Phase: **Design**

Decommissioning Process **"Fuel Debris Retrieval"**
Investigation Subject **"Structural integrity"**
Issue **"Ensuring structural integrity of PCV and building"**

Needs

1. Inspecting and monitoring structures for integrity

Desired state and reasons for it

- In order to maintain the support functions of important equipment and facilities such as the PCV and the RPV for safe fuel debris sampling and retrieval, it is desirable to inspect and monitor the integrity of the structures that have functions to be maintained (including the support function and the confinement function).
- For the inspection and monitoring, it is desirable to develop accessibility, installation, and evaluation methods for inspection equipment. In addition, alternative inspection or monitoring methods and maintenance technologies are desirable for cases where access is not possible due to a high radiation environment.
- Careful measures need to be taken to maintain the long-term integrity of RPVs and PCVs, including their confinement performance and the strength of the reactor building, against the threat of loss of strength and deterioration of confinement performance caused by corrosion of metal materials and loss of strength of the affected concrete structural materials.
- For this purpose, it is particularly necessary to diligently confirm the status of damage inside the PCV and to evaluate the integrity of the PCV based on the latest information on the inside of the PCV, assuming long-term risks that may occur in the future, such as earthquakes and age-related deterioration. Although there is always uncertainty in this evaluation due to the limited information on the damage status, it is necessary to update the data to be evaluated and reflect the latest in-vessel information to reduce the uncertainty.

Current state against ideal

- Due to the earthquake that occurred off the coast of Fukushima Prefecture on February 13, 2021, a drop in the PCV water level was confirmed in Unit 1 and 3. It is assumed that this drop in water level may have been caused by an increase in the amount of leakage from inside the PCV due to changes in the status of the PCV damaged areas that have been confirmed so far and the occurrence of new damaged areas. The necessary technology development is required to strengthen the monitoring system to grasp changes in plant conditions, to evaluate the impact of such changes on the maintenance and management of facilities and buildings with a medium- to long-term perspective, and to understand the status of the plant.
- Since the suppression chamber (hereafter S／C) legs are submerged by stagnant water, it is assumed that corrosion thinning will progress. Therefore, in order to suppress corrosion thinning in Government-led R&D Program on Decommissioning, Contaminated and Treated Water Management, an electrolytic corrosion prevention method considering the actual equipment environment is being investigated.
- A survey conducted in 2023 in the PCV of Unit 1 revealed the loss of concrete in the pedestal section. Based on this result, it was determined that the following should be done: (1) evaluating

the impact of dust dispersion at the site boundary, including the case when the RPV sinks to cause an opening equivalent to a main steam pipe in the PCV, based on the assumption that the support function of the pedestal cannot be expected, (2) implementing possible countermeasures regardless of the evaluation results, and (3) conducting evaluation regarding the structural impact on the RPV and PCV in the event that the support function is lost and the RPV sinks.

- Regarding the evaluation of the loss of support function, it is evaluated that this function will not lead to large-scale damage as a result of the strength evaluation assuming earthquake motion.
- A survey of the interior of the PCV (part of the PCV that remains in the air) was conducted by a small wireless drone in February 2024. The information obtained from the survey was as follows (1) No major damage was found on the outer wall of the pedestal. In addition, although there were some fallen objects outside the CRD replacement opening, it was confirmed that the existing structure generally maintained its shape and that there were no notable obstructions around the CRD replacement rail. (2) The CRD housing (including several CRD-related devices) that had fallen off was partially blocking the CRD replacement opening in the pedestal, and a lumpy object (some parts of which looked like icicles) was observed attached to the top of the housing, which was presumed to have migrated from the above. (3) No significant damage was observed on the inside wall of the pedestal, and existing facilities such as cable relay boxes and openings of existing TIPs (mobile in-core instrumentation) were also observed.

Issues to be resolved

- It is required that the monitoring system is strengthened to understand changes in plant conditions, impact assessments are made to manage the maintenance of equipment and buildings with a medium- to long-term perspective, and the necessary technology is developed to understand the status of the plant.
- As concrete is constantly changing in response to the environment, it is necessary to constantly evaluate concrete deformations by image analysis, install accelerometers to monitor responses to small earthquakes and peculiar deformation behaviors, and evaluate building rigidity based on the vibration properties. In addition, in order to understand the allowable amount of deformation, it is desirable to continuously monitor not only cracks and corrosions but also deformations and fractures.
- For structures that cannot be accessed due to the high-dose environment, or for structures that cannot be inspected sufficiently for structural integrity even with remote technology, it is necessary to develop methods to estimate the condition and environment of the structure (including statistical analysis methods and various testing methods).

2. Evaluating structures for long-term integrity

Desired state and reasons for it

- In order to take measures to maintain the functions (including the support function and the confinement function) to be maintained by important equipment and facilities such as the PCV and the RPV, it is desirable to understand the effects of the accident, the earthquake resistance of structures based on aging and deterioration, and the effects of damage suffered in the accident. In such a case, it is desirable to evaluate the integrity of the structures by analyzing the accident progress, using the status and condition of the structures obtained from actual plant investigations.
- In order to maintain the integrity of structures and piping, which forms a boundary having a function of confining radioactive materials during the debris retrieval, it is desirable to

understand the degradation phenomena such as corrosions under various conditions, including high-radiation environments, environments influenced by microorganisms originating from seawater or groundwater, environments in which oxygen-containing air flows into the PCV due to negative-pressure control, and conditions in which corrosion progresses continuously during the decommissioning process. With respect to corrosion degradation, coordinated measures are required, as significant differences may arise depending on the methods adopted to ensure confinement functions, which can lead to changes in oxygen concentration inside the PCV.

- It is desirable to be able to confirm the presence or absence of degradation (for example, corrosion and cracks) specific to the 1F environment in a flow in the gas and liquid phases.
- In order to evaluate the long-term integrity of structures, it is desirable to produce outputs with high accuracy by combining the inspection and evaluation methods.

Current state against ideal

- The PCV, which forms a confinement boundary for use in the atmosphere, is made of carbon steel with low corrosion resistance. After the accident, the 1F is forming a special environment containing suspended matter and deposit with high radiation under high room temperature and knowledge about corrosion phenomena in this environment is insufficient. Water is supplied into the PCV to cool fuel debris, and carbon steel is immersed in water. It is also known that oxidizing chemical species such as hydrogen peroxide and various radical species are generated by radiolysis of water.
- If the PCV is maintained under negative pressure during fuel debris retrieval, the oxygen concentration will increase due to an air inflow, and there is a concern over a progress of corrosion in structural materials of the RPV and the PCV and necessary piping. Based on the past investigations, however, it is expected that the seismic safety margin against standard earthquake motions can be secured even if reduced steel thickness due to corrosion for 40 years is taken into account.
- For further corrosion inhibition measures, on the other hand, Government-led R&D Program on Decommissioning and Contaminated Water Management is investigating the applicability of corrosion inhibition measures to prevent corrosion of structural materials of the RPV and the PCV and necessary piping over the long-term decommissioning period and maintain the current status in actual equipment.
- For the PCV, the RPV, and the piping, the effectiveness of corrosion inhibitors for steel materials has been tested in consideration of the effects of radiation environment and seawater input. Candidates for effective corrosion inhibitors have been identified for general or localized corrosion. In addition, methods for visualizing corrosion conditions on steel surfaces and for estimating the causes of corrosion are being examined.
- In order to control corrosion thinning of the S／C pedestal, which is submerged by stagnant water, an electrolytic corrosion prevention method considering the actual equipment environment is being investigated in Government-led R&D Program on Decommissioning and Contaminated Water Management.
- The survey in the PCV of Unit 1 conducted in 2022 and 2023 confirmed that a part of the concrete in the pedestal was missing.

Issues to be resolved

- While steadily advancing efforts to confirm the damage conditions inside the PCV and obtaining the necessary information, it is also necessary to carry out integrity evaluations of the PCV and the reactor building, taking into account future hazards such as earthquakes and aging degradation. Since the information obtainable from damage-condition investigations is limited

for the purpose of integrity evaluation, it is essential to continue investigations and data collection in order to reduce uncertainties and to update the data used for evaluation.

- In order to mitigate the effect of corrosion inhibitors on the existing circulating water cooling and purification system, it is necessary to reduce the concentration of corrosion inhibitors at the preliminary stage of purification. In future investigations on the PCV circulating cooling system, it is necessary to comprehensively examine the measures for corrosion inhibition and the measures for satisfying other required functions.
- In particular, the possibility of corrosion of the S／C legs will be an issue. It is essential to develop a monitoring method for the position. Since inspection is difficult, combination with evaluation technology is required.
- Further investigation is needed on the long-term deterioration of concrete. Parts that can be inspected are not considered to be a problem, but for example, the pedestal foundation of the RPV is difficult to monitor, so a combination with an evaluation technique is essential.

3. Establishing a measure for maintaining structural integrity

Desired state and reasons for it

- It is desirable to have a technology for maintaining structural integrity in case aging, coolant leakage, or failure of dynamic equipment is discovered as a result of integrity evaluation by inspection and evaluation technologies, or in case it is necessary to add a new structure to the existing one.

Current state against ideal

- Regarding integrity assessment using inspection and evaluation technologies, the investigation on evaluation methods for seismic resistance was conducted in the past.

Issues to be resolved

- It is necessary to establish methods for evaluating integrity through inspection and evaluation technologies, and to investigate the technology for maintaining integrity assuming about factors that may affect integrity.

Relevant Issues

- FDR-102 “Understanding status of structures inside PCV and RPV”
- FDR-208 “Understanding status of fuels for maintaining stable conditions”
- FDR-213 “Fuel debris retrieval policy”
- FDR-214 “Establishing debris collection strategy”
- FDR-217 “Establishing access route to fuel debris”
- FDR-218 “Developing fuel debris retrieval equipment and devices”
- FDR-303 “Continuously maintaining and ensuring safety function”