Phase: **Design**

Decommissioning Process **"Fuel Debris Retrieval"**
Investigation Subject **"Confining radioactive material"**
Issue **"Establishing confinement function"**

Needs

1. Repairing PCV penetration points to stop water leakage and safely managing water inside the PCV

Desired state and reasons for it

- In order to improve the confinement function of the lower liquid phase of the PCV and to prevent the diffusion of radioactive material, it is desirable to establish repair and water stoppage technologies for PCV penetrations.
- In order to carry out water stoppage work appropriately, it is desirable to clarify the field applicability of the work corresponding to each water stoppage method (including vent pipe water stoppage, downcomer water stoppage, and strainer water stoppage).
- In order to improve the containment function, it is desirable to identify leak paths in the PCV under a high dose environment.
- In addition, while ensuring consistency with the examination of fuel debris retrieval methods and long-term contaminated water countermeasures, it is desirable to further reduce the volume of retained water inside the PCV.

Current state against ideal

[General]

- In order to improve the containment function, it is desirable to identify leak paths in the PCV under a high dose environment.
- The PCV and the reactor building (torus room) have been confirmed to have penetrations and to have been damaged by the earthquake. At present, the water level difference with the groundwater has been maintained to prevent contaminated water containing radioactive material from flowing out from the reactor building to the soil outside the reactor building.
- In order to ensure the reliable confinement function, water stoppage by repairing the lower part of the PCV has been investigated. Based on the results of the previous investigations, it has become clear that it is difficult to completely stop water leakage by repairing the lower part of the PCV. Considering the PCV repair technology and the results of its actual scale test, the confinement function, including a system that combines leak suppression by applying water stoppage technology with a cooling water circulation and purification system are considered.
- In Unit 1 and 3, a drop in the PCV water level was confirmed after the February 13, 2021 earthquake off the coast of Fukushima Prefecture. When conducting internal investigation of the Unit 1 PCV using a submersible ROV, the risk of interference with sediments, etc. increases when the water level is low, so it is being investigated increasing the water injection volume to raise the water level to the pre-earthquake level and then returning the increased water injection volume after the survey is completed to lower the water level to the current level.
- As one of the debris removal methods, a flooding method (ship hull method) is being considered. In this method, the entire reactor building is surrounded by a new structure called a

hull structure as a confinement barrier. This structure is useful for sealing the upper part of the PCV, which has been an issue with the conventional flooding method.

[D/W water stoppage]

- In order to improve the confinement function, it is desirable to identify leak paths in PCV in a high dose environment.
- In order to improve the confinement function of the liquid phase in the lower part of the PCV, several methods, such as vent pipe sealing, downcomer sealing, and strainer sealing, have been investigated to control the leakage of cooling water into the torus room. Based on discussions in Government-led R&D Program on Decommissioning and Contaminated Water Management, the application of the current water stoppage technology involves difficult problems. If water stoppage work is to be performed, even partially, it is necessary to consider the water level in the PCV, the PCV circulation cooling system, and the water level control during the water stoppage work on the vent pipe. In addition, due to the small seismic margin of the S／C support column and the existence of leakage routes other than the S／C, investigation is under way on a circulating cooling system in combination with water level control in the PCV and the torus room.

Issues to be resolved

- In order to confirm and investigate the influence of fuel debris retrieval operations on the liquid phase, it is necessary to monitor the circulating water system. At the same time, to reduce the concentration of radioactive materials at the inlet of the existing water treatment facilities, it is necessary to consider adding or installing new facilities. Based on the monitoring and evaluation of changes in the status of liquid waste including alpha nuclides, it is desirable to expand the scale of fuel debris retrieval gradually.
- In order to control the expansion of contamination and to prevent contaminated water from diffusing from the Jetdiff to the S／C, it is necessary to establish water stoppage technology, including the installation of a closure plate on the Jetdiff or a weir in the D／W.
- In order to prevent the expansion of contamination to the S／C, currently the method of dividing the formwork to carrying it is used (feeding dry mortar into the foldable formwork (mesh)). In this method, issues are to complete the work under the time constraint until the mortar hardens, and to select a mesh bag with the optimum roughness and quality.
- Considering the possibility of underwater work, it is especially necessary to have a water stoppage technology workable in a flowing water environment.

2. Maintaining the gas confinement function

Desired state and reasons for it

- It is desirable to establish a confinement function for the building and the gas phase of the PCV in order to suppress external diffusion of radioactive particles generated during debris retrieval and to control the dose effect on workers and the public within an acceptable range, assuming the presence of alpha-emitting nuclides. At that time, it is desirable to multiplex the confinement function including the PCV.
- In order to maintain the negative pressure control, it is desirable to confirm the technical feasibility of maintaining the negative pressure based on the on-site information such as the damage status of the PCV, etc.
- In addition to strengthening confinement functions, it is also desirable to enhance monitoring capabilities, including measures to suppress dust dispersion during retrieval work, improvement

of dust concentration monitoring inside the PCV, and the estimation of dust migration outside the PCV by understanding the correlation between retrieval activities and in-PCV dust concentrations.

Current state against ideal

[General]

- In the Fukushima Daiichi NPS, the reactor building, the PCV, etc. were partially damaged by hydrogen explosions, degrading the confinement function. Therefore, for the construction of a dynamic confinement function by negative pressure control during fuel debris retrieval is considered. At present, nitrogen is injected into the PCV to maintain a nitrogen atmosphere in order to prevent hydrogen explosions due to hydrogen regularly generated by water radiolysis and to prevent corrosion by oxygen of structural materials (inactivation). Radioactive material release is controlled in this exhaust gas by the PCV gas control system, which removes radioactive material with filters and measures radioactivity.
- Accessing the inside of the reactor for fuel debris retrieval will adversely affect the confinement state maintained currently. In addition, special operations and maintenance work in the fuel debris retrieval process will increase the radiation exposure of the workers engaged in the work.
- During the drill opening of the inner door of the X-2 penetration for the internal investigation of the PCV of Unit 1, changes in dust concentration (in June 2019, the dust monitor for work monitoring reached the control value) were confirmed. At that time, the work was conducted with limited cutting volume, and based on the obtained data on dust diffusion characteristics, measures were taken such as cutting with controlling peak concentrations and the addition of a new dust monitor for work monitoring. Considering this, in Unit 2, preparations are underway for low-pressure water washing of sediments, spray curtains to the penetration outlet, and measures to reduce the pressure in the PCV.

[Determining the feasibility of negative pressure management in the PCV]

- In order to maintain negative pressure inside the PCV, an exhaust ability is required according to the damage status of the PCV. The exhaust ability is set based on the data of the nitrogen supply volume in the actual equipment and PCV pressure fluctuations, although the damaged parts have not been identified yet.

[Necessity of a secondary confinement function]

- In case the primary confinement function with negative pressure control is lost and causes radioactive material to leak from the confinement boundary, the necessity of a secondary confinement function is considered, by installing a building cover or a container in the existing reactor building, that enables the reactor building to control at a slight negative pressure and collect and process radioactive material.

Issues to be resolved

[General]

- Assuming the possibility of increasing impact on the surroundings, it is necessary to construct a confinement function of equalizing or reducing pressure inside the PCV and to determine the necessity of installing a secondary confinement function.

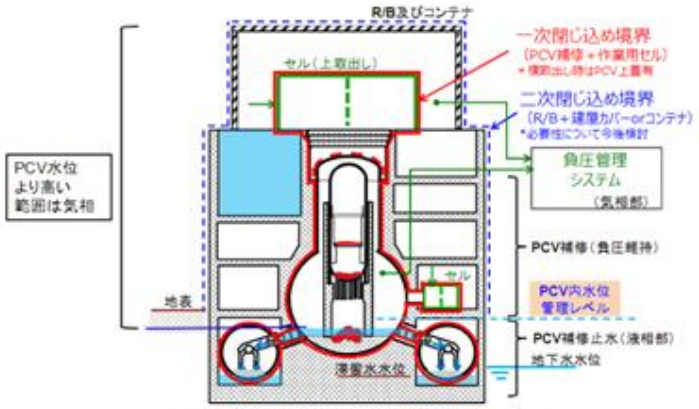

図 20　負圧管理による閉じ込め機能（気相部）の構築例

- If leakage in the gas phase of the PCV can be detected, leakage of radioactive materials inside the PCV to the outside can be controlled and prevented. Further, if the leakage area can be blocked by repairing, etc., the risk of external leakage of radioactive materials can be reduced more. In doing so, it is required to develop a technology that takes into account the following factors: the extremely high radiation air dose rate near the outside of the PCV makes the workers inaccessible; the many narrow areas make it difficult for the workers and equipment to enter; and the outer wall of the PCV has a very complicated shape with numerous pipes penetrating through it, etc. These are getting important more and more in retrieving the fuel debris.

[Determining the feasibility of negative pressure management in the PCV]

- It is necessary to set the differential pressure with a margin to prepare against a pressure rise inside the PCV due to abnormal events, such as an inside temperature rise or stoppage of the exhauster.
- If necessary, repair of the upper part of the PCV will be considered. Such repairs, performed under high radiation doses, require remote work, or otherwise involve such problems as worker exposure. It is important to determine the technical feasibility of maintaining the negative pressure inside the PCV, based on the field conditions and the information obtained during the fuel debris retrieval.
- It is necessary to conduct, step by step, those tests that are feasible with the current system configuration, such as adjustment tests of nitrogen supply and exhaust flow rates.

[Necessity for a secondary confinement function]

- The volume of the reactor building is large, and the airtightness of the building may decrease due to the accident. For this reason, a large-scale exhauster will be needed to maintain the negative pressure. Therefore, it is necessary to specify the functionality required as a secondary confinement function and to develop relevant technology, based on the results of the dust dispersion trend.

3. Detecting leakages

Desired state and reasons for it

- In order to prepare against leakage of radioactive material from the confinement boundary, it is desirable to measure and control (monitor) the concentration and amount of the material released, on a regular basis, and to take measures to mitigate the impact of abnormal events including unexpected leaks, by detecting them promptly.

Current state against ideal

- TEPCO is monitoring radiation levels at the boundary of the Fukushima Daiichi Nuclear Power Plant site and around the buildings.

Issues to be resolved

- In the management of exhaust air accompanied with negative pressure control, radioactive materials in gaseous wastes that may contain nuclear fuel material derived from fuel debris should be maintained below the dose standard for the public around the facility, by measuring and controlling the released concentration and amount.
- It is necessary to add alpha- and beta (gamma)-emitting nuclides derived from fuel debris to the scope of evaluation, and to evaluate in advance the range of normal fluctuation by conducting regular monitoring and measurement during fuel debris handling work, so that abnormal events such as leaks can be detected at an early stage and appropriate mitigation measures can be taken, thereby preventing impacts on workers and the environment.

Relevant Issues

- FDR-102 “Understanding status of structures inside PCV and RPV”
- FDR-103 “Understanding status of FP”
- FDR-105 “Collection of knowledge on conditions inside PCV”
- FDR-204 “Site boundary dose assessment”
- FDR-211 “Ensuring Structural Integrity of PCVs and Buildings”