Primary Containment Vessel Internal Investigation, Sampling and Analysis

July 26, 2018

IRID TEPCO

Tokyo Electric Power Company Holdings, Inc.

1. Overview

- Ascertaining conditions inside the PCV, the characteristics of fuel debris and the potential impacts of removal, and learning as much as possible about these issues, is vital for fuel debris removal. Therefore, the following sequence of tasks by which the scale of operations will be gradually enlarged shall be employed. "Primary Containment Vessel (PCV) internal investigation (including sampling)"→"Small-scale removal of fuel debris"→"Large scale removal of fuel debris".
- The implementation of further investigations is being considered to obtain additional knowledge about each unit in preparation for fuel debris removal.

【Unit 1】

  - PCV internal investigation by inserting a submersible boat-like access/investigation device through the X-2 penetration (scheduled for the first half of FY2019)

【Unit 2】

  - PCV internal investigation using the guide pipe through the X-6 penetration used for the investigation in January, 2018 (scheduled for the second half of FY2018)
  - PCV internal investigation through the X-6 penetration using an arm-like access/investigation device (scheduled for the second half of FY2019)

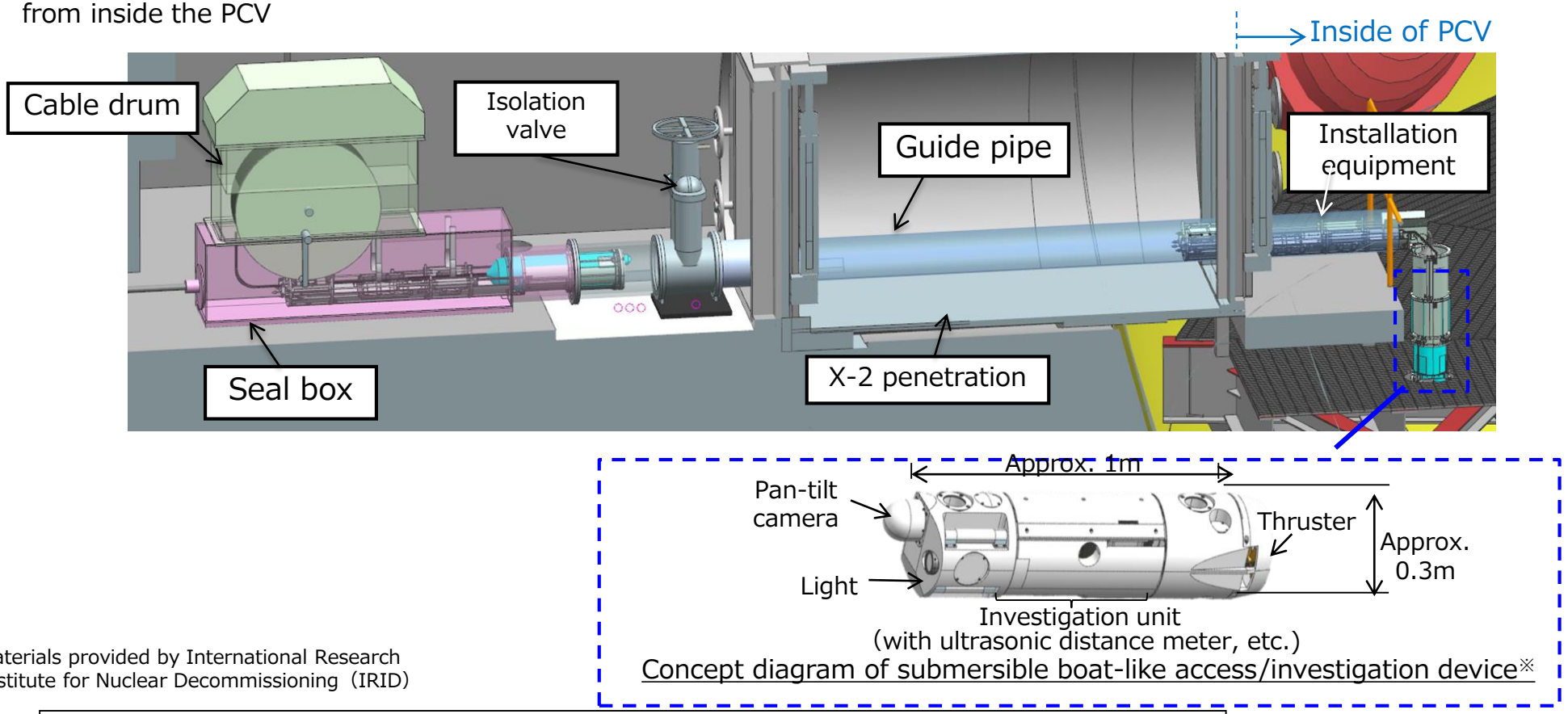
【Unit 3】

  - Methods for lowering water levels are being examined in preparation for fuel debris removal. At the same time, whether or not additional investigations using the submersible ROV used for the previous investigation are necessary is also being examined.

- A small amount of deposit samples will be collected from the bottom of the PCV during the PCV internal investigations of Units 1 and 2 scheduled for FY2019.
- Transporting the collected samples to an institute in Ibaraki prefecture that has experience handling samples from the 1F accident and requesting analysis is being deliberated. Since the samples from Unit 2 may contain a large quantity of uranium and plutonium a facility that has acquired a permit to handle fuel debris will be asked to perform the analysis.
- The size of the samples taken during FY2020 may be larger than those taken during FY2019, so necessary transport preparations are being made.

2. Unit 1 PCV Internal Investigation through the X-2 penetration (scheduled for the first half of FY2019) (1/2)

- The access/investigation device being developed for the Unit 1 PCV internal investigation is being designed to primarily ascertain the distribution of structures and deposits outside the pedestal.
- Since the deposits observed during the investigation in March, 2017 are under water a submersible boat is being developed for access/investigation purposes. An access route formed by drilling a hole in the X-2 penetration will be used for the investigation.
- As with prior PCV internal investigations, the concentration of radioactive materials in dust will be monitored during the investigation with dust monitors to confirm that there is no impact on the surrounding environment by the leakage of gases from inside the PCV



Concept diagram of submersible boat-like access/investigation device※

Materials provided by International Research Institute for Nuclear Decommissioning (IRID)

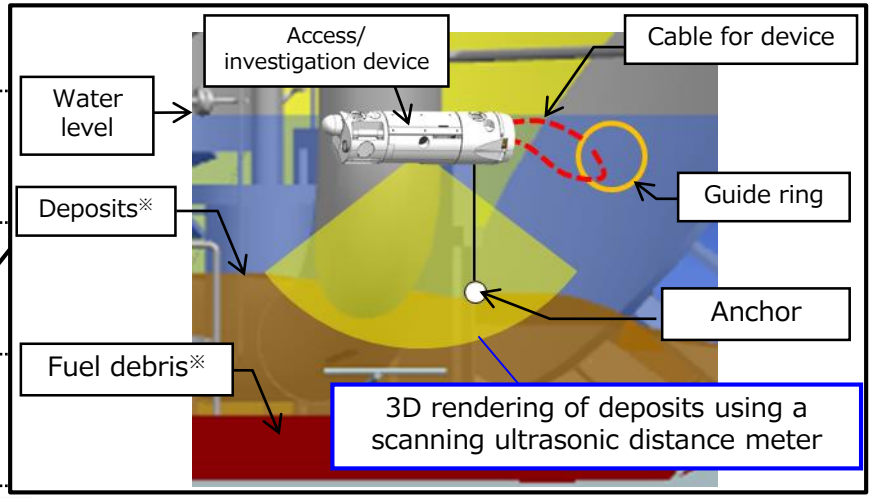
Concept diagram of the Unit 1 PCV internal investigation through the X-2 penetration

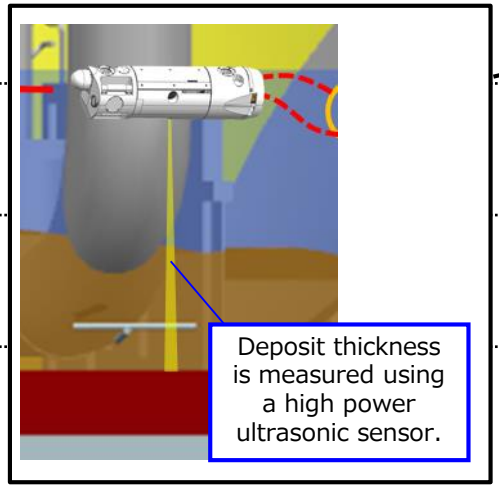
※Changes may be made depending on design progress

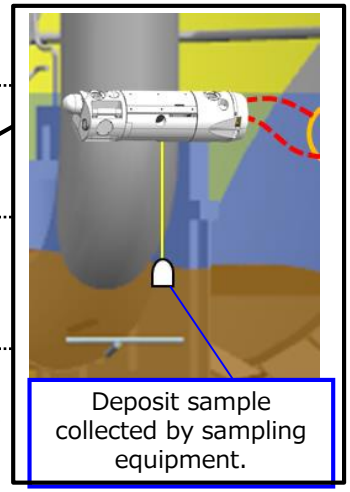
2. Unit 1 PCV Internal Investigation through the X-2 penetration (scheduled for the first half of FY2019) (2/2)

- Six types of submersible boat-like access/investigation devices will be developed to provide each of the following functions.

Task	Operation flow (Concept diagram)
Installation of installation equipment and seal box	
Attachment of guide ring (Installed inside the PCV to prevent the cable from getting tangled)	ROV-A
Detailed visual investigation (Checking conditions inside the PCV using a pan-tilt camera)	ROV-A2 (small ROV)
3D rendering of deposits (A 3D rendering of deposits shall be made using a scanning ultrasonic distance meter)	ROV-B
Deposit thickness measurement (Measured by high power ultrasonic sensor)	ROV-C
Neutron flux measurement (Neutron flux on surface of deposits measured using a detector)	ROV-D
Sampling of small amounts of deposits	ROV-E
Removal of installation equipment and seal box	





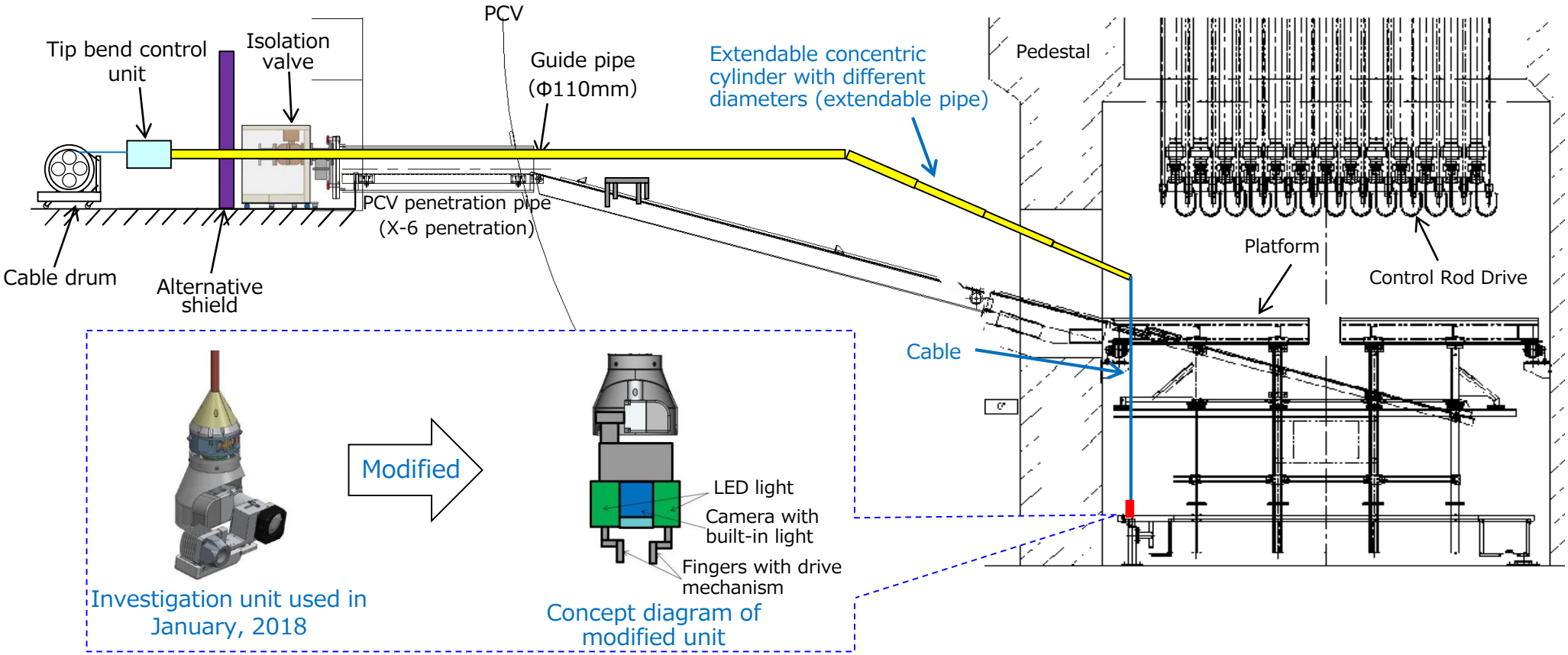


※ The thickness of deposits and whether or not fuel debris is present, and the thickness of that debris, are unknown. They are shown in the concept diagram for explanatory purpose.

Materials provided by International Research Institute for Nuclear Decommissioning (IRID)

3. Unit 2 PCV Internal Investigation using the guide pipe (scheduled for the second half of FY2018)

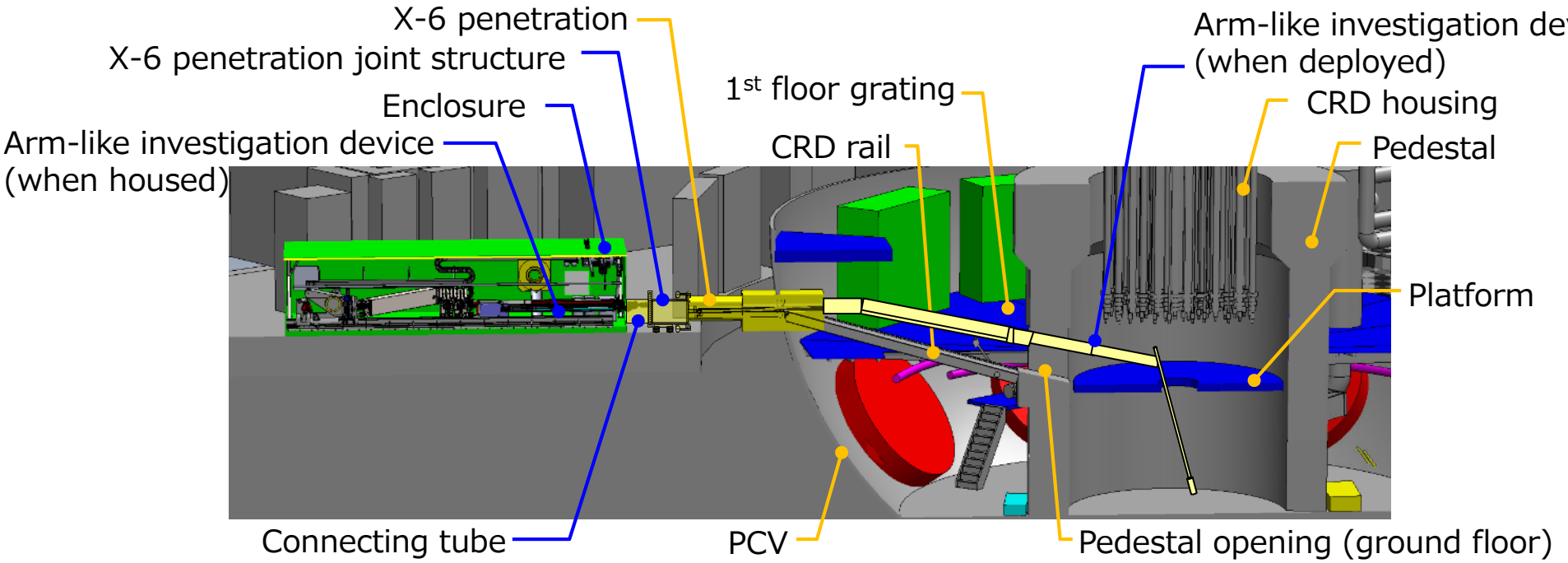
- It is important to ascertain the behavior of deposits observed at the bottom of the Unit 2 pedestal beforehand because the characteristics (hardness, frailty, etc.) of these deposits are as yet unknown.
- Modifying the end of the investigation unit used in January, 2018 to add mechanical force to deposits and observe behavior is being considered.
- As with prior PCV internal investigations, the concentration of radioactive substances in dust will be monitored during the investigation using dust monitors to confirm that there is no impact on the surrounding environment from the leakage of gases inside the PCV.



Concept diagram of Unit 2 PCV internal investigation using the guide pipe

4. Unit 2 PCV Internal Investigation through the X-6 penetration (scheduled for the second half of FY2019) (1/2)

- The access/investigation device being developed for the Unit 2 PCV internal investigation is being designed to primarily ascertain the distribution of structures and deposits inside the pedestal.
- Water level is low inside the Unit 2 PCV so the X-6 penetration can be used. Therefore, an arm-like access/investigation device is being developed to improve accessibility and increase payload. The investigation will be performed through an access route formed by opening the X-6 penetration.
- As with prior PCV internal investigations, the concentration of radioactive substances in dust will be monitored during the investigation using dust monitors to confirm that there is no impact on the surrounding environment from the leakage of gases inside the PCV.

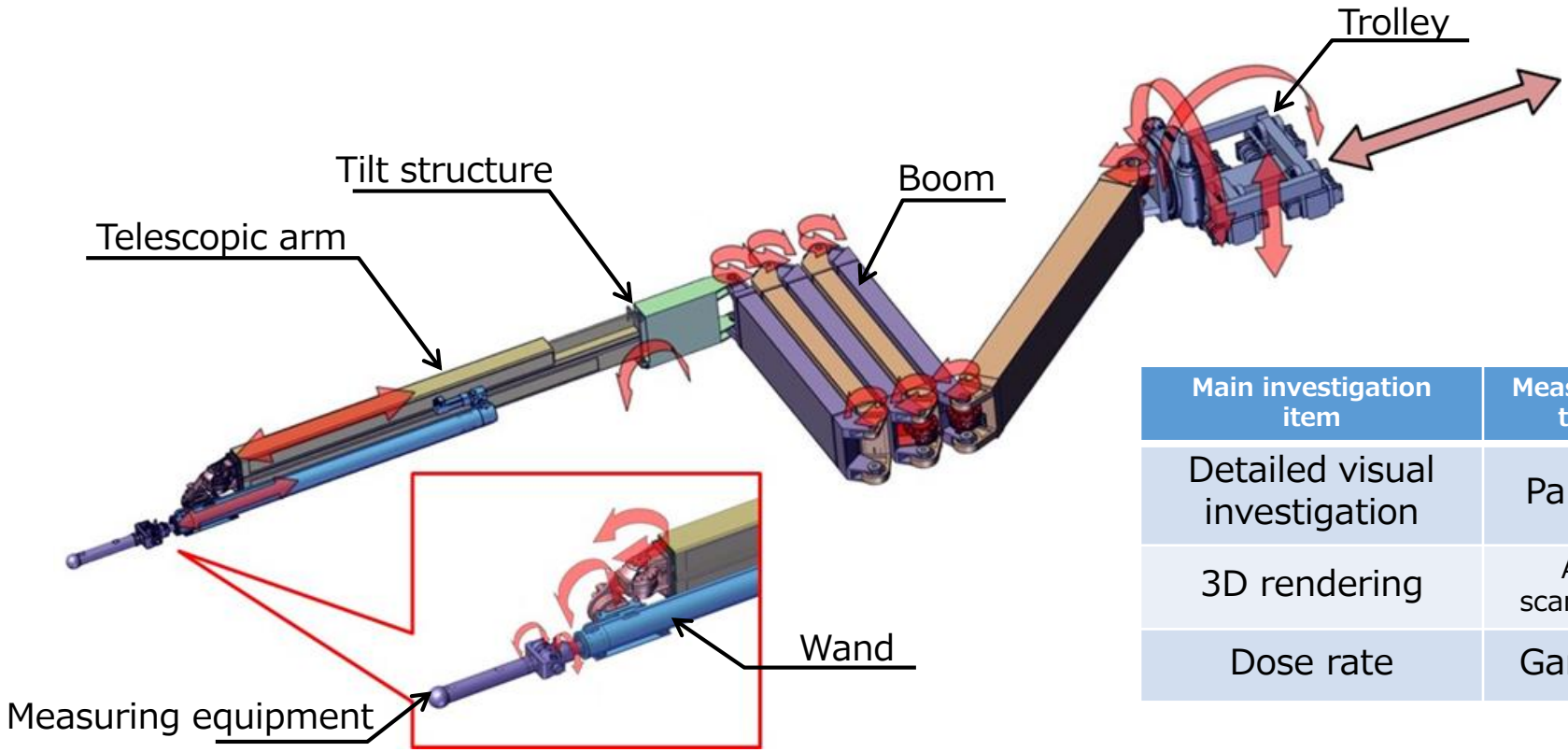


Concept diagram of Unit 2 PCV internal investigation through X-6 penetration

Materials provided by International Research Institute for Nuclear Decommissioning (IRID)

4. Unit 2 PCV Internal Investigation through the X-6 penetration (scheduled for the second half of FY2019) (2/2)

- Access/investigation device has a wand on the end for attaching measuring equipment. Suitable equipment is attached depending upon what is to be investigated.
- Collecting small amounts of deposits from inside the pedestal with a small sampling tool attached to the wand is being deliberated.



Main investigation item	Measuring equipment to be mounted
Detailed visual investigation	Pan-tilt camera
3D rendering	Airborne laser scanning equipment
Dose rate	Gamma camera

Concept diagram of the arm-like access/investigation device※

※Changes may be made depending on design progress

Materials provided by International Research Institute for Nuclear Decommissioning (IRID)

5. Analysis of collected samples

- JERA is building a radioactive substance analysis/research facility (administration building, buildings No.1 and 2) as an R&D base adjacent to Fukushima Daiichi in accordance with the mid-and-long term roadmap. Analysis of fuel debris will be carried out in the No.2 building (currently being designed).

- Starting to collect small samples in FY2019 before the opening of the No. 2 building is being considered. Transporting collected samples off-site for analysis at an institute in Ibaraki prefecture that has experience handling samples from the 1F accident is also being considered.

- A facility that can handle the samples and fulfill the objective of sample analysis will be selected from those that have acquired a permit to handle fuel debris.

※ Reference

It may be possible to collect material that has adhered to the equipment during the PCV internal investigation currently being deliberated. Collecting small amount of samples from the surface of deposits during the Unit 1 PCV internal investigation in the first half of FY2019 is also being considered. It is assumed that there is not much uranium and plutonium on the surface of deposits based on the results of prior investigations (March, 2017). Therefore, transporting the samples off-site for analysis, as was done with 1F samples, is being considered.

6. Transporting collected samples

- Samples will be transported appropriately depending on the level of radioactivity in abidance with laws and regulations. Since it is assumed that the samples collected during the next one to two years will be small in size, Type A transport procedures (less than several grams) will be employed and preparations are currently underway.
- Since increases in sample size may require Type B transport procedures in the future, (in excess of several dozens to several hundreds grams), preparations, such as containers and the handling environment, are also underway.

Type A transport vessel (not shielded)

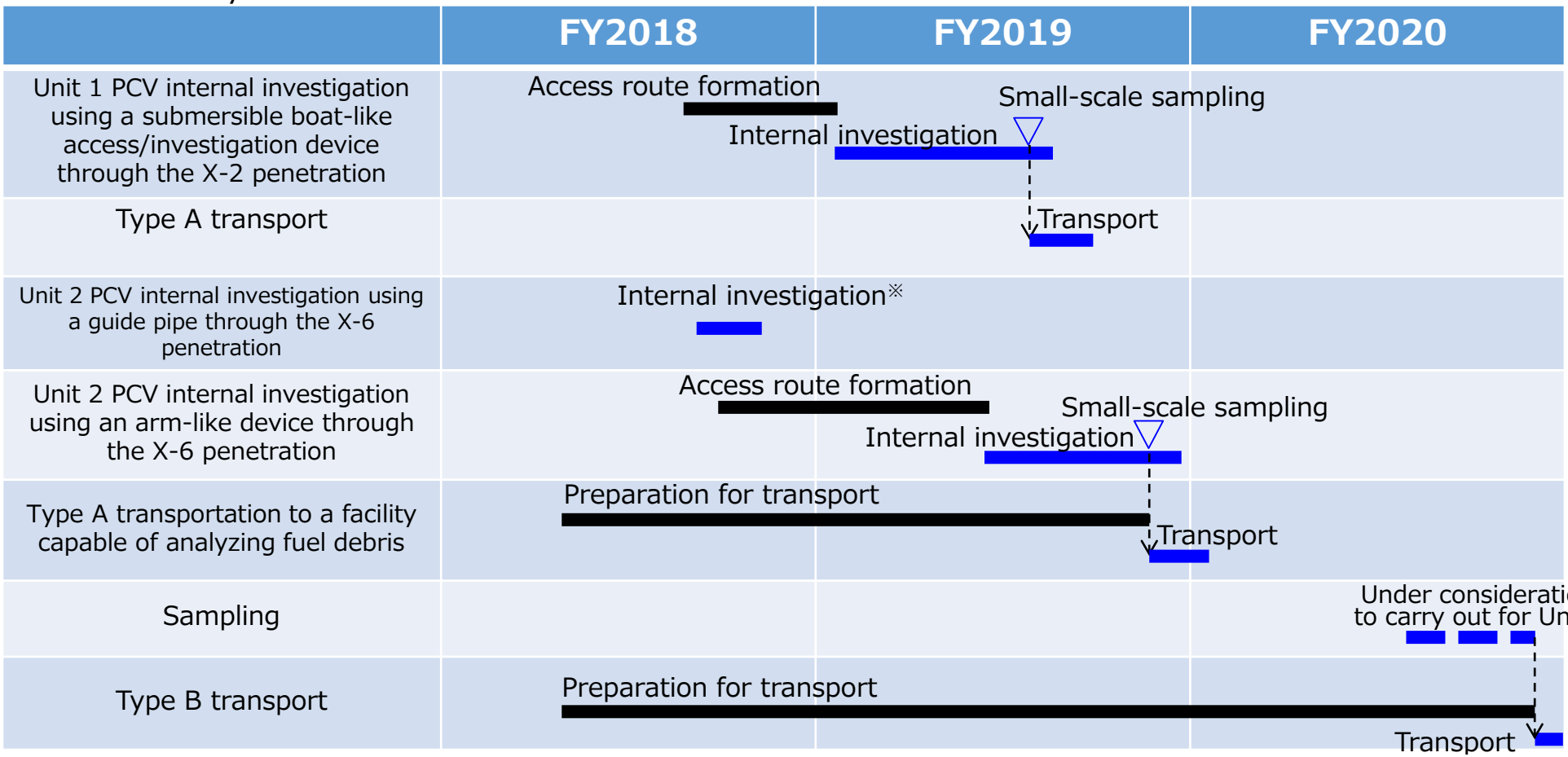
Type A transport vessel (shielded)

Type B transport vessel

Low — Level of radioactivity, dose — High

7. Future schedule

- The following is a general outline of the schedule for PCV internal investigations, sampling and analysis. Details such as the schedules for equipment development and mock-up construction will be announced as soon as they are decided.



※Collecting, transporting and analyzing substances that have become adhered to investigation equipment, if any, in the usual manner to date is also being considered.

※※Methods to lower the water level in Unit 3 are being deliberated in preparation for fuel debris removal. At the same time, whether or not additional investigations using the submersible ROV used for the previous investigation are necessary is also being examined.

Reference: Purpose of sample analyses

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- Information obtained from sample analysis will be used to estimate sample characteristics and the distribution of fission products (FP) which will in turn be used to design fuel debris removal equipment and fuel debris container/storage equipment, formulate decommissioning plans, such as for keeping fuel debris subcritical, and select work methods.

Evaluation item (examples)	Analysis item and method (examples)	Use of analysis results (examples)
Property 1)Fuel-based objects ・composition of (U, Zr)O_2 ・content rate of Gd 2)Structural material based objects ・(Fe oxidizing, content of B)	Composition: SEM-EDS, TEM-EDS, ICP-MS Microstructure: TEM-EDS, Electron diffraction	・Formation mechanism is hypothesized from the microstructure of samples. ⇒Fuel debris removal, container/storage facility design ・Content rates of Gd and B are important for subcritical control
FP distribution (concentration of Cs, Sr)	FP composition: Radiation analysis, ICP-MS Burn-up: TIMS(quantitative Nd148)	・Initial amount of FP generated is estimated from burn-up rate to evaluate remaining percentage of FP. ⇒Container/storage facility design
Dose rate	Radiation analysis	・Used to reduce exposure during fuel debris handling
Machinability	Vickers hardness etc.	・Used to design cutting jig

- SEM: Scanning Electron Microscope, EDS: Energy Dispersive X-ray Spectroscopy, TEM: Transmission Electron Microscope, ICP-MS: Inductively Coupled Plasma Mass Spectrometry, TIMS: Thermal Ionization Mass Spectrometry

Reference: Package transport regulations

	Type A packages ※Amount of radioactivity does not exceed a specific value, and package is designed to ensure safety even in the event of normally foreseen events.	Type B packages ※Amount of radioactivity exceeds a specific value. However, safety is ensured by using a strong container that can sufficiently withstand a major accident.
Amount of radioactivity	Sum of A2 value ratio is 1 or less.	Sum of A2 value ratio is greater than 1
Dose equivalent rate	Dose equivalent rate of package surface ⇒ 2mSv/h or less Dose equivalent rate at 1m distance from package surface ⇒ 100μSv/h or less	
Surface contamination density	Surface contamination density of package ⇒ α : 0.4Bq/cm^2 or less ⇒ others : 4Bq/cm^2 or less	

※
A2 value : Radioactivity storage limit determined for each nuclide by law. Serious exposure would not ensue even if radioactive substance were to leak as a result of damage to the container.
(examples) ^{137}Cs＝0．6［TBq］, ^{238}Pu＝ 0．001［TBq］
A2 value ratio: Ratio between the level of radioactivity of the package and the limited value (A2 value) for each nuclide. If there are multiple nuclides, it is confirmed that the sum of A2 ratios for each nuclide is below 1.