B1 Work Environmental Improvement Inside and Outside of Reactor BuildingB1 Development of Technologies for Work Environmental Improvement in ReactorBuilding

[Purpose]

Towards the scaling up retrieval of fuel debris and internal structures, technology development related to work environmental improvement shall be implemented as it is necessary for the safe and efficient work inside the Reactor Building (R/B) where there are still places with the damage status caused by the accident is unknown and the dose rate is still high.

<Current issues (Technologies to be necessary)>

A remote monitoring and removal operation system shall be developed for the removal of Primary Containment Vessel (hereinafter referred to as "PCV") penetration pipes etc. as a technological development related to work environmental improvement. In the previous subsidized project ("Development of Remote Handling Technologies for Obstacles Removal and Work Environmental Improvement"), removal technologies had been developed for obstacles in high place (cable trays etc.), heavy objects (shielding etc.) and pipes etc., elemental tests had been conducted, and fundamental specifications of the device had been proposed to summarize issues of the development and countermeasure policies for the actual application. Based on these results, engineering by Tokyo Electric Power Company Holdings, Inc. has been investigated. However, in order to promote the work environmental improvement inside of the R/B, with regard to the removal of high dose PCV penetration pipes etc. which exist in the narrow area inside of the R/B and have a possibility to include contaminated fluid and hydrogen etc. inside, the technical issues from the perspectives of safety and reliability such as corresponding for crowding and ensuring the monitoring under the situation obstacles exist

The following main issues shall be implemented.

- Reduction of dose rate
- Removal of pipes containing hazardous materials
- > Remote operation of work monitoring and removing pipes

<Development in fiscal 2025>

Systems for Remote Monitoring and Removal Operation for Removal of PCV Penetration Pipes etc.

B2 Investigation Inside of PCV/RPV, Fuel Debris Characterization B2② Development of Investigation Technology of Inside of RPV

[Purpose]

In order to contribute to consideration concerning fuel debris retrieval from inside of Reactor Pressure Vessel (RPV), the investigation technology for grasping the situation with fuel debris etc. inside of RPV shall be developed.

 $<\!\! \text{Current}$ issues (Technologies to be necessary) $\!\!>$

In order to verify the situation inside the RPV and the internal conditions such as radiation dose, ensuring confinement functions by remote operations under the environmental conditions such as high-dose radiation and highly radioactive contamination, it shall be developed a drilling device to construct an access route (new opening work etc.) and a device and system to carry the investigation equipment into the RPV as the purpose of this project.

For investigation inside the RPV, actual applicability of two types of methods had been examined until FY2019: one was to get access to the reactor core from the top and the other was to get access to the reactor core from the side. It is assumed that it takes a certain amount of time to apply them to the site. Therefore, it had been considered important to advance the development of a method that has the potential to carry out the internal investigation of the RPV earlier. From FY2020, the development of access from the bottom of the RPV to investigate inside the RPV has been proceeded by inserting the investigation devices thorough the opening that assumed to exist at the bottom of the RPV. Furthermore, a method to drill PCV head, RPV head etc. from the side starting from the dryer separator pit and an investigation of inside of RPV by using existing pipes shall be considered. It is important to develop the device and system necessary for this investigation.

The following main issues shall be implemented.

- Access method into RPV
- Investing device
- > Acquisition of inside information

<Development in fiscal 2025> Access-from-Top/Side Investigation Method Access-from-Bottom Investigation Method Investigation Technology of Inside of RPV by using Existing Pipes $\mathsf{B2}\textcircled{3}$ Development of Analysis and Estimation Technology for Characterization of Fuel Debris

[Purpose]

In order to contribute to the development of fuel debris retrieval method and internal structures and technologies for containing, transportation and storage of fuel debris, technology necessary for quantitative analysis of components and estimation for characterization of fuel debris shall be developed.

<Current issues (Technologies to be necessary)>

It is necessary that the data and information on fuel debris and deposits, etc. obtained inside of the PCV, shall contribute to grasp the properties of fuel debris that exist inside the reactor, by way of conducting the investigation of retrieval, containing and storage, and subsequent processing and disposal, etc. of fuel debris. Also, to ensure that the data and information thus acquired is useful for decommissioning, it is necessary to develop technologies for analyzing fuel debris retrieved and samples obtained in PCV internal investigations, etc. as well as for correctly estimating the fuel debris and surroundings and those conditions expected in the future.

It is presumed that fuel assemblies and the control rods had been melted in the reactor at a temperature higher than normal operation temperature in superheating steam and then they had been flown out from RPV involved surrounding structures. Thus, it is presumed that the chemical composition and structure of the fuel debris are considerably quite complicated and unequal since many substances existed in the area where melting and solidification occurred, and the temperature history was unclear. It is important to determine the properties of fuel debris comprehensively based on the analysis results of not only chemical composition but also chemical form and crystal structure. In addition, since the analysis is performed in parallel with the fuel debris retrieval works, the development of analytical technology for simplified and speed-up detection of fuel components at or near the work site (in-situ) is essential. The following main issues shall be implemented.

- Advancement of analytical ability
- > Abbreviated (In-situ) analysis of fuel debris
- > Nondestructive measurement technology of fuel debris

<Development in fiscal 2025>

Analysis and Estimation Technology for Characterization of Fuel Debris Technology for Abbreviated Analysis and Non-destructive Measurement of Fuel Debris B3 Retrieval System, Safety System, Maintenance System, Storage Equipment B3 1 Development of Fuel Debris Retrieval Method

[Purpose]

Towards scaling up retrieval of fuel debris and internal structures, development of elemental technology and tests necessary for retrieval method feasibility shall be conducted and on-site applicability shall be evaluated.

<Current issues (Technologies to be necessary)>

Assuming the fuel debris retrieval conducted by remote operations under high radiation dose and high contamination with uncertain environmental 2 conditions, the technology development is underway to ensure long-term continuous works of fuel debris retrieval. Since FY2024, basing on proposals etc. regarding the selection of methods indicated in the Report of "Sub-committee for the evaluation of fuel debris retrieval methods", the detailed design considerations are studied. Also, the scenario of the retrieval and the feasibility of retrieval method are studied. In these considerations, among the new issues identified, the issues that specify high necessity for development or high technological difficulty shall be developed.

The following main issues shall be implemented.

> Technologies for Continuous Fuel Debris Collection

<Development in fiscal 2025>

Technology for continuous effective collection of granular fuel debris deposited at the bottom part of PCV

B3② Development of safety systemB3②-2 Development of analytical technology for contamination monitoring

[Purpose]

Towards scaling up retrieval of fuel debris and internal structures, tests and elemental technology development necessary for ensuring of safety during works shall be conducted.

<Current issues (Technologies to be necessary)>

During the fuel debris retrieval radioactive dust dispersion suppression, removal of heat generated by processing, cooling of fuel debris etc. it is necessary to conduct spraying and blasting cooling water onto fuel debris. Due to the contact of fuel debris, nuclear fuel materials and radioactive elements are dissolved into the circulating cooling water in the liquid processing system. Additionally, gaseous radioactive materials are also precipitated as fine particles due to decay or chemical changes. Nuclear fuel materials and radioactive elements in fluids such as water and gas are adhered to walls and floors or mixed with existing stagnant water and cooling water. Because of that, the contamination is distributed over a wide area in the building. Although the concentrations of these nuclear fuel materials and radioactive elements are lower compared, large number of samples need to be collected for monitoring the contamination levels. Therefore, in the analysis targeting the samples which include nuclear fuel materials and radioactive elements, etc. for contamination monitoring in the reactor building, technology development for acceleration, efficiency, automation and laborsaving of the pretreatment etc. shall be conducted.

The following main issues shall be implemented.

- > Analysis of nuclear fuel materials and elements etc. with difficulty
- > Acceleration or efficiency technology of analysis

<Development in fiscal 2025>

Technology of accelerated and efficient analysis for α radioactive elements Technology of accelerated and efficient analysis for β radioactive elements Technology for accelerated pretreatment of low-energy radioactive elements B32-3 Development of Technologies for Impact Assessment due to Dust Dispersion

[Purpose]

Towards scaling up retrieval of fuel debris, necessary for ensuring safety of retrieval works technology shall be developed for assessment of dust dispersion impact.

<Current issues (Technologies to be necessary)>

For scaling up retrieval of fuel debris, it is necessary to develop safety assessment techniques for the retrieval methods under consideration for normal operations and an event of accident. It has been in progress the acquisition of fundamental data on dust dispersion under both dry and wet conditions to understand the impact due to dust dispersion generated during fuel debris retrieval. Furthermore, it is necessary to estimate the actual impact of dust dispersion from data obtained during the processing of fuel debris and optimize safety assessments of the next stage.

- > Test in PCV inside conditions (wet, water, partial water)
- > Acquisition of dust dispersion and migration data during processing of fuel debris
- > Safety assessments using dust dispersion data

<Development in fiscal 2025>

Acquisition of Dust Dispersion Rate Data using simulated debris (cold materials, uranium-containing simulated debris, etc.) in assumed environments (wet conditions, etc.)

Test of dust migration behavior to environment using large-scale test equipment

B32-4 Technology Development of Analytical Method for Exposure Dose Evaluation

[Purpose]

Towards scaling up retrieval of fuel debris and internal structures, the elemental technologies to ensure safety during these operations shall be developed and conducted the tests.

<Current issues (Technologies to be necessary)>

In scaling up retrieval of fuel debris and internal structures, it is essential to ensure the safety of workers by checking regularly that 2 there is no intake of α -nuclides and other nuclides into the body. In case of an unlikely event of radiation intake, it is necessary to know quickly the amount of the radioactive materials taken in and evaluate the exposure dose to take appropriate actions in an early stage. In case of an intake of α -nuclides and other nuclides, due to the situations from a difficulty of α -ray measurement, an excessively high internal exposure dose conversion factor, etc., an evaluation by bioassay etc. is essential. The Fukushima Daiichi NPS differs significantly from existing facilities in Japan and overseas in terms of the nuclide composition and concentration of radioactive materials to be handled, the status of work and the number of workers to be managed and other factors of the working environment related to decommissioning. Considering these situations technically and comprehensively, it is required to develop a new protocol used for analysis and measurement including the development of hardware.

The following main issues shall be implemented.

- Protection technology of internal exposure
- Measurement technology of internal exposure
- Evaluation of internal exposure

<Development in fiscal 2025>

Technology for Measuring and Evaluating Internal Exposure

Technology for Measuring and Evaluating Body Contamination

 $\mathsf{B3}(4)$ Development of Technology for Containing, Transportation and Storage of Fuel Debris

[Purpose]

In order to establish a scenario for the process from fuel debris retrieval to its storage, the system shall be developed for safe, secure and reasonable containment, transportation and storage of retrieved fuel debris.

<Current issues (Technologies to be necessary)>

To ensure the containment, transportation and storage of retrieved fuel debris to be done safely, securely and reasonably, it is 2 necessary to have storage containers including canisters (hereinafter referred to as "storage containers"),

equipment/facilities for transportation and storage, as well as treatment and handling methods and procedures that are appropriate for the characteristics and conditions of retrieved fuel debris. Particularly, some of the powdery fuel debris generated during the fuel debris cutting or crushing process in the retrieval process is planned to be collected in the cooling water circulation system etc., which is expected to result in slurry/sludge-like fuel debris. In cooperation with related research and development projects, investigations on measures against hydrogen gas generation (advancement of hydrogen gas generation prediction method and establishment of measures for hydrogen gas accumulation) shall be conducted.

To safely, reliably, and reasonably store fuel debris, it is important to maintain the integrity of the containment boundaries of the storage containers. To examine the necessity of monitoring corrosion of the storage containers that could affect the integrity of the containment boundaries, it is necessary to develop and verify a corrosion progression models based on the materials of the storage containers and other factors affecting corrosion such as. storage conditions of the storage containers. The following main issues shall be implemented.

- Safety ensuring of handling slurry/sludge state fuel debris
- > Transportation technology of slurry/sludge state fuel debris
- Storage technology of slurry/sludge state fuel debris

<Development in fiscal 2025>

Technology for handling of powdery and slurry/sludge state fuel debris Technology for maintaining the stable storage of fuel debris B3(5) Development of Assistive Technologies for Integration Management of Decommissioning of the Fukushima Daiichi Nuclear Power Station

[Purpose]

Technologies related to the assistive system necessary for smooth integration management of decommissioning of the Fukushima Daiichi NPS (1F) including scaling up retrieval of fuel debris and internal structures shall be developed.

<Current issues (Technologies to be necessary)>

An information management system which enables accurate and quick on-site response by longterm and continuous monitoring of environmental changes during the fuel debris retrieval, and by integrating and sharing the operation data including monitored data and trouble information, technological development using digital technologies is studied. Therefore, examination of "overall concept of assistive system for integration management" and development of "the integration management technology development using digital technologies" is important.

The following main issues shall be implemented.

- > Conceptual study of system for integration management
- Digital twin technology
- > Construction of database for integration management

<Development in fiscal 2025>

Assistive technologies for integrated decommissioning management of 1F

C Research and Development of Processing and Disposal of Solid Waste

[Purpose]

Considering the prospects of processing and disposal method and technology related to its safety, as provided in FY2021, in order to form waste streams suitable for the characteristics of solid wastes, proceeding the progress of waste characterization, it shall be conducted to develop, compare, and evaluate storage/management, processing, recycling and disposal options and planned to investigate towards presenting the appropriate measures for the practical solid waste overall management (management from solid waste generation up to its recycling and disposal).

<Current issues (Technologies to be necessary)>

Regarding the measures for solid waste, further possibilities for more waste volume reduction shall be examined and in order to construct waste streams suitable for the characteristics of solid waste studies shall be conducted towards presenting appropriate measures for practical solid waste management.

The following main issues shall be implemented.

- To reflect the overall solid waste management, acquisition and management of analysis data shall be conducted, and activities for efficient waste characterization shall be proceeded
- For safe and reasonable storage and management, reduction and recycling technologies shall be developed to reduce the amount of waste.
- With respect to processing technology, an investigation shall be conducted on issues related to the applicability of low-temperature processing, the stability of the solidified waste manufactured by various processing technologies, the interim processing technology contributing to expanding the range of applications of the low-temperature processing technology, and flexible and reasonable processing technology.
- With respect to disposal technology, the proposal of disposal concept options shall be established and presented, as well as critical scenarios affecting safety functions of a disposal site shall be identified to assess its safety.

<Development in fiscal 2025>

Waste characterization

- Acquisition and management of analytical data to be reflected in the overall solid waste management
- Enhancement of efficiency of waste characterization

Storage/management

- Development of Technologies for reduction and recycling Contaminated Metals Processing and disposal
- Addressing issues related to the applicability of normal-temperature processing technologies (some new)
- Bulk solidification technology development for rubbles etc. difficult to segregate
- Presentation of the proposal of disposal concept options and development of safety assessment technology