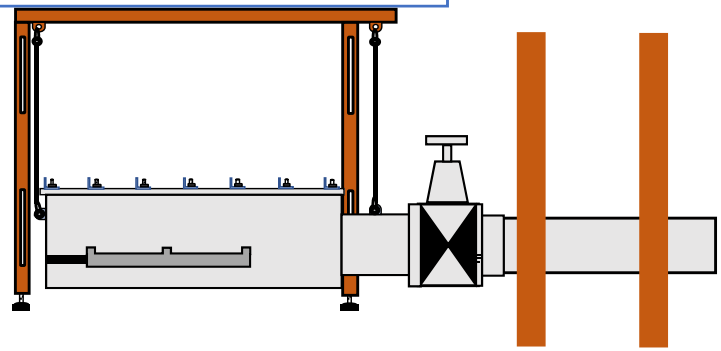
Sealed container installation mock-up

(Reference) Primary work steps

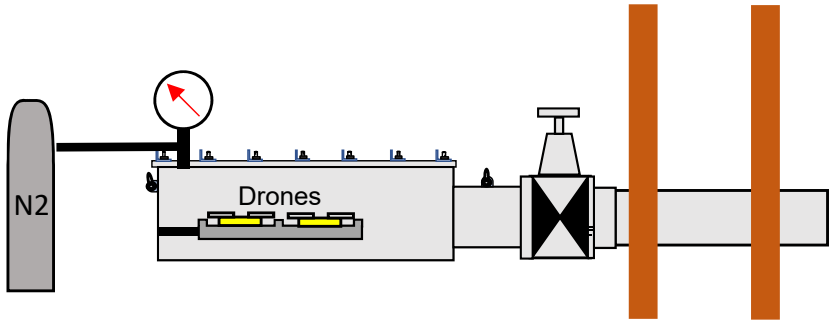
① Sealed container positioning



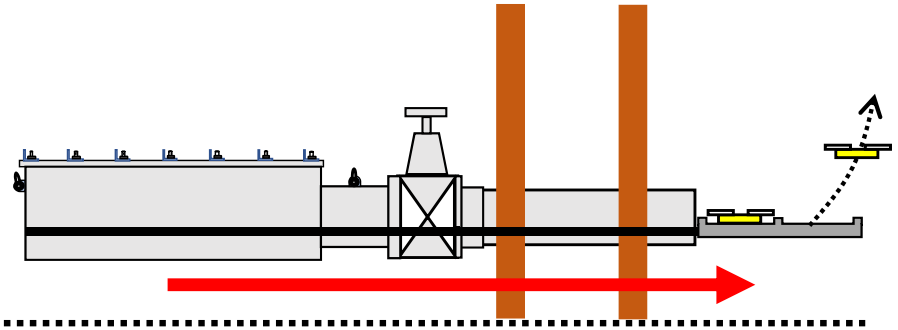
② Sealed container coupling



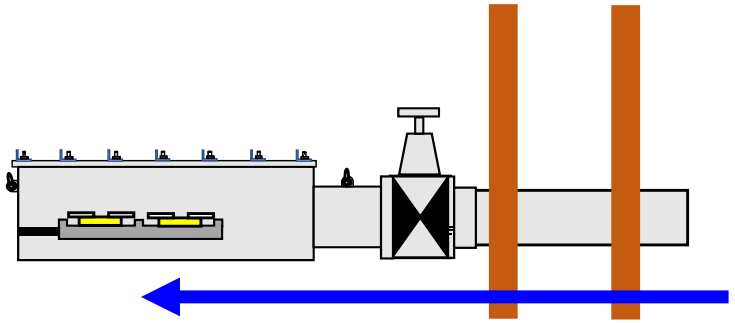
③ Investigation devices put in sealed container, leak check



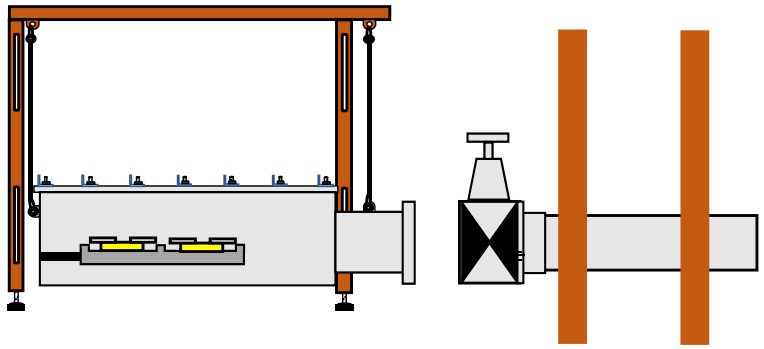
④ Investigation device insertion ⇒ Snake-like robot relocation ⇒ Drone flight



⑤ Investigation device recovery



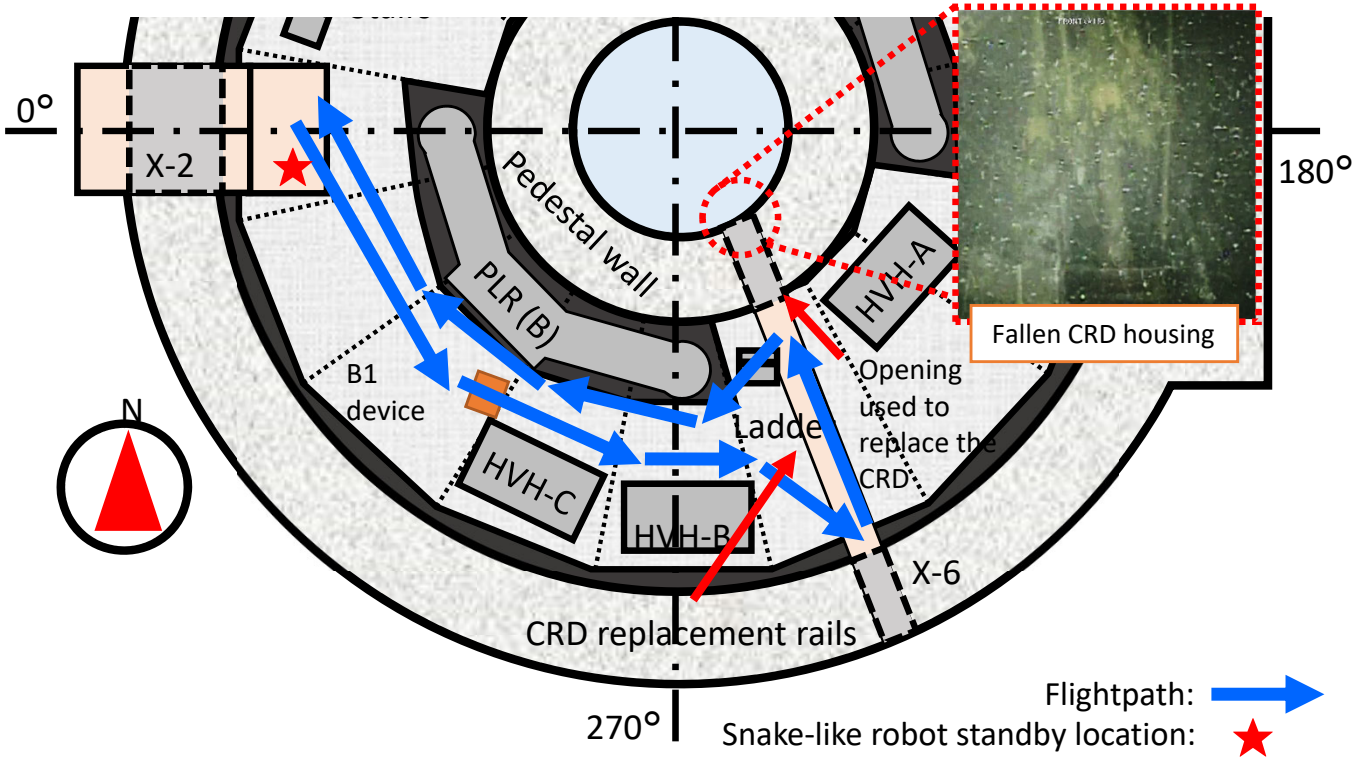
⑥ Sealed container decoupling



＊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) Investigation route (outside the pedestal on the south side)

- The south side of the outside of the pedestal will be investigated using the first drone.
  - 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

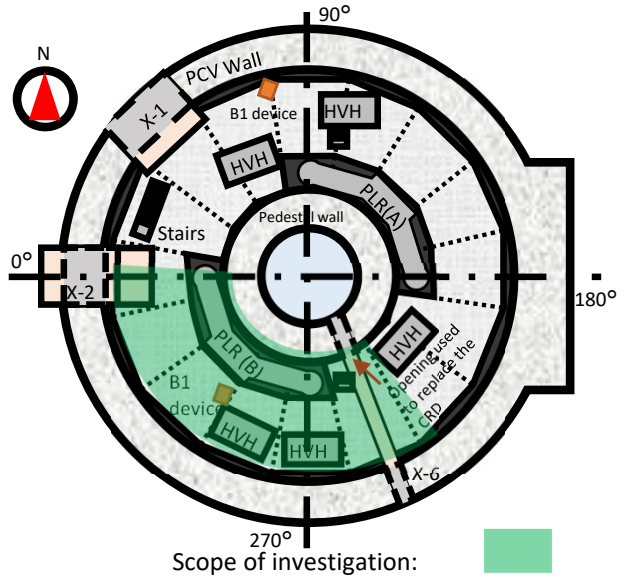
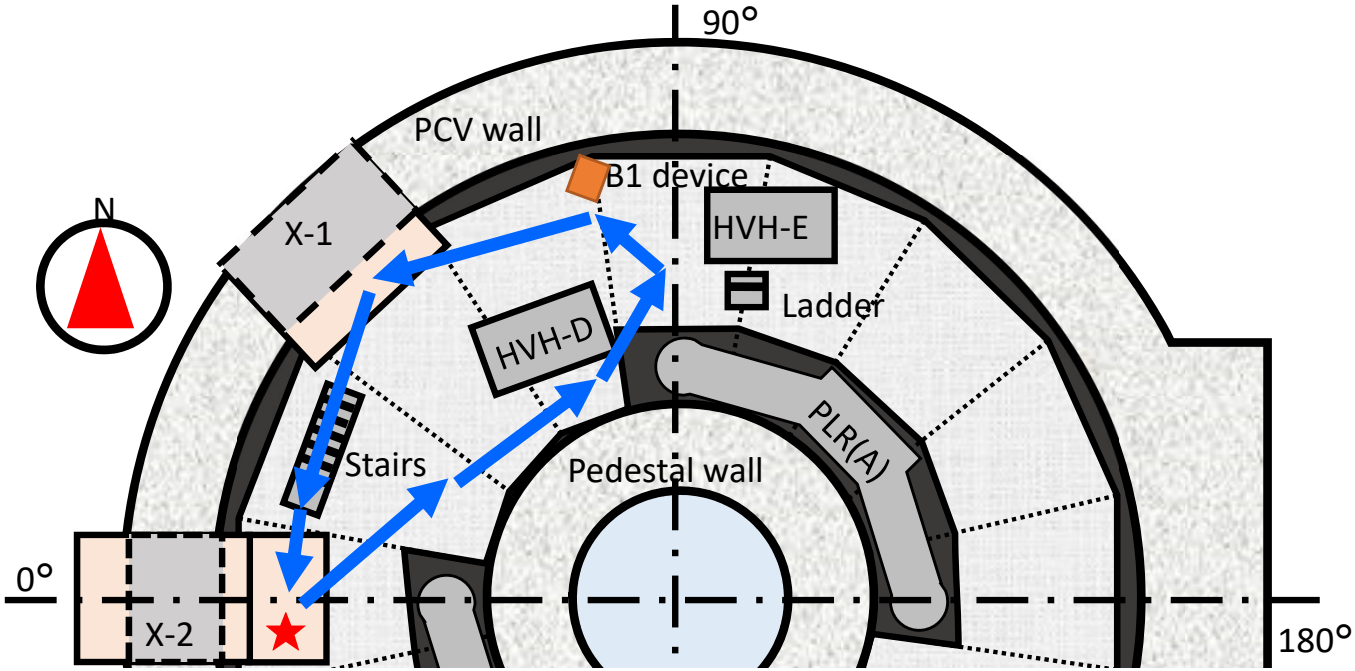


Diagram of the entire first floor inside the Unit 1 PCV

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

(Reference) Investigation route (outside the pedestal on the north side)

- The north side of the outside of the pedestal will be investigated using the second drone.
  - 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 third and fourth drones).



Snake-like robot standby location: ★ Flightpath: →

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

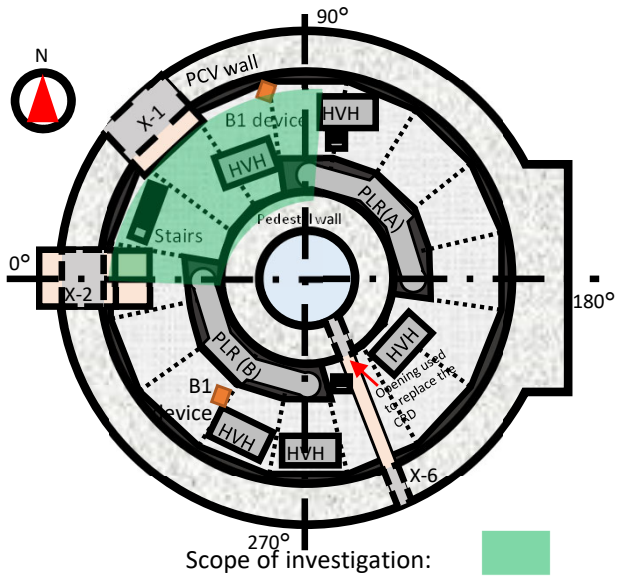


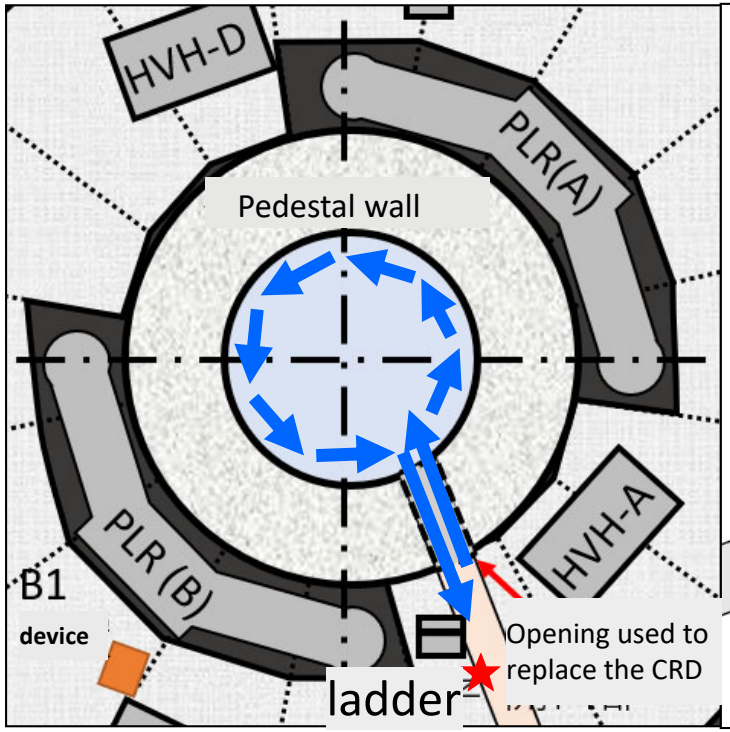
Diagram of the entire first floor inside the Unit 1 PCV

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

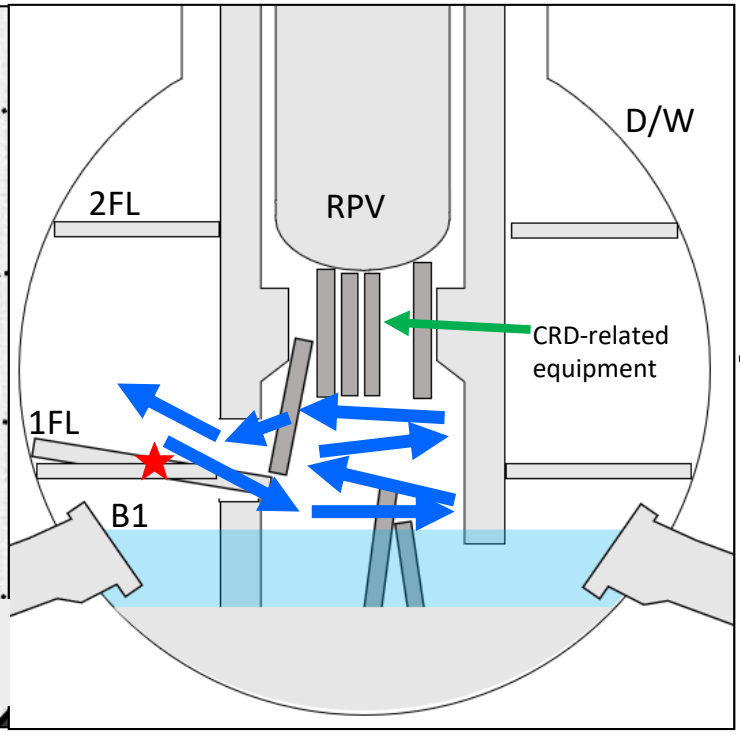
(Reference) Investigation route (inside the pedestal)

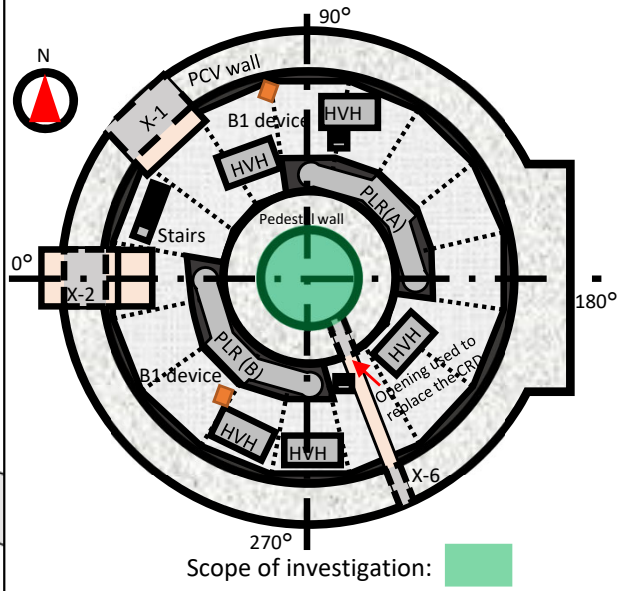
- The investigation of the inside of the pedestal will be conducted using the third and fourth drones
  - Investigation target: Inner walls of the pedestal, internal structures of the pedestal, and condition of the fallen CRD housing
  - Snake-like robot relays radio signals from around the CRD replacement rails
  - The third drone will be used to take as much footage of the inside of the pedestal as possible, and the fourth drone will be used to photograph places of interest found with the third drone
  - 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

(Reference) Risks during the investigation

- **Not being able to recover inspection devices from inside the PCV**
  - Although there is the risk that we may not be able to recover the small drones or the snake-like robot due to the effect of radiation or loss of communication, **even if they are left inside there will be no impact on PCV status**.
- **Inability to acquire video (partial acquisition, unclear images)**
  - Recorded images may be unclear due to the poor conditions such as radiation noise (flickering), fog, etc., **but video recording tests have shown that flight is possible in the poor conditions and that taking photograph of inspection targets is possible if we get close to them**.
  - If a drone crashes we will be unable to directly acquire video data, **but if communications are intact we can download the video from the drone, and even though the quality is poor, we will continually save operations screen data.**
  - If the snake-like robot becomes immovable, or if it becomes impossible to pass through the opening used to replace the CRD replacement hatch, we will be unable to acquire video inside the pedestal, **so during the investigation we will first use drones to confirm the access route for the snake-like robot and confirm the status of the opening used to replace the CRD in advance to determine whether or not access can be gained (video taken during the submersible ROV investigation appears to show that the area can be accessed).**
- **Dust dispersion risk**
  - In general, the risk of dispersing dust during a drone flight is high. **However, the drones to be used for this investigation are small and light, so they churn up very little dust. Furthermore, since the environment inside the PCV is moist, there should be little impact from dust dispersion (monitoring with dust monitors will be conducted during investigation).**
- **Leak of PCV gases or PCV internal pressure decrease**
  - There is the risk that PCV gases may leak from the sealed containers. However, **airtightness tests will be performed during the mock-up training and immediately prior to opening the isolation valve to confirm that there are no leaks.**

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(Reference) Location of the remains of the B1 investigation device

- 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