Phase: **Design**

Decommissioning Process **"Fuel Debris Retrieval"**
Investigation Subject **"Strategy and risk"**
Issue **"Establishing fuel debris retrieval strategy"**

Needs

1. Identifying issues for fuel debris retrieval

Desired state and reasons for it

- In order to ensure the fuel debris retrieval, fuel debris needs to be safely retrieved with careful preparation and brought into a state of controlled and stable storage.
- It is also desirable to organize the items to be considered in anticipated throughputs and clarify issues to be addressed.
- Since the selection of a method requires specialized and intensive investigation, the "Subcommittee for Evaluation of Fuel Debris Retrieval Methods" was established under the Technical Committee on Decommissioning, etc., a committee of the NDF, with a resolution of the Committee in February 2023. The Subcommittee reported its findings to the Technical Committee on Decommissioning, etc. in March 2024. TEPCO plans to complete specific design investigations in about one to two years in accordance with the contents of the report and use the findings to proceed to the basic design phase.

Current state against ideal

- Fuel debris retrieval methods have not yet been finalized and are still under evaluation and study.
- A target of 10 years has been set for the fuel debris retrieval process. Meanwhile, the throughput evaluation under Government-led R&D Program on Decommissioning and Contaminated Water Management estimates that it will take about 4 years to construct access routes and 27.3 to 37.2 years for fuel debris retrieval.
- In order to determine the throughput, it is necessary to take into account not only the work processes, such as access to the PCV, positioning and cutting of fuel debris, packaging into the recovery container, and transfer, but also potential process delay risks, such as maintainability, buffer in case of trouble, and capacity of storage facilities.
- The main factors that make fuel debris retrieval difficult are as follows: (i) The interior of the PCV and RPV is subject to extremely high radiation levels (dose rates on the order of several Sv／h to several hundred Sv／h), making human entry impossible. (ii) The reactor building has high radiation levels (dose rates on the order of several mSv／h to several tens of mSv／h), limiting human entry to very short duration. (iii) Due to the constraints described in (i) and (ii), obtaining on-site information is difficult, and many aspects must be examined based on estimates that involve significant uncertainties. (iv) When using the existing reactor building and PCV as confinement barriers, it is necessary to consider accident-induced damage and aging degradation. Conversely, if constructing new confinement barriers, seismic resistance and other factors must be considered according to on-site conditions. (v) Although a subcritical state is maintained inside the PCV and RPV, it is necessary to consider the potential for criticality if changes occur in the distribution of fuel debris. (vi) To reduce the burden of waste storage and

management, it is necessary to minimize the amount of solid waste newly generated during decommissioning activities.

Issues to be resolved

- It is difficult to uniquely identify issues in fuel debris retrieval because it is necessary to proceed while constantly facing the unknown and flexibly reviewing the work, based on new knowledge obtained from various analyses and work experience, etc.
- As a method for systematically identifying issues inherent in the proposed fuel debris retrieval methodology, it is effective to examine the construction sequence—from preparatory work through fuel debris retrieval operations, maintenance, and completion of retrieval—and to extract issues within each process that may significantly affect on-site applicability and technical feasibility.
- Furthermore, by subdividing the construction sequence as much as possible, the comprehensiveness of the extracted issues can be improved.
- In addition, before proceeding to the next stage of examination, it is necessary to consider countermeasures for the identified issues and confirm that they can be addressed.

2. Establishing a comprehensive strategy for fuel debris retrieval

Desired state and reasons for it

- In order to optimize fuel debris retrieval, it is desirable to develop a comprehensive strategy for collecting fuel debris, including prioritization of the location and shape of the fuel debris to be retrieved, collection methods, and advance the state estimation based on the analysis results of collected fuel debris.

Current state against ideal

[Unit 1]

- Based on previous surveys and analyses using muons, it has been evaluated that there is almost no fuel debris in the core. In addition, an investigation inside the RPV has not been conducted yet, although the PCV internal investigation has been conducted so far.
- Compared to Units 2 and 3, the RPV and PCV are smaller in size due to the smaller plant output, and the layout of plant equipment is different. In addition, the distribution of sediments in the RPV and inside and outside the pedestal is expected to be different from those in Units 2 and 3, although this is expected to be clarified in future investigations.
- Although damage has been confirmed in part of the pedestal during PCV internal investigations, past R&D studies have shown through seismic evaluations—assuming a range of damage—that the support function would not be significantly impaired.
- R&D and engineering to apply the results to the site should be pursued, and the knowledge obtained through the test retrieval at Unit 2 and the gradual expansion of the scale of retrieval should be reflected to the design of equipment, retrieval procedures, safety assessment, etc. It is planned that the results of the investigation of the method in Unit 3, which is the preceding Unit, should also be reflected.

[Unit 2]

- A test retrieval is currently underway, after which the scale of retrieval will be expanded in stages.
- According to the PCV internal investigation(inside the pedestal) and the investigation and analysis using muons, etc. conducted so far, it is considered that a large amount of fuel debris exists at the bottom of the RPV. In addition, it is pointed out that there is a possibility to exist a

part of the fuel in the core. The fuel debris that fell to the bottom of the PCV is unlikely to have spread outside the pedestal.
- No survey has been conducted inside the RPV and outside the pedestal.

[Unit 3]

- The investigation of the method for further expansion of the scale of retrieval is underway ahead of other Units, and based on the recommendations from the "Subcommittee for Evaluation of Fuel Debris Retrieval Methods," investigations of retrieval scenarios and technical feasibility of the methods should be carried out.
- The PCV internal investigation (inside the pedestal) has been conducted so far, and it has been confirmed that the CRD housing support has partially fallen off and is deformed, and that several structures, including presumed in-core structures, have fallen down in the lower part of the pedestal. In addition, sediments that are presumed to be fuel debris have been confirmed.
- Furthermore, from muon surveys and analyses, it is estimated that more fuel debris than in Unit 2 fell into the pedestal and may have spread out of the pedestal through the worker access port.
- No survey has been conducted inside the RPV and outside the pedestal.
- TEPCO has conducted design studies for the fuel debris retrieval method for Unit 3 since FY2024, in accordance with the contents of the Subcommittee Report, and has compiled the results of examinations on the retrieval scenario, equipment planning, layout planning, and work schedule. The method is based on a combination of the air-based method and its optional variants, with key policies including access through small openings, standardization and simplification of fuel debris handling (such as processing and collection), and the combined use of top and side access approaches.
- In addition, TEPCO plans to construct a new "additional building" on the south side of the reactor building to house gas and liquid systems, power supply equipment, and other facilities. Two options are being considered for the support structure for top access: a north–south platform configuration and an east–west gantry configuration.

[All Units]

- Although damage to a part of the pedestal has been confirmed in the ongoing Unit 1 PCV internal investigation, it has been also confirmed in the past R&D that the seismic evaluation assuming the extent of damage does not significantly impair the support function.

Issues to be resolved

[Unit 1]

- As for the utilization of the knowledge to be obtained through the test retrieval at Unit 2, it is necessary to reflect, for example, the status of existing structures and distribution of sediments, distribution of gamma radiation and neutron counts, the degree of impact on confinement caused by loading and unloading of equipment, and information on fuel debris to be collected during the retrieval in equipment design, retrieval procedures, safety assessment, etc.
- In addition, it is necessary to investigate the retrieval method considering the results of the investigation of the method in the preceding Unit 3.
- Although it has been evaluated that there is almost no fuel debris in the core from the survey and analysis using muons, it is not a direct, so a direct video survey is required in the future investigation.

[Unit 2]

- Since not all of the fuel debris is planned to be retrieved by the side access method, it is necessary to investigate the method for further expansion of the scale of retrieval.
- Considering the knowledge to be obtained through the test retrieval, it is necessary to proceed with the design, fabrication, and installation of fuel debris retrieval facilities, safety systems

(confinement, fuel debris cooling, criticality control, etc.), maintenance facilities for fuel debris retrieval and storing facilities.

- It is necessary to investigate the method, taking into account the possibility that some fuel may remain in the core.
- Since the investigation outside the pedestal has not been conducted, a direct video survey is necessary in future investigation.

[Unit 3]

- In order to increase the certainty of the selected method, it is necessary to investigate plans for surveys to understand the distribution of sediments outside the pedestal, as well as additional surveys in the pedestal and in the RPV, and to reflect the results of these surveys in the investigation and design of the method.
- In investigating the method, it is necessary to investigate confinement facilities considering the damage status of the reactor building.
- While adopting the east–west gantry configuration as the primary option for the top-access support structure, it is necessary to remain open to flexible revisions, including a shift to the north–south platform configuration or the removal of the waste-processing building.

[All Units]

- It is necessary to enhance the knowledge through internal investigations, etc., and to consider the events during the accident inferred from the discharge of high-temperature sediments (fuel debris) out of the pedestal. Taking these knowledges and considerations into account, it is necessary to investigate the method of retrieving sediments inside and outside the pedestal, the possibility of sediments flowing into the S／C, etc., and to reflect the knowledge obtained from the internal investigation in the fuel debris retrieval method, including those of other Units.
- Since the information obtained so far about the inside the PCV of each Unit is limited and there are many areas where direct visual information has not been obtained, investigations on further surveys such as internal investigation of the PCV and RPV of each Unit should be proceeded to collect more information at an early stage, including the damage situation at the bottom of the RPV and the existence and distribution of sediments outside the pedestal.
- Maintenance of remote equipment and restoration in case of failure also need to be considered. It is necessary to investigate a method considering the entire work sequence from preparation to retrieval and the throughput, and it is necessary to select a method that can be used for retrieval even if the entire site situation cannot be identified, and a method that is not affected by external events such as earthquakes (robust method).
- After retrieving the fuel debris, it is necessary to investigate the criteria for shifting to building dismantling. In other words, it is important to determine to what extent fuel debris retrieval can be said to be complete and how to confirm this.
- Furthermore, based on the results obtained during the preparation phase for Unit 3, it is important to consider the horizontal deployment of knowledge to Units 1 and 2, as well as the overall optimization of work processes and equipment design, including parallel operations and the sharing of support systems.

Relevant Issues

- FDR-101 “Understanding status of fuel debris”
- FDR-104 “Understanding doses inside PCV and RPV”
- FDR-105 “Collection of knowledge on conditions inside PCV”
- FDR-211 “Ensuring structural integrity of PCV and buildings”
- FDR-301 “Fuel debris retrieval inside PCV”

- FDR-302 “Fuel debris retrieval inside RPV”
- BST-006 “Risk assessment”