Annual Research Report
2017

IRID
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for Nuclear Decommissioning

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Greeting

"The Mid-and-Long-Term Roadmap toward the Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS), Tokyo Electric Power Company (TEPCO) Holdings, Inc." was revised by the government based on the updating of the Technical Strategic Plan for 2017 Decommissioning of Fukushima Daiichi NPS, TEPCO Holdings, Inc." by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) last September.

The indication was then given that retrieving the debris from the bottom of the Primary Containment Vessel (PCV) shall take place in advance with a focus on the "Partial Submersion-Side Access Method" as the fuel debris retrieval policy.

The International Research Institute for Nuclear Decommissioning (IRID) has been engaged in the research and development (R&D) of the technology required in the decommissioning of the Fukushima Daiichi NPS as an urgent issue since being established in August 2013.

This has resulted in the situation with the PCV and the reactor being clarified upon as well identifying the technical issues to be overcome using the development of technology for use in investigating inside the PCV and detecting the fuel debris using cosmic rays.

The Annual Research Report 2017 is intended to summarize the achievements of the R&D projects (15 subsidized projects and 2 in-house research) undertaken by the IRID in FY2017. We would appreciate if this report helps to cast light on the R&D achievements the IRID has been responsible for.

Seven years have now elapsed since the accident that occurred at the Fukushima Daiichi NPS after the Great East Japan Earthquake and the situation has been largely improved upon when compared to just after the accident, however, the decommissioning work is about to enter a crucial phase. The IRID is committed to proceeding with our R&D on the steady and timely nuclear decommissioning in thereby fulfilling our responsibilities.

We sincerely appreciate your kind guidance and continued support.

March 2018

Hideo Ishibashi

President of International Research Institute for Nuclear Decommissioning

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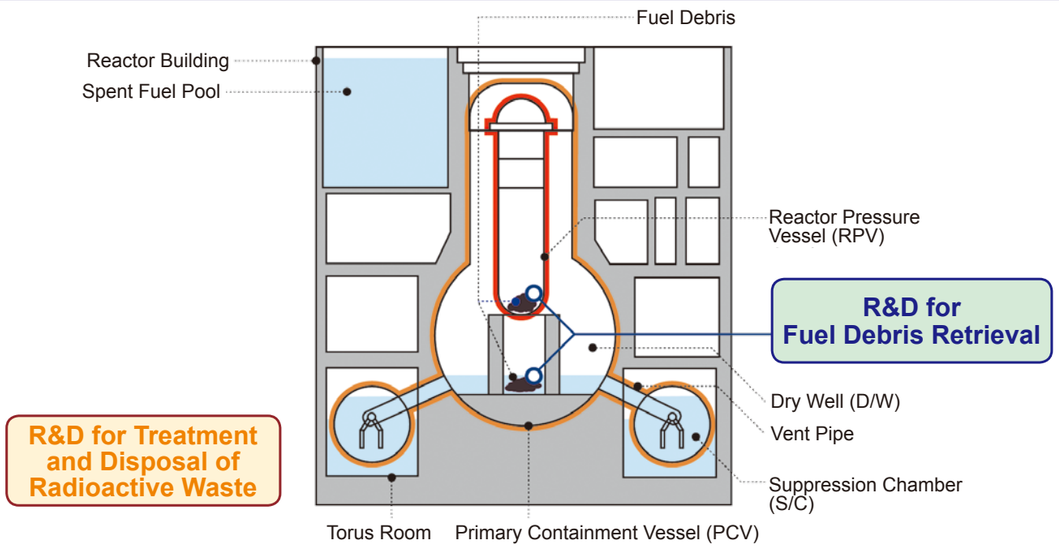
Overview of Nuclear Building and IRID's R&D Project



R&D for Fuel Debris Retrieval

Development of Technology for Investigation inside PCV

►Background

The consideration is that the reactor cores melted and nuclear fuel exists in some parts of the reactor inside as fuel debris in the Reactor Pressure Vessel (RPV) and Primary Containment Vessel (PCV) of the Fukushima Daiichi NPS Units 1–3. Fuel debris presumably spread from the opening at the bottom of the pedestal to outside it after dropping through the bottom of the RPV into the pedestal supporting it, although the status of the fuel debris is yet have been identified.

►Purpose

Regarding the conditions inside the PCV, visual images, the radiation dose, and temperature have been obtained by accessing the PCV internally via X-100B penetration at Unit 1 and X-53 penetration at Units 2 and 3.

The environment is quite severe with high doses of radiation and humidity, and limited visibility was confirmed due to the steam and accumulated water and inherent darkness. Moreover, the possibility of falling or interfering objects due to the accident also exists.

This then results in the necessity for the above issues to be resolved alongside the development of technology that enables the PCV to be internally investigated.

►Major Approach and Results

1 Development of Access, Investigation Device, and System for Specific Area

① Investigation inside the Unit 2 Pedestal (A2/A2′ investigation)

An A2 investigation device, which accesses the PCV through the X-6 penetrating Unit 2 and investigates above the platform through the pedestal, and A2′ investigation device, which investigates under the platform, were developed to investigate the conditions within the pedestal and as a verification test of the devices. The results of the investigation revealed parts of the grating to have fallen onto the platform and deposits that look like pebbles/clay all over the bottom of the pedestal. In addition, the investigation confirmed that part of the fuel assemblies had fallen, and in which deposits suspected to be fuel debris (Fig. 1).

② Investigation inside the Unit 3 Pedestal (Investigation for Unit 3)

A submersible type robot for use in accessing the inside of the PCV from X-53 penetration of Unit 3 and thereby investigating the internals of the pedestal was developed, and which was then used in a validation test. The results of the survey confirmed that the structures were damaged and molten material, that had presumably solidified, was attached to the structures within the pedestal. Moreover, lava-like deposits were confirmed in multiple locations within the pedestal via the verification test (Fig. 2).

③ Planning for Investigation of Basement Floor, Element Test

Continuing on from FY2016 an element test for the measurement technology was performed. The test confirmed the capabilities of the CdTe semiconductor detector in the high dose rate environment. In addition, the technology used to measure the pedestal wall surface ology was changed from the impact elastic wave method to the low frequency ultrasound method because of the latest status of the PCV in Unit 1, and which then enabled knowledge to be gained on identifying the aggregate and bottom surface echo.

►Future Developments

We intend to perform detailed design/test manufacturing/on-site validations within the project of “Development of PCV inside Detailed Investigation Technology” and use the data obtained in this project to obtain further information on inside the PCV, and will then prepare for on-site verification of Units 1 and 2.

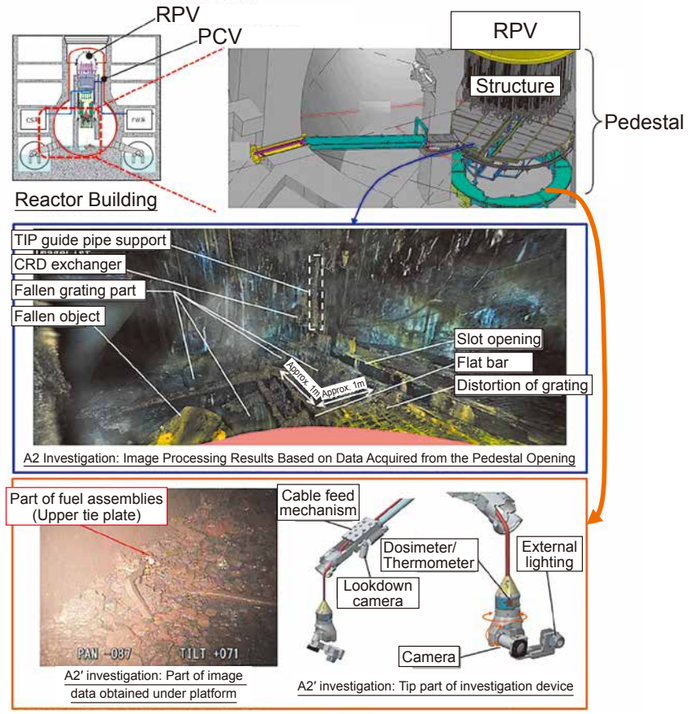


Fig. 1: Data Obtained from A2 investigation/A2′ investigation

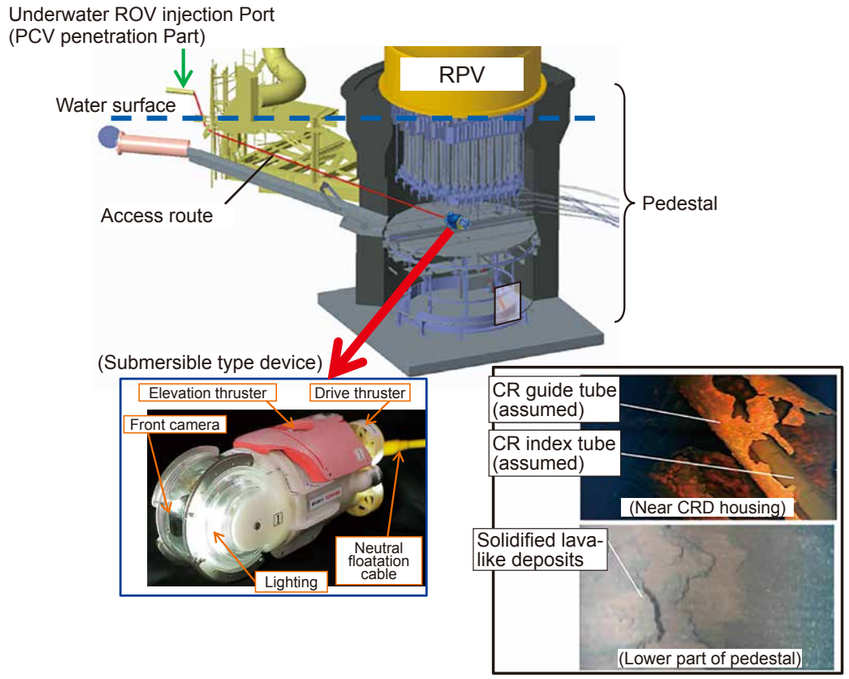


Fig. 2: Appearance of Submersible Type Device and Survey Route

R&D for Fuel Debris Retrieval

Development of Technology for Detailed Investigation inside PCV

►Background

The reactor cores have been considered to have melted and nuclear fuel to exist in some parts inside the reactors and as fuel debris in the Reactor Pressure Vessels (RPV) and Primary Containment Vessels (PCV) in the Fukushima Daiichi NPS Units 1–3. The PCVs were internally investigated: outside the Unit 1 pedestal (B1/B2 investigations), inside the Unit 2 pedestal (A1/A2/A2′ investigations) and inside the Unit 3 pedestal using a small submersible ROV (Remotely Operated Underwater Vehicle), thus providing very valuable information. However, this did not satisfy the requirements with respect to the fuel debris retrieval because the existing opening has restrictions to it.

►Purpose

“The Detailed Investigation inside PCV” project that follows the existing “Investigation inside PCV” project requires an investigation through a larger access route in the PCV by enlarging the investigation device and upgrading the measurement technology to be installed on the device in thereby obtaining the necessary data for the fuel debris retrieval process.

For this reason, the urgent priorities are obtaining information on a method of retrieving the fuel debris and a detailed design of a fuel debris retrieval device, along with establishing an access route into the PCV as well as developing technology for a detailed investigation of inside the PCV in thereby fulfilling the aims of the surveys.

►Major Approach and Results

1 Development of Access/Investigation Devices

① Establishing Access Route into PCV via X-6 Penetration

The basic design of an X-6 penetration connection structure (Fig. 1) that is operated by remote control from an isolated room, which was studied in the FY2016 project of “Development of Technology for Investigation inside PCV”, has been completed. After the basic design was completed a more detailed design and test manufacturing were then commenced upon.

② Establishing Access Route into PCV via X-2 Penetration

Detailed designs and test manufacture of equipment related to establishing an access route into the PCV via X-2 penetration (Air lock) (Abrasive Wear Jet Equipment for use in perforating the grating and air lock door, etc.) for Unit 1, which is a high dose area near the X-6 penetration, have been completed. On-site validation (function test) was then commenced upon (Fig. 2).

③ Access/Investigation Device

After selecting an arm type access device, which is able to move through the air to gain access from the X-6 penetration internally into the PCV of Unit 2, a detailed design and test manufacture were commenced upon (Fig. 3).

2 Applicability Validation of Element Technology

Measurement technology to be installed on the access unit was reviewed based on an updated survey plan, and test manufacturing has been commenced upon toward the compatibility validation of size/shape measurement technology and radiation measurement technology.

►Future Developments

We intend to continue to establish an access route into the PCVs and perform detailed designs, test manufacturing, and on-site validation of devices for use in detailed investigations of inside the PCVs and preparing for site validations at Units 1 and 2.

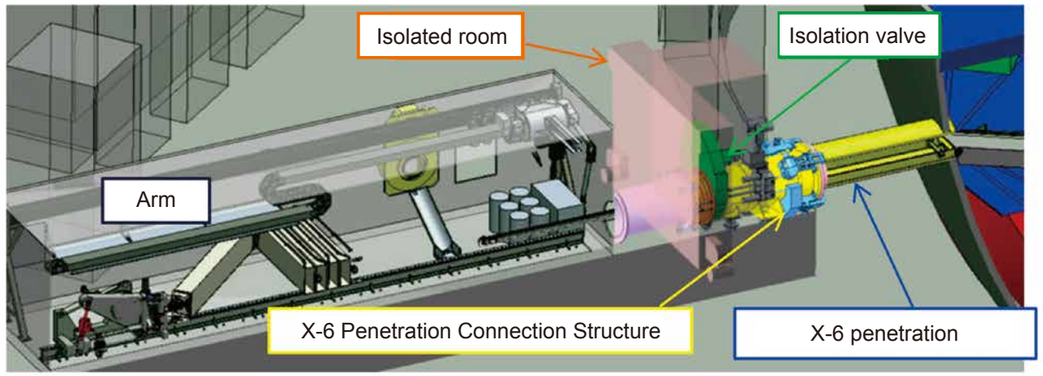


Fig. 1: X-6 Penetration Connection Structure

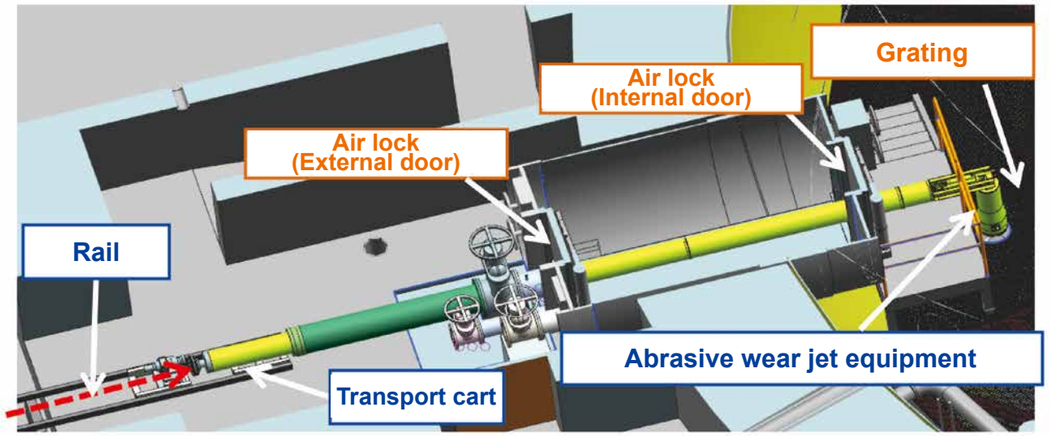


Fig. 2: Perforation Device for X-2 Penetration (Air Lock) Internal Door

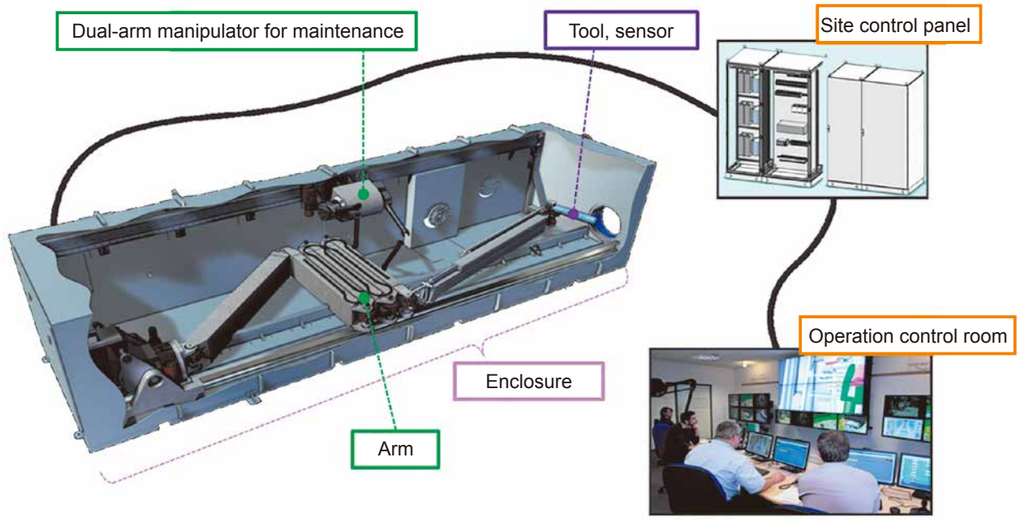


Fig. 3: Arm Type Access Unit

R&D for Fuel Debris Retrieval

Development of Technology for Investigation inside RPV

►Background

Information on the fuel debris and inside the Reactor Pressure Vessels (RPVs) needs to be obtained in advance and including their location, shape, and the internal situation. However, directly obtaining the information is difficult because RPVs have internally complicated structures and extremely high radiation levels.

►Purpose

Making progress with future decommissioning, including fuel debris retrieval in a safe and smooth manner, necessitates amassing information on the currently unclear situation. Therefore, the investigative targets will be clarified based on the relevant information, and feasible technology developed for the investigation that requires a method of perforating the reactor core by it accessing from the top or the side of the RPV.

►Major Approach and Results

1 Development of Equipment to Access Reactor Core

① Development of Equipment to Access the Reactor Core from the top

①-1 Development of Drilling Device to Access through RPV Head

A possible method was confirmed by reviewing the work plan, specifications, and test manufacture of a device assuming that the well cover, Primary Containment Vessel (PCV) Head, and RPV Head would need to be drilled through in establishing an access route to inject the device which will then require investigating whether the device is able to enter from the operation floor on the upper part of the RPV up to the reactor core of the RPV. In addition, and regarding the RPV Head processing device, an element test for the removal method of RPV Head spare nozzle located in the access route was conducted to avoid any interruption in the internal structures of the RPV, and remote processing/workability confirmed.

①-2 Development of Boundary Function Maintenance Device/Access Work Device

In order to access the RPV without compromising the boundary function (contamination prevention system) and maintaining a negative pressure environment, and assuming the installation of an access device for the work (work cell) on the operation floor and connection to the PCV head via a guide pipe, the possibility of method was confirmed by reviewing the work plan, equipment specifications, and a sealing property element test.

In addition, specifications for a work cell were clarified with respect to the connection method of the tool box that will contain the processing equipment and survey equipment, and the carry-in/out and transport method for each equipment.

①-3 Development of Device for Drilling through Upper Grid Plate

Assuming a need to drill through the reactor internals (steam dryer, steam-water separator, and shroud head) from the operation floor to the upper grid plate just below the perforation position of the RPV head, the feasibility of a method was confirmed by reviewing work plan, equipment specifications, and test manufacturing.

Assuming a need for remote processing in a narrow part of the RPV, an element test of a mock-up facility was performed combining an Abrasive Wear Jet (AWJ) Cutting Device and access equipment installed in a work cell, and the possibility of remote cutting then confirmed.

② Development of Method of Accessing from Side

An access route into the reactor core from the side of the reactor building was determined upon, and concepts of the methods for use established that included selecting the applicable tools for excavation and sealing work. In addition, the specifications for all the equipment were clarified, including the design of a facility for use in maintaining the equipment.

2 Development and Selection of Methods of Investigating the Reactor Core

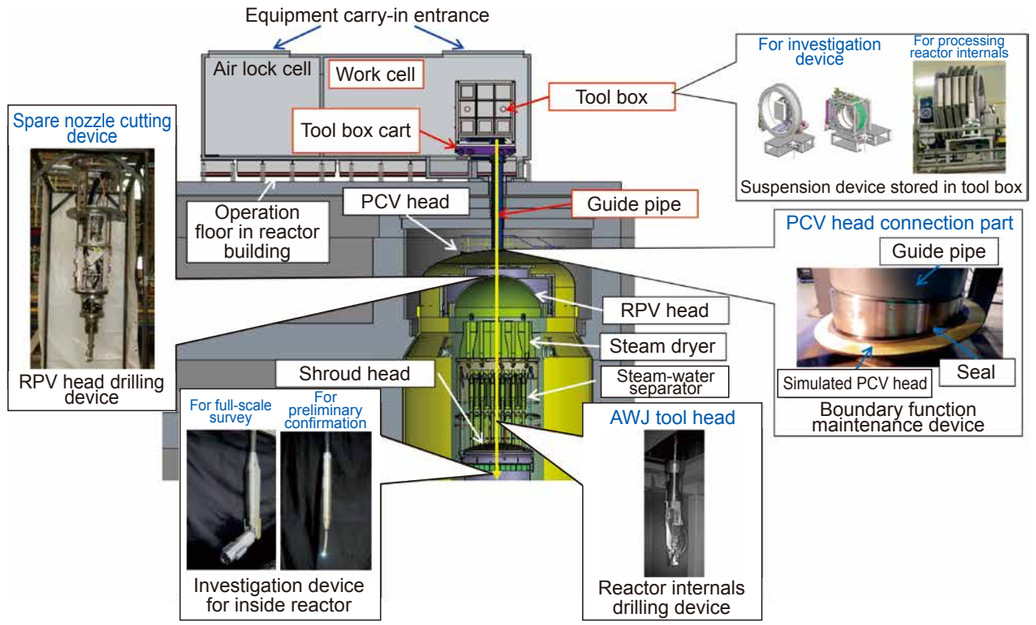
Two kinds of specifications for investigation devices in prior confirmation of access routes via a small diameter opening and an actual investigation via a large diameter opening were studied besides the investigative steps, visibility, and radiation resistance being confirmed by an element test. In addition, an accessibility test using a mock-up facility that simulated openings was performed and the remote workability confirmed. The expansion mechanism in investigating the deepest part of the reactor core via horizontally accessing the center of the reactor core from the upper grid in the shroud head was test-manufactured, and the feasibility of the mechanism then confirmed by an element test.

3 System Design and Planning Methods for Overall Investigation Device

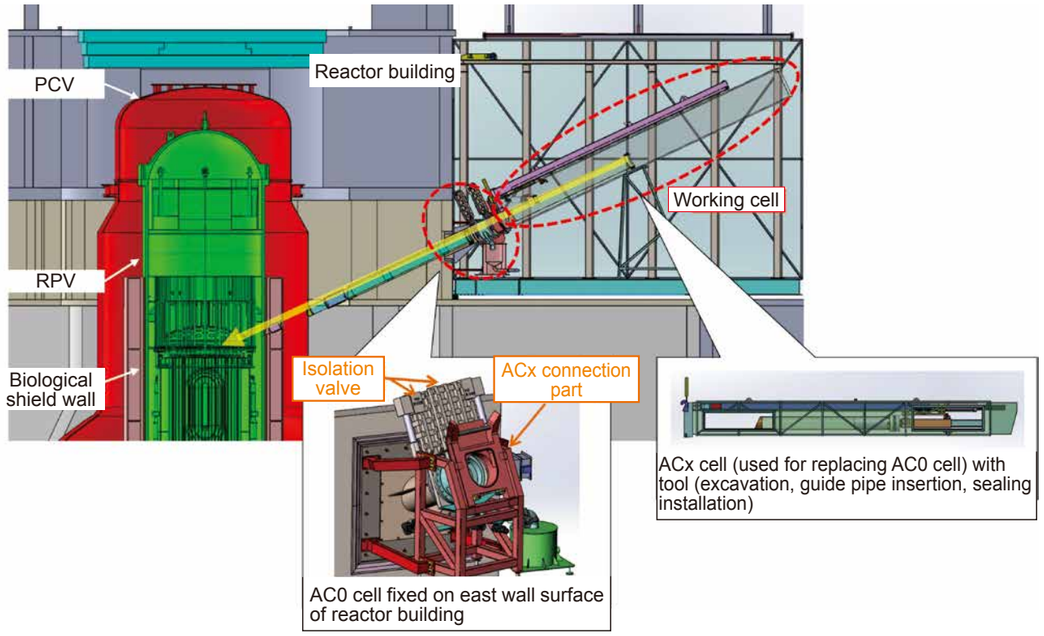
An exposure evaluation during an investigation after accessing the PCV from the side was conducted under the current micro-positive pressure situation in the PCV. Moreover, An exposure evaluation during an investigation method via access from the top is being planned for after the establishment of negative pressure and from the aspect of any spreading of the contamination caused by dust diffusion due to the large amount of the reactor internals that radioactive material is assumed to be adhering to.

►Future Developments

Toward the design of the applicable device for on-site investigations, an element test on the workability will be conducted as necessary based on the environmental information and conditions at the work site, and the test results reflected in the design of the device. Furthermore, coordination with the related construction work required for the device design, facilities, and the utility supply system required for the site survey, along with the applicability of the incidental system, will be reviewed.



Overview of Investigative Method with Access from the Top



Investigation with Access from the Side: Appearance

R&D for Fuel Debris Retrieval

Upgrading the Comprehensive Identification of Conditions inside Reactor

►Background

Identifying the conditions inside the reactor and Primary Containment Vessel (PCV) is essential in establishing a method of retrieving the fuel debris and developing safety measures. However, a direct survey of and observation within the reactor are difficult because the radiation levels within the reactor at the Fukushima Daiichi Nuclear Power Station (NPS) Units 1–3 are extremely high.

►Purpose

This project aims at a steady approach to the decommissioning of the Fukushima Daiichi NPS. The conditions therefore inside the reactor and PCVs are being estimated using comprehensive analysis and evaluations based on information gained through accident progression analysis and other research and development (R&D), and analysis of measured data such as the pressure, temperature, and other information during the accident. This is a joint project with the Institute of Applied Energy.

►Major Approach and Results

1 Comprehensive Analysis/Evaluation of Reactor Internals

① Comprehensive Analysis/Evaluation Based on Actual Data and Results from other Projects

Using the assumed conditions inside the Reactor Pressure Vessels (RPV)/PCV of all the units an information summary map, which summarizes the various types if information from the RPV, PCV, and reactor building, was created. The information was then comprehensively analyzed and evaluated, and used to provide an estimate diagram of the fuel debris distribution (Fig.1), an estimate of the FP (Fission Products) distribution, and an estimate of the radiation dose distribution.

② Establishment of Database Required for Comprehensive Analysis/Evaluation

An English language search system for the database was added and graphic display system for the measurement data, although mainly for the 3 weeks after the accident, improved in promoting the utilization of expertise from overseas organizations. In addition, the database with search tags established in this project and information are being updated in contributing to more comprehensive analysis and effective evaluation, as described in 1①.

2 Fuel Debris/FP Behavior and Characterization in Comprehensive Analysis and Evaluation

① Reduction of Uncertainty Using Analysis Method

Sensitivity and other analysis taking into consideration the boundary conditions and an analysis model for events assumed to have occurred within the reactor were conducted using the accident progression analysis code, and which then provided expertise that will contribute to the more comprehensive analysis/evaluation described in 1①. For example, continuing on from the last fiscal year a simulated fuel assembly plasma heating test (Fig. 2) was performed, which provided expertise leading to reducing the uncertainty of events such as the core meltdown and movement within the BWR fuel assembly system.

② Evaluation of FP Chemical Properties

In evaluating the FP chemical properties, and with a focus on Cs, which is largely contributing to the radiation dose during the decommissioning, a study has commenced upon the distribution of Cs and its chemical properties, including identifying the chemical species that need to be considered in addition to standard chemical species such as CsI and CsOH, and the insoluble Cs particles whose production has been confirmed in the environment, and the possibility of uneven Cs distribution associated with the reaction in the upper structures of the RPVs. In addition, on-site test samples have been analyzed, and a study of the composition and spatial distribution of uranium and FP conducted from the aspect of identifying the conditions inside the reactor (Fig.3).

③ Utilization of Domestic/Overseas Knowledge through International Joint Research

The International Joint Research (OECD/NEA BSAF Phase2) project involves the sharing of accident progress scenarios and plant information with overseas organizations by utilizing the database that was established and which is shown in 1②, and the evaluation results of the accident progression and debris/FP distribution by participating organizations being compared to actual measured values and the results of site surveys. The results confirmed that the deviation in analytical results of the organizations could be significantly reduced when compared with Phase-1 through a better common understanding of the progression of the accident and plant conditions, and the evaluation results of the FP emission amounts to be consistent with the amounts emitted into the environment. The estimate accuracy of the fuel debris distribution was improved via more thorough knowledge of the progression of the accident. The expertise obtained through discussions with overseas organizations was utilized in the comprehensive analysis and evaluations described in in 1①.

►Future Developments

This project will be completed at the end of FY 2017 (end of March, 2018). Tokyo Electric Power Company Holdings, Inc. intends to continue comprehensive analysis and evaluations that reflect the results of site surveys results in then estimating the conditions within the RPVs and PCVs in the future.

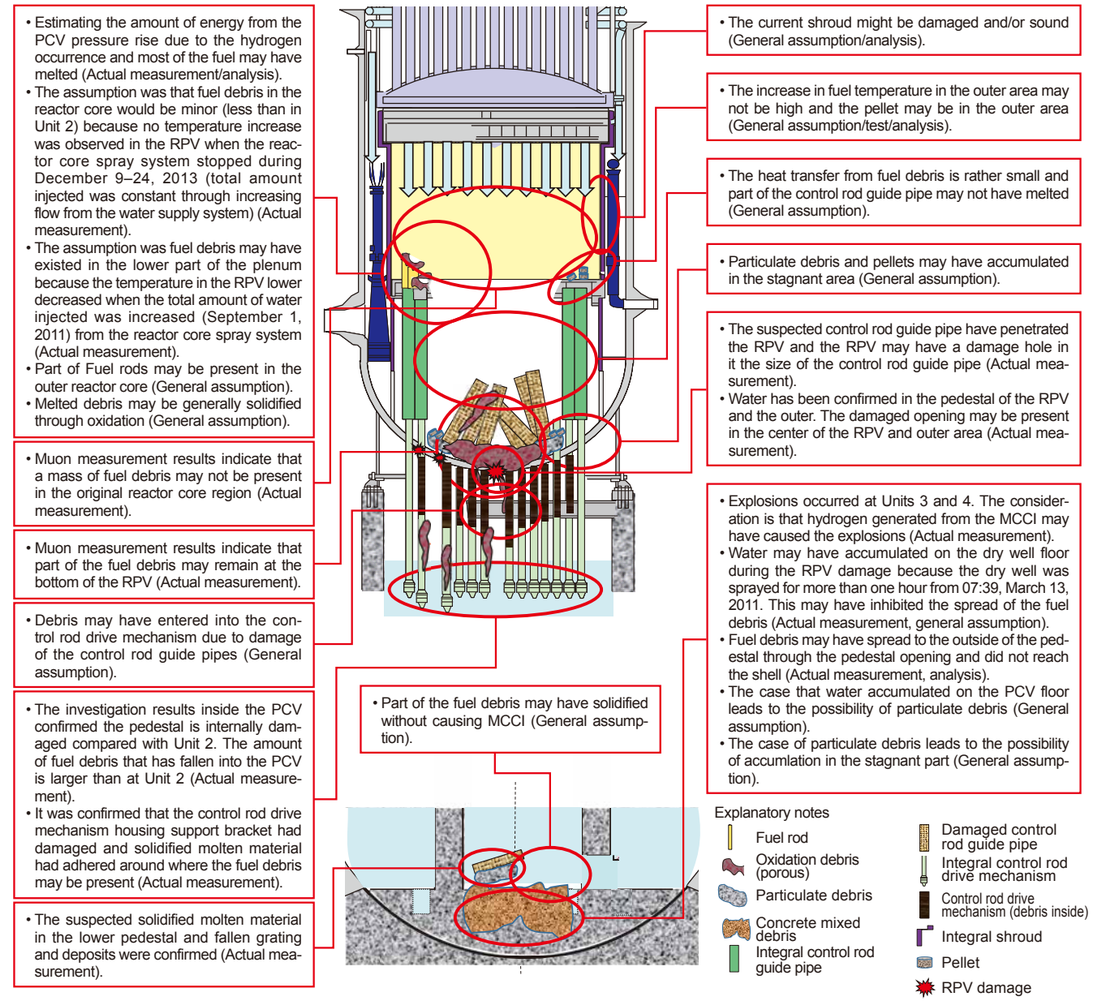


Fig. 1: Diagram of Estimated Fuel Debris Distribution (Example of Unit 3) As of February 28, 2018

Test equipment appearance Test result example

Fig. 2: Plasma Heating Test of Simulated Fuel Assemblies

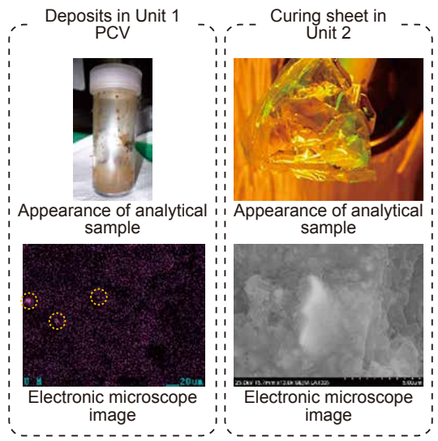


Fig. 3: Example of Analysis Sample and Analysis Results

R&D for Fuel Debris Retrieval

Development of Technology for Fuel Debris Analysis/ Fuel Debris Characterization

▶Background

The reactor at the Fukushima Daiichi NPS was internally investigated in studying fuel debris retrieval methods and the collection/storage of it after it has been retrieved. Progress with safe and steady decommissioning work will necessitate identifying the characteristics of the fuel debris generated in the reactor. In addition, technology needs to be developed for use in analyzing fuel debris samples.

▶Purpose

This project is aimed at surveying and assuming about the characteristics of the fuel debris that include the hardness of the fuel debris, which will be useful in studying the necessary retrieval device, and the behavior of the dry fuel debris, which will be necessary in studying the collection/storage of fuel debris and in order to provide information for the project that will be about proceeding with the actual decommissioning work. In addition, the properties of the fuel debris, which consists of complicated materials that include fuel, structural materials, and concrete, will be promptly and accurately clarified, and analysis technology prepared for updating the “Fuel Debris Property List”.

▶Major Approach and Results

1 Assumption of Fuel Debris Properties

A surface dose rate evaluation method for the fuel debris was studied and test evaluations of the surface dose rate of fuel debris sample cases performed. In addition, the “Fuel Debris Property List”, which involves fuel debris property assumptions, was updated using the results of analysis of large scale MCCI (Molten Core Concrete Interaction) test products obtained in FY 2017.

2 Characterization via Use of Simulated Debris

① Evaluation for Characterization of Uneven MCCI Products

Large MCCI test products were analyzed that had been produced in the test facility owned by the French Alternative Energies and Atomic Energy Commission (CEA) in FY 2016, and for use in obtaining information which includes an element map of MCCI test product layers (Fig. 1), and the crystal structure and hardness, etc. Confirmation took place that no significant change in the estimation is needed based on the basic test results so far, even if after taking the conditions at the Fukushima Daiichi NPS into consideration.In addition, expertise related to the time variation with concrete erosion shapes was obtained by analyzing data obtained from the MCCI test.

② Emission Behavior Evaluation of Fission Products during Dry Heat Treatment

The emission behavior of Fission Products (FPs) was studied for use in the design of an off-gas facility and the dry treatment which is under consideration as method of pretreatment when the fuel debris is stored. A reference investigation was performed with regard to the FP emission behavior via heating in FY2017, and a medium volatile FP candidate that has a large impact on the environmental emission evaluations selected (Fig. 2). In addition, confirmation took place that emission start temperature/emission speed could be clearly measured using a thermogravimetric device/differential thermal analyzer and test samples containing Ru.

3 Development of Elemental Technology for Fuel Debris Analysis

The necessary element technology was selected and technology for fuel debris analysis is being developed. And with regard to the melting of the fuel debris and development of a multi-element analysis method, confirmation took place that components derived from the structural materials of the fuel debris, including Cr2O3 and Fe3O4, could be melted using the alkali fusion method. In addition, results of analysis using the multi-element simultaneous analysis method and the inductively-coupled plasma emission spectrometry device (ICP-AES) with MOX simulated debris proved to have high levels of repeatability.

Fuel debris analysis technology using an X-Ray CT was developed, and porosity measurements and simulated debris samples performed with the same porosity measurements as with an optical microscope. The components of samples proved capable of being clarified using the methodology of a combination of X-Ray CT and γ-Ray tomography and test samples with a mix of spent fuel and covering materials (mixed melted sample materials).

With regard to the development of technology for the multiple nuclide rationalization analysis method using an induction coupling plasma mass spectrometer (ICP-MS), interfering ions with the nuclide measurements were specified and target values determined for their removal, and an impact reduction method for the hindering nuclides (Nb, Mo). A removal method is also being studied.

In addition to the above achievement’s analysis items were examined and an analysis procedure was prepared for the fuel debris sampling that is presumed to be taking place to be conducted at the existing analysis facility in Ibaraki Prefecture.

▶Future Developments

The dose rates on the surface of the fuel debris are continuing to be evaluated for use in assumptions regarding the characterization of the fuel debris and the results will be reflected in the “Fuel Debris Property List”. In addition, and regarding the FP emission behavior evaluations during dry heat treatment, the emission behavior of selected medium volatile FPs will be evaluated. Furthermore, the development of a multiple nuclide rationalization analysis method using the ICP-MS is intended for use in establishing a method of reducing the impact of any interfering ions. An analysis procedure is being examined in combination with the flow of the overall analysis. In addition, transporting the fuel debris samples will be studied.

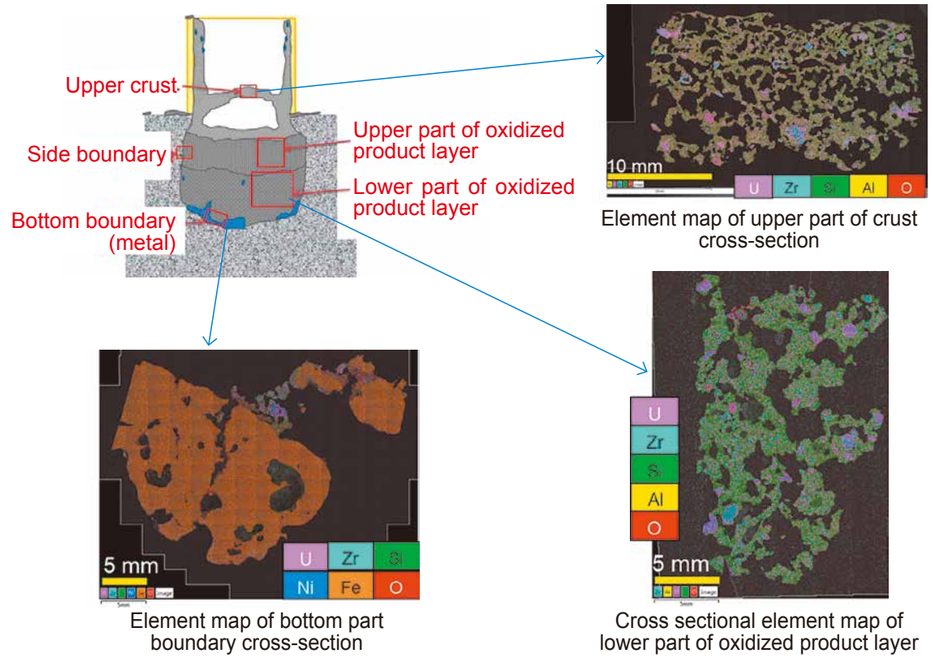


Fig. 1: Element Distribution of Large MCCI Test Products

With regard to the large MCCI test products produced in FY2016, the porous regions and metal layers were observed with their uneven status. The results of analyzing each layer revealed that the test samples, mainly consisting of the upper part of the crust and lower part of the oxidized product layers consisted of U-Zr oxidation and other products in a high Si containing (containing Ca, Al) matrix. In addition, the discovery was made that the metal block at the bottom of the boundary consists of an alloy which mainly consists of Fe.

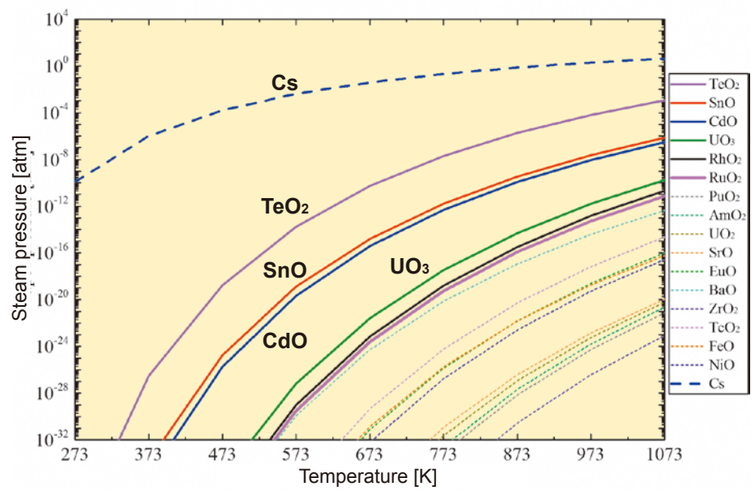


Fig. 2: Calculation Results of Steam Pressure of Oxidized Products

The steam pressure of oxides to be generated to counteract the nuclides that will have a significant impact on the environment was calculated. With the fuel debris dry heat treatment the conditions of the volatile fuel uranium oxides are yet to have been determined and hence chemical compounds with higher steam pressures than UO_3 pressure are being focused upon. Meanwhile, the off-gas treatment needs to be considered as all the high volatile FPs such as Cs will get emitted. The compounds that therefore have a lower steam pressure than Cs but a higher steam pressure than UO_3 were selected as the candidate medium volatile FPs and included Te, Sn and Cd.

R&D for Fuel Debris Retrieval

Development of Repair Technology for Leakage Points inside PCV

►Background

The assumption is that melted fuel has not only fallen within the Reactor Pressure Vessel (RPV) but has also reached the Primary Containment Vessel (PCV) at the Fukushima Daiichi nuclear power station (NPS). In order to retrieve fuel debris, the plan is to accumulate water in or inject water into the PCV. Water will therefore need to be prevented from leaking from the PCV.

►Purpose

This project aims at establishing repair technology for the water leakage points of the PCV in order to substantiate a fuel debris retrieval method by submersing it in or injecting water into it.

►Major Approach and Results

1 Process Study and Plan for Submersing PCV

In order to retrieve the fuel debris in a dry condition, several feasible PCV water levels were proposed based on guidelines that including the purpose of repairing the PCV, the safety requirements, work exposure levels, and seismic capacity, and the target of the water stoppage capabilities of the individual repair technologies determined.

2 Development of Repair Technology for Lower Part of PCV

① Reinforcement/Water Stoppage Technology for Suppression Chamber (S/C) and Vent Pipes

①-1 Reinforcing Technology for S/C Support Columns

The effectiveness of the reinforcement was confirmed based on the results of evaluating the strength after placing reinforcement materials in a full-scale mock-up facility, flow analysis, and simulations performed in FY 2017.

①-2 Water Stoppage Technology via Filling in Vent Pipes (Fig. 1)

Water stoppage materials using radiation resistant rubber and self-injecting concrete, and repair materials using sludge water were developed in securing water stoppage capabilities. The workability and water stoppage capabilities were confirmed in a 1/1 scale test using self-injecting concrete as the water stoppage material.

①-3 Water Stoppage Technology via Filling in S/C (Fig. 1)

A function validation test on the S/C guide pipe implementation required in inserting the hose for the concrete injection, the water level control, and water drainage in the S/C were performed in confirming their workability.

② Water Stoppage Technology via Filling Vacuum Break Line (Fig. 2)

Installation of water stoppage plugs and a plug insertion device through the flexible guide pipe were improved upon, and a workability test using a 1/1 scale test facility performed in thereby confirming their water stoppage capabilities. No leakage was confirmed at 0.45 MPa (fully submersed condition) during a water pressure resistance test.

③ Boundary Formulation Technology for Connecting Pipes

Development of water stoppage materials for the inside/outside of the various connection pipes and a repair method, and element development of remote construction and an access devise were performed in confirming the feasibility of the method.

3 Development of Repair Technology for the Upper Part of PCV

Water Stoppage Technology for Sealant Part (equipment hatch)

Abrasion of the equipment hatch water stoppage device, each of the welding heads, and the access device were studied with view to their improvement, and with the workability of the sealing method then enabling their improvement.

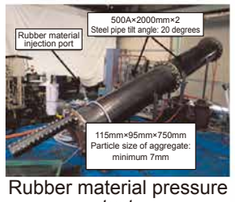
4 Conceptual Study of Environment Improvement toward Applicable Repair Method (Fig. 3)

The radiation exposure during the water stoppage work needed to repair the lower part of the PCV was evaluated, and a method of reducing the radiation exposure by decreasing the amount of water stoppage work and the place studied in thereby identifying the issues that need to be solved. In addition, the exposed dose reduction effect through improving the environment was also confirmed.

►Future Developments

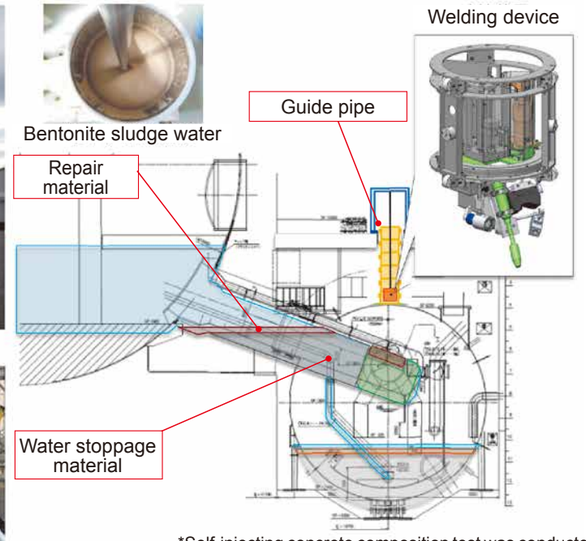
In order to establish a fuel debris retrieval policy for each of the units, repair and water stoppage technology will be reevaluated as part of an investigation of the PCV internals and studying the fuel debris retrieval method, and in case the prerequisites and conditions change.

Vent pipe 1/1 scale test



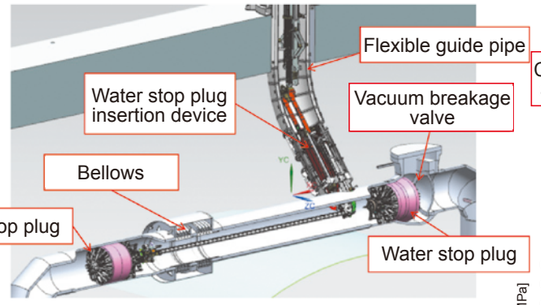
Rubber material pressure test

Concrete water stoppage test

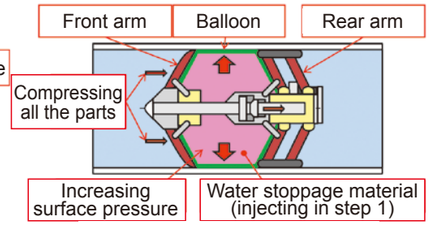


*Self-injecting concrete composition test was conducted at Kochi University of Technology (Ouchi laboratory)

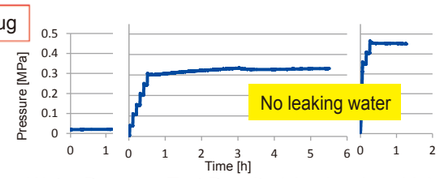
Fig. 1: Overview of Repair of Lower Part of PCV (Filling in Vent Pipe and S/C)



Drawing of water stop plug for vacuum breakage line

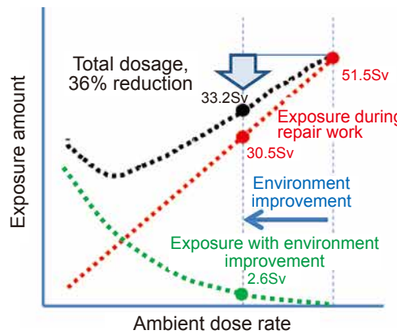


Overview of Water Stoppage Plug

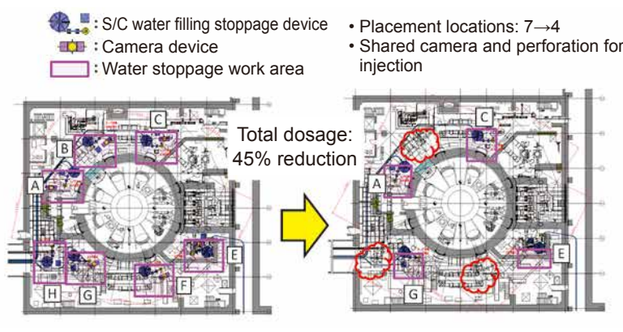


Water Pressure Test Results (check valve side)

Fig. 2: Overview of Repair of Lower Part of PCV (Vacuum Breakage Line Filled)



Exposure Evaluation with Water Stoppage Repair work (Unit 2)



Review of total dose reduction during repairs (Unit 1)

Fig. 3: Conceptual Study of Environment Improvement for the Applicable Repair Method (Example)

R&D for Fuel Debris Retrieval

Full-scale test for Repair Technology for Leakage Points inside PCV

►Background

The Fukushima Daiichi NPS has a severe environment with high doses of radiation and narrow spaces. There is a number of places where it is extremely difficult for people to access and do the necessary decommissioning work. This then necessitates the development of a method of repairing and stopping the water leaking from the Primary Containment Vessel (PCV), and for a remote operation device for use in retrieving the fuel debris.

►Purpose

A full-scale test to validate the technology and operational training was conducted in order to apply the technology developed to repair and stop the water leaks on site (methods and remote operation device, etc.). This project is taking place at the Naraha Remote Technology Development Center that was organized by Japan Atomic Energy Agency (JAEA).

►Major Approach and Results

1 Full-scale Test of Repair Technology for the Lower Part of PCV

A full-scale test using a test facility (Fig.1) was conducted with respect to the following items.

① Suppression Chamber (S/C) Support Columns

A test wherein high-fluidity reinforcement materials were placed and injected into the lower part of the S/C was conducted in confirming its feasibility using the assumed procedures and the actual situation. In addition, the feasibility of the operation monitoring, including the installation height, was also confirmed (Photo-1).

② Vent Pipe Water Stoppage

A workability verification test was conducted in which interfering objects were removed and the vent pipes perforated via remote operation. Accessibility to the operation area was thereby confirmed with the actual situation (Photo-2).

③ Water Stoppage by Filling S/C (Down-comer Water Stoppage)

A workability verification test confirmed that there is no problem in the facility with the applicability of the prepared remote operation, the repair of the PCV, and work in the high dose environment. In addition, improved workability was considered based on the knowledge obtained from the test.

The operation monitoring feasibility, including installation height, was also confirmed using the assumed procedures in the actual situation (Photo-3).

2 VR Data Preparation for Preliminary Simulation Test

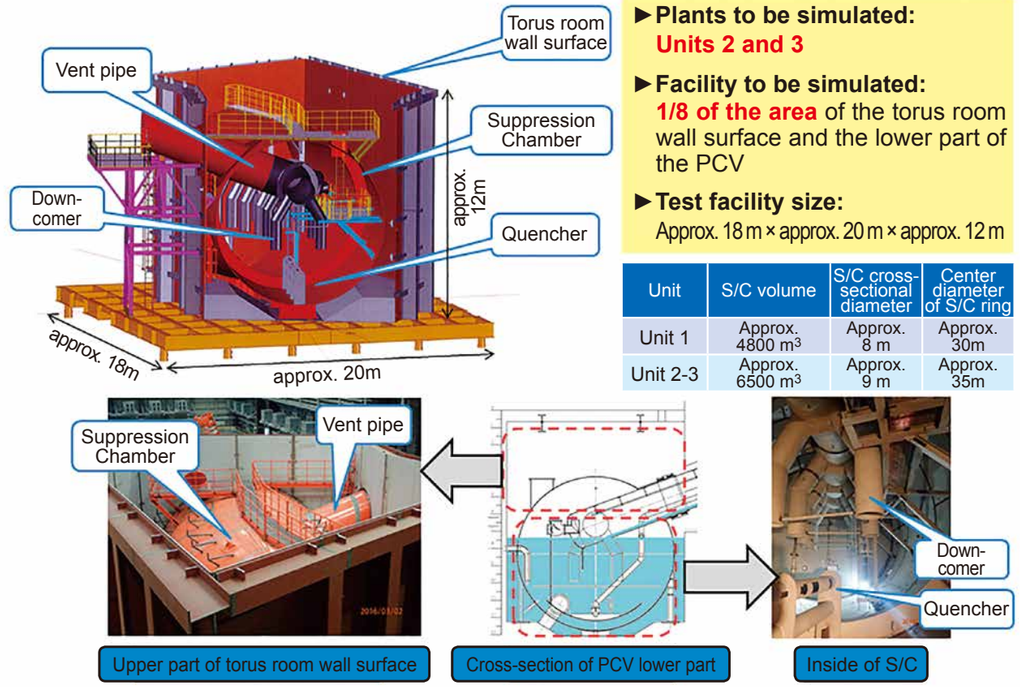
A remote operation device to be used for stopping the water in the vent pipe was duplicated using a virtual reality (VR) system for the operational training environment as below.

- Operation measurements of remote device via motion capture, etc.
- Operation comparison validation with remote device and VR system reflecting its operating data.

VR system effectiveness evaluation during operational training was performed (Photo-4).

►Future Developments

Technology for strengthening the S/C support columns and stopping the water in the vent pipes and by filling in the S/C requires the identification and clarification of the issues with practical application based on the results of full-scale tests. Vent pipe water stoppages are being prepared for via placement tests. VR data for preliminary simulation tests will then be completed for use in establishing training environments for remote device operators.



►**Plants to be simulated:**
Units 2 and 3

►**Facility to be simulated:**
1/8 of the area of the torus room wall surface and the lower part of the PCV

►**Test facility size:**
Approx. 18 m × approx. 20 m × approx. 12 m

Unit	S/C volume	S/C cross-sectional diameter	Center diameter of S/C ring
Unit 1	Approx. 4800 m^3	Approx. 8 m	Approx. 30m
Unit 2-3	Approx. 6500 m^3	Approx. 9 m	Approx. 35m

Fig. 1: Overview of Test Facility

Photo-1: Implementation of S/C Support Column Reinforcement Test

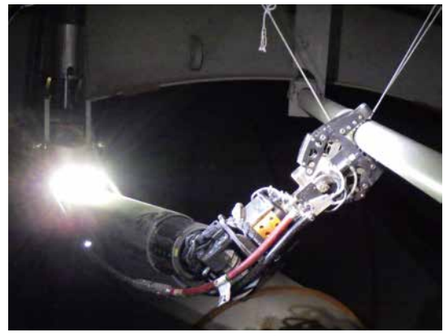


Photo-2: Implementation of Vent Pipe Water Stoppage Workability Verification Test

Photo-3: Supplying Water Stoppage Material for Injecting Filling to Stop Water inside S/C

Photo-4: Operating Panel of VR System and 3D Screen

R&D for Fuel Debris Retrieval

Upgrading of Approach and Systems for Retrieval of Fuel Debris and Internal Structures

►Background

The status with the fuel debris in the Reactor Pressure Vessels (RPVs) and Primary Containment Vessels (PCVs) of the Fukushima Daiichi NPS is currently ensuring stable cooling. However, the reactor buildings, RPVs, and PCVs were damaged in the accident and the plant itself is unstable. The aim is to retrieve the fuel debris from the unstable conditions and establish safer conditions by preventing the spread of any radioactive material.

►Purpose

The technology for upgrading the approach and a system to use in retrieving the fuel debris and internal structures has safety issues: ensuring the confinement function, capturing and removing the dust derived from the fuel debris, and the monitoring of alpha-nuclides (collective term for the radioactive nuclides that release alpha rays). This project aims at developing technology that solves the above issues and optimizing the method and system in ensuring the utmost safety.

►Major Approach and Results

1 Development of Technology related to Confinement Function

- Elemental technology was developed to ensure the confinement function works via differential pressure control, and an implementation policy that combines analysis and element tests formulated. Analysis and element tests will continue to take place in their confirmation.
- The opening area estimation method for the damaged PCV boundary was studied. A confirmation test with the actual use was then proposed.

2 Development of Technology for Dust Collection/Removal Derived from Fuel Debris

- An investigation of the technology for use in dust collection/removal process with respect to the gas and liquid systems was performed using existing technology and the benchmarks identified, and which also identified the necessary items for confirmation in the selection of technological advantages and the element tests. The element tests will be conducted to obtain the findings in the future.
- Assuming the possibility of the alpha-nuclides having melted into the water an investigation of the necessary technology for the collection/removal of dissolved nuclides in the liquid system was performed using existing technology and the benchmarks identified, and which also identified the necessary items for confirmation in the selection of technological advantages and the element tests. The element tests will be conducted to obtain findings in the future.

3 Study of Alpha-Nuclide Monitoring System Associated with Fuel Debris Retrieval

- The alpha-nuclide monitoring technology was clarified regarding the necessity and purpose of the fuel debris retrieval as well as the required measurement range of the gaseous system examined.
- A survey of existing technology used with alpha-nuclide monitoring of gaseous systems was performed and issues with the actual use dealt with.

4 Study on Optimization of Ensuring Safety of Methods and Systems

- With a focus on the partial-submersion side access method, the design conditions of the method with the applicability to each unit were taken into consideration and reviewed and the cell installation method substantiated (Fig. 2).
- The safety requirements and functional requirements during fuel debris retrieval were reviewed and brushed up in re-confirming the required systems.
- The results of public exposure evaluations conducted up to last fiscal year were re-confirmed as well as an important study on workers' exposure during fuel debris retrieval commenced upon.

►Future Developments

Element technology for the collection/removal of dust derived from the fuel debris and alpha-nuclide monitoring is currently being developed, and the study results will be reflected in the optimization of the fuel debris retrieval method and systems. In addition, the safety and functional requirements will continue to be monitored and their feasibility confirmed. The partial-submersion side access method has priority but other methods with the applicability to each unit will be taken into consideration and further examined in confirming their feasibility.

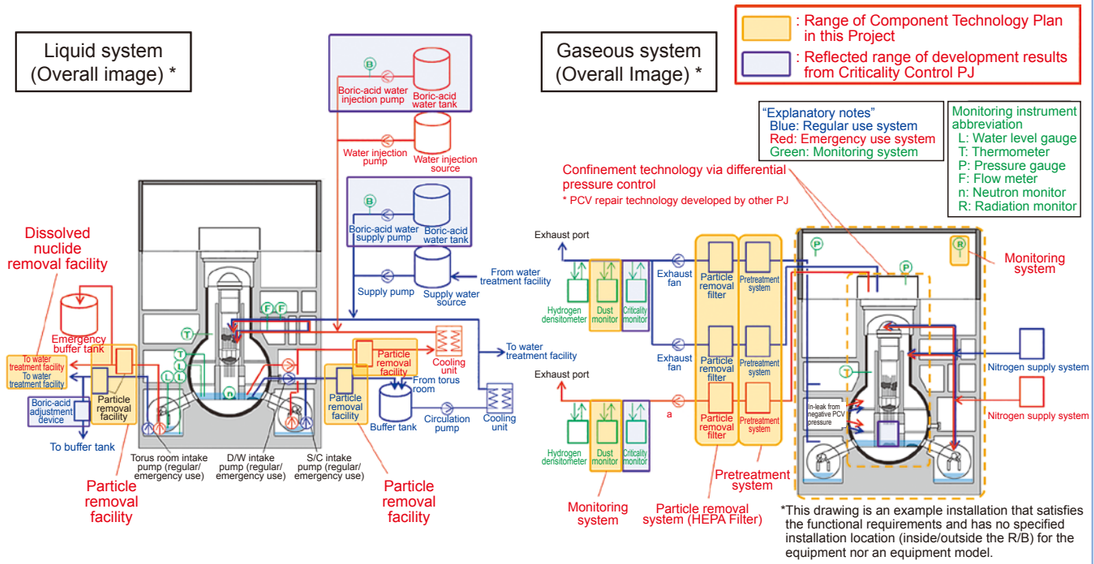


Fig. 1: Scope of Element Technology Development for System Formulation

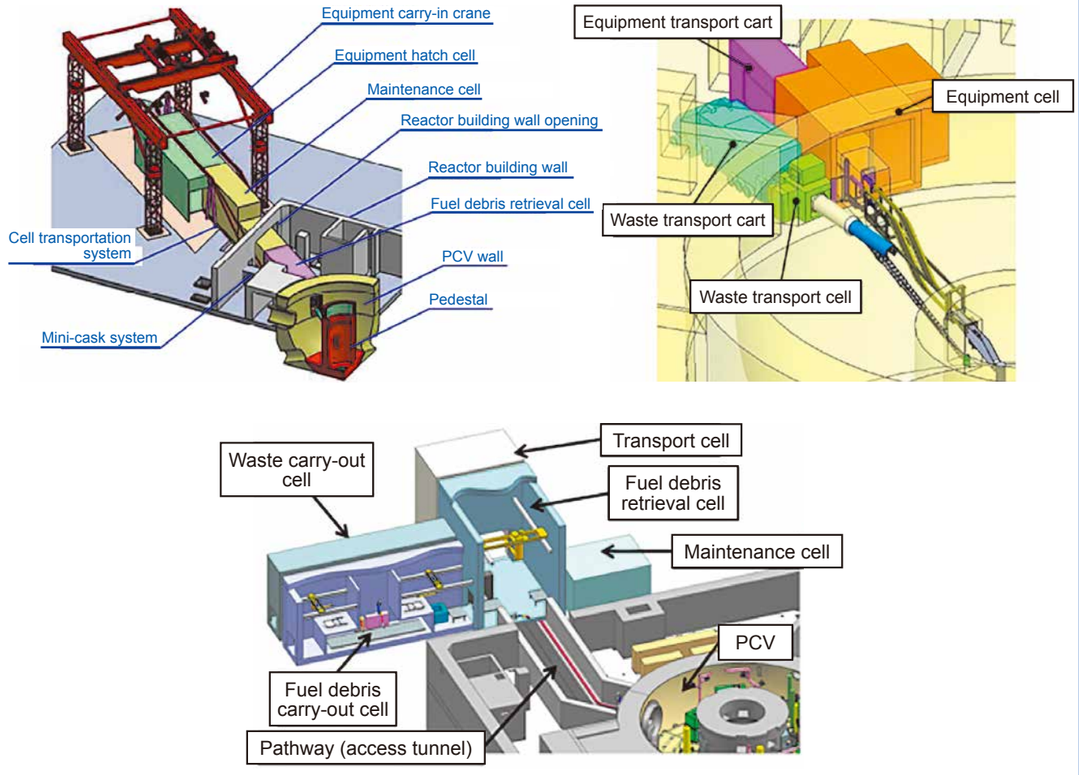


Fig. 2: Installation Image of Fuel Debris Retrieval Cell

R&D for Fuel Debris Retrieval

Upgrading of Fundamental Technology for Retrieval of Fuel Debris and Internal Structures

►Background

The fuel debris retrieval policy was determined upon and hence the focus of the study is on the partial-submersion side access method. This project aims at acquisition of the necessary data and information via element tests and a conceptual study in thereby evaluating the feasibility of the retrieval method.

►Purpose

The subsidized project of the Upgrading of Approach and System for Retrieval of Fuel Debris and Internal Structures is being used to study theoretical retrieval methods. This project aims at the highest possibility of its realization not only through theoretical study but also through obtaining the relevant data through element tests.

In addition, the development plan will be formulated after identifying any issues that need to be reviewed.

►Major Approach and Results

1 Development of Technology for Prevention Fuel Debris Spreading

① Development of Fuel Debris Collection System

- Exiting technology for the collection of powdery fuel debris was clarified and a conceptual study on applicable technology conducted.
- Using the assumed collection process for the fuel debris at the bottom of the Primary Containment Vessel (PCV) (including fuel debris generated from cutting process) a conceptual diagram of powdery fuel debris collection was created.

② Development of Fuel Debris Cutting/Dust Collection System

- Fuel debris to be cut and collected was clarified with respect to where and what shape the fuel debris would be, and the most effective processing method collection method studied.
- MCCI products included in the fuel debris have been estimated to be largely present at the bottom of the PCV. Two processing methods, which are the most efficiently (chisel processing method and ultrasound core boring method), were identified as requiring confirmation via element tests.
- The test sample produced for use in the simulated fuel debris processing tests were used to study the components of the MCCI products, their size, and the trial production method required for the test.

③ Development of Preventing Fuel Debris Spreading

- Associated with the fuel debris retrieval work technology for preventing the fuel debris at the bottom of PCV from spreading into the vent pipes and Suppression Chamber (S/C) etc. was studied in the implementation plan and based on results of investigating the PCV internals.

2 Development of Element Technology for Retrieval Device Installation

① Element Technology Development for Work Cells

- Technologies for the cell confinement and connecting to the PCVs were compared and clarified.
- The inflatable seals, or the sealing method used to connect the cells to the PCVs, involved identifying the items that would require confirmation via element tests, and test preparation launched.

② Development of Technology for Interfering Object Removal during Fuel Debris Retrieval

- With a focus on the partial-submersion side access method a processing method that could be used to remove any objects interfering with reaching the fuel debris at the bottom of PCVs was clarified.
- The element test plan regarding the interfering object removal was substantiated through the results of investigating the interfering objects, and the facility required for the work steps and element test discussed.
- The element test plan for confirming the operational performance of the combination of a robotic arm and access rail was substantiated upon.

3 Development of Remote Maintenance Technology for Fuel Debris Retrieval Equipment

- The basic idea of remote maintenance, for example the cell-inside equipment of the partial-submersion side access method, was studied, and the area classification and maintenance equipment clarified.

►Future Developments

The element test plans will be used in the tests that will be prepared and including the production of a test device. The element test results with respect to the collection of the interfering objects that require retrieval and the processing of the fuel debris will be reflected in the fuel debris retrieval method in thereby increase its feasibility.

A conceptual study of the technology needed to collect the powdery fuel debris has already taken place and a development plan will be formulated as well as the conceptual study substantiated.

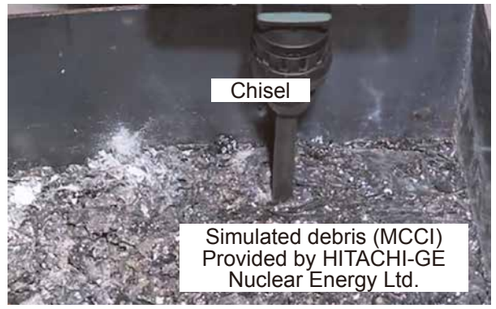


Fig. 1: State of Chisel Processing Preliminary Test

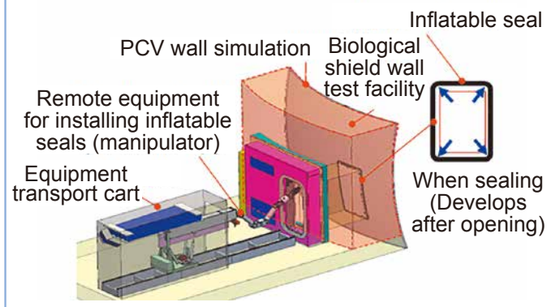


Fig. 2: Inflatable Seal Element Test

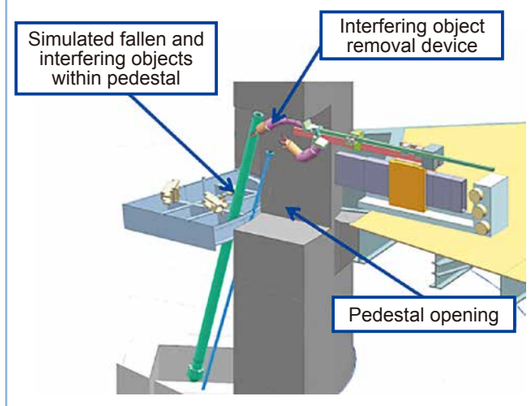


Fig. 3: Element Test of Removal of Interfering Objects in Pedestal

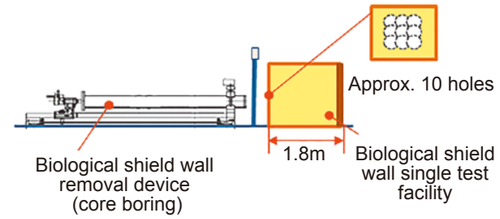


Fig. 4: Element Test of Biological Shield Wall Removal

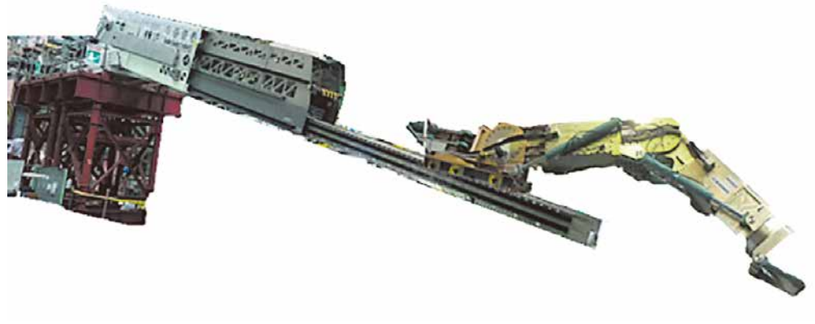


Fig. 5: Combined Element Test Image of Robotic Arm and Access Rail

R&D for Fuel Debris Retrieval

Development of Sampling Technology for Retrieval of Fuel Debris and Internal Structures

►Background

Collecting the fuel debris from the lower part of the Primary Containment Vessel (PCV) and the reactor and identifying the components and mechanical properties in thereby ensuring appropriate safety management and for use in the facility design for the fuel debris retrieval are very important. This project therefore concerns the study of a fuel debris sampling method as part of the analysis facility and in order to obtain information that cannot be obtained using a camera.

►Purpose

This project involves the scenario of the realization of the formulation of a sampling survey that will utilize the results of investigating inside the PCVs. It aims at studying the design, test production, and safety facilities of sampling devices as well as proceeding with a study of the capability to carry out collected samples to the analysis facility, and thus obtain debris information in a safe and prompt manner.

►Major Approach and Results

1 Study and Formulation of Fuel Debris Collection/Sampling Scenario

An overall scenario for the fuel debris collection was formulated and a developmental plan considered and updated through the following steps.

①Collection place, amount, and various types of collection devices were considered based on the needs and results of preceding investigations inside the PCVs.

②A development plan for the necessary technology, for example the sampling tools, was formulated.

③The safety system during the sampling that depends on the type of collection method was evaluated.

2 Fuel Debris Sampling System and Device Design/Test production in PCV

The design and test production of the required technology specific to the fuel debris sampling were promoted for the items below while utilizing the results of other technology developments.

① Basic Design of Fuel Debris Sampling System

The system requirements were clarified with respect to ensuring exposure/criticality safety and depending on the collected types of debris including cylinder shape and pebbly/sandy debris. In addition, this study explored the use of monitoring sensors that detect neutrons in ensuring the utmost safety with the relatively large cylinder shape debris to be collected, and the technology needed for the remote handling of the canisters and the transport canisters for transporting the collected samples from the high radiation area at the site (the enclosure in the reactor building) to the analysis facility.

② Design and Test Production of Devices for Accessing Fuel Debris

In order to design the access devices that depend on the type of debris collection, this study explored the versatility of arm type access devices that will make a detailed investigation inside the PCV, a link mechanism reduction for the installation of sampling tools and sensors, and advanced access device.

③ Design and Test Production of Fuel Debris Sample Collection Device

The technology for use with the pebbly and sandy debris collection was evaluated through a confirmation test and concerning the elements that included the adhesion, and with both grabbing and scooping being performed and a concept collection device designed. In addition, the conceptual design of the tools needed for effective collection of the powdery debris generated from cutting was conducted in an element test.

3 Conceptual Study of Fuel Debris Sampling System in RPV

Based on the status of the development of the internal investigation of the RPV, this project involved studying the concept of the system to be used to collect the fuel debris from inside a reactor via access from two directions, namely the upper surface and side surface of the reactor building, and with identification of the technical issues and element tests being planned.

►Future Developments

Based on progress made in FY2017 and the results of the latest internal PCV investigation, the necessary tools and an arm type access device toward early debris collection will be developed in FY2018. This project will be developed effectively and promptly in cooperation with the project of “the Development of Technology for Detailed Investigation inside PCV”.

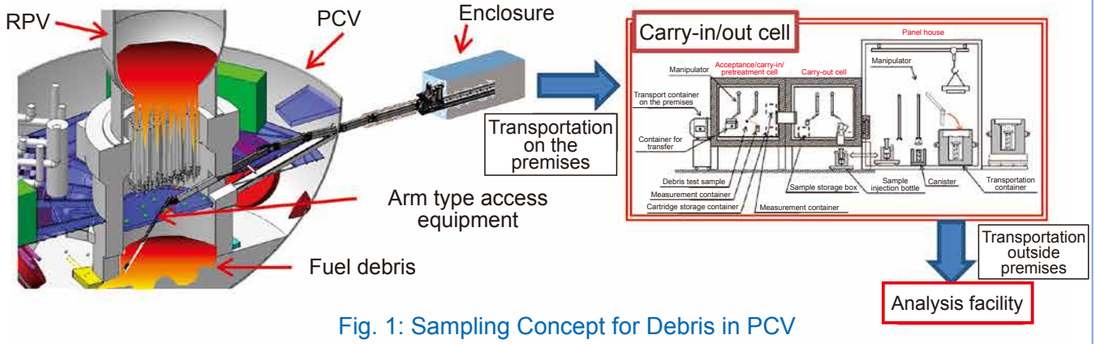


Fig. 1: Sampling Concept for Debris in PCV

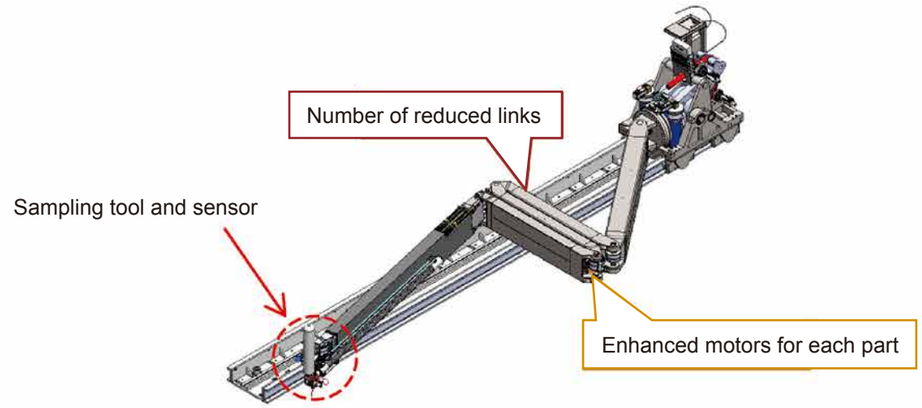


Fig. 2: Example of Access Device Used for Sampling

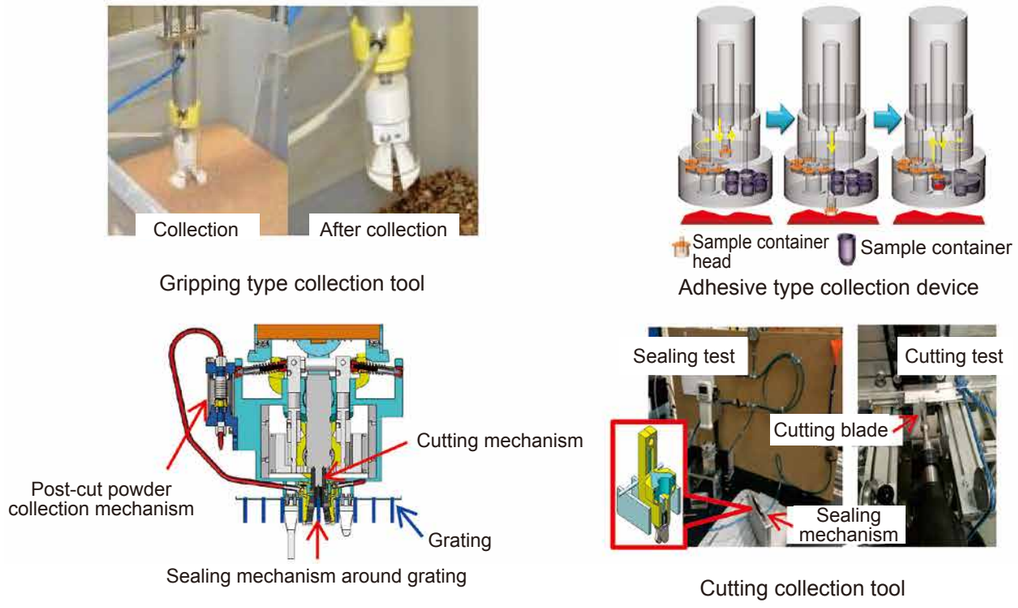


Fig. 3: Example Collection Device

R&D for Fuel Debris Retrieval

Development of Technology for Collection, Transfer and Storage of Fuel Debris

►Background

According to the Mid-and-Long-Term Roadmap towards the Decommissioning of the Fukushima Daiichi NPS of the Tokyo Electric Power Company (TEPCO) Holdings, Inc., the plan with the fuel debris retrieved from the Fukushima Daiichi NPS is for it to be stored after being removed from the reactor building until such time effective treatment and disposal methods have been determined. This therefore necessitates the establishment of storage/collection, transfer, and storage systems for the fuel debris.

►Purpose

Based on the experience of Three Mile Island Nuclear Power Generation Station Unit 2 (TMI-2) in the United States, and existing technology used to transport and store spent fuel, this project aims at developing a fuel debris canister (hereinafter referred to as “canister”) and a canister handling device for safe and efficient collection, transfer, and storage. This project mainly aimed at optimizing the specifications and shape of the canister and the canister handling device for the relevant fuel debris retrieval method in FY2017.

►Major Approach and Results

1 Investigation and Establishment of Research Plans for Transfer and Storage

An investigation of the approval and authorization documents of the Rokkasho Nuclear Fuel Reprocessing Facility, Japan Nuclear Fuel Limited (JNFL), and information on the transportation and storage of damaged fuel at overseas’ facilities (including the Idaho National Laboratory in U.S.) obtained by the end of FY2016 were reexamined, and can be considered to have contributed to the study in section 2–4 below. Technical knowledge regarding regulatory safety requirements and management items for the transportation and storage of radioactive waste was also obtained.

2 Study on Safety Requirements and Specifications and Storage Systems for the Transfer/Storage of Fuel Debris Canisters

A flowchart of the process to use with the fuel debris retrieval, collection, transfer, and storage (including drying treatment) was created, and a primary evaluation of the throughput (including amount of required treatments, number of canisters, and storage area) based on the prerequisites were used in a revised plan about reducing the canisters (Fig. 1). In addition, confirmation took place that the revision would not currently be necessary based on the latest information from related projects regarding the wet and dry storage systems for fuel debris that took place in FY2016.

3 Development of Safety Evaluation Methods and Safety Validation

The Fukushima Daiichi NPS requires validation of the safety of the canisters with respect to criticality, the structures, aged deterioration of materials, and hydrogen generation in thereby ensuring the safe collection, transfer, and storage of the fuel debris, including the MCCI products which are assumed to contain seawater components at the Fukushima Daiichi NPS, and thus differ from the case of the TMI-2 fuel debris.

Continuing on from FY2016 this project involved a sub-criticality evaluation (study on the applicability of restricting the amount of water but increasing the inner diameter of the canisters in thereby increasing the workability of the fuel debris retrieval and mitigating the sub-criticality conditions), a study on the canister structure (canister-lid structures with the handling flow and safety requirements taken into consideration), evaluation of aged deterioration of materials (corrosion evaluation with the environmental conditions taken into consideration), a study on countermeasures against any hydrogen gas generation (measurement tests of the amount of hydrogen generated from spent fuel (Fig. 2), and convection evaluation with respect to the canisters and an efficiency evaluation of a hydrogen recombination catalyst (Fig. 3). The necessary knowledge for the establishment of a safety evaluation method has therefore been gained.

4 Study on Fuel Debris Collection Method

The basic specifications for the canisters determined in FY2016 were studied with respect to the collection method and with the fuel debris properties taken into account and based on the safety requirements and safety validation results described in 2 and 3 above, and the canister specifications updated.

►Future Developments

The results of studying the fuel debris retrieval and collection that were conducted in the project involving the fuel debris retrieval method and system, and relevant project on upgrading the fundamental technology, will be reflected in the canister specifications, along with the handling equipment specifications being optimized using an updated evaluation of the safety, handling properties, and throughput. In addition, the required specifications for the transfer and storage systems for the canisters will be clarified.

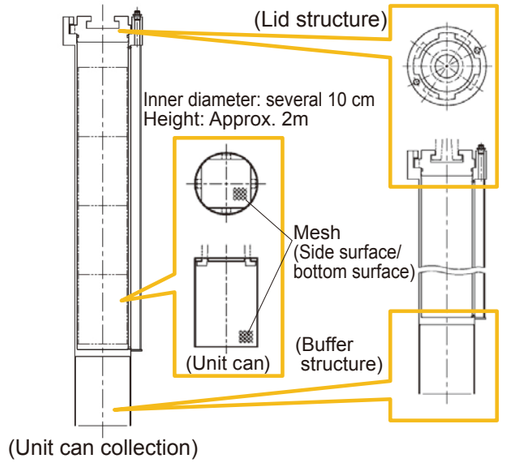


Fig. 1: Basic Draft Canister Plan

One example of the plan of a canister in a mockup test is shown. The shape will be optimized in cooperation with the project involving the fuel debris retrieval method and system in the future.

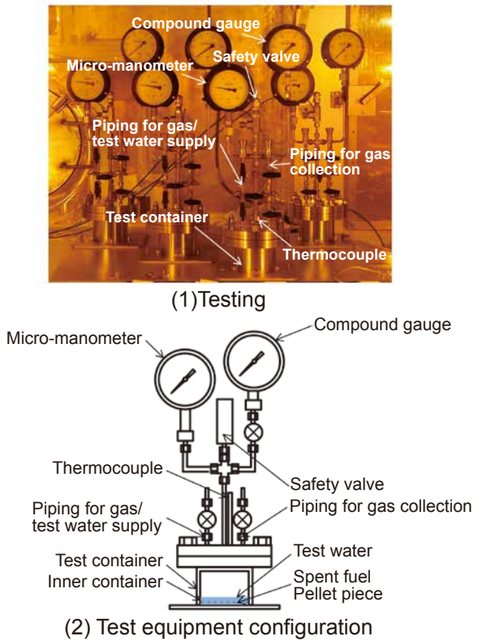


Fig. 2: Test Measurement of Amount of Hydrogen Generated Using Spent Fuel

The amount of hydrogen generated was measured in tests using fuel debris in thereby confirming the impact on hydrogen generation with or without the existence of alpha-rays. The test data obtained will be reflected in the hydrogen generation amount evaluations.

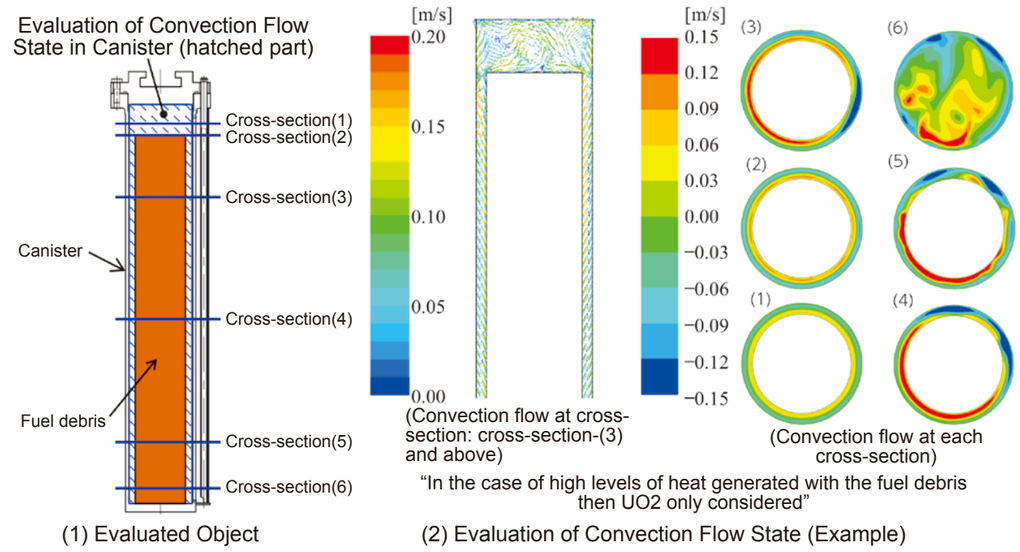


Fig. 3: Evaluation of Convection Flow State in Canister

Since any hydrogen concentrations generated in the canisters should be lower than an explosive level thermal flow analysis using numerical fluid dynamics (CFD) will be performed in thereby confirming the convection flow state within the canisters, and results of the analysis reflected in the efficiency evaluation of hydrogen gas countermeasures, including the allocation of the hydrogen recombination catalyst.

R&D for Fuel Debris Retrieval

Development of Small Neutron Detectors

►Background

Retrieving the fuel debris necessitates identifying the position and amount. The neutron measurement method, which makes measurements using the neutrons generated from the spontaneous fission of elements in the fuel debris, is one of the methods for retrieving the fuel debris. However, existing sensors may not be capable of being used due to the dimensional restrictions, thus making a smaller censor necessary.

►Purpose

The weak neutrons need to be measured under the high-dose gamma-rays by accessing the vicinity of the fuel debris with a detector in order to actually detect the fuel debris. However, the route used to access the vicinity of the fuel debris is rather narrow, thereby making a smaller sensor necessary. This project aims at developing a small neutron detector that will satisfy that requirement.

►Major Approach and Results

1 Specifying the neutron detection technology applicable to the fuel debris retrieval at the Fukushima Daiichi NPS and element test survey results of its feasibility (Phase-1)

Element test of a CMOS semiconductor type neutron detector was performed and its performance verified (Fig. 1).

①Basic property tests were conducted at a single neutron location in confirming that the sensor was capable of obtaining the neutron flux from the neutron count (Fig. 3). In addition, confirmation also took place that the signal strength obtained against the gamma-rays was linear in the single gamma-ray location (Fig. 2).

②The detection performance under the combined irradiated environment of gamma-rays and neutron-rays was confirmed in identifying the cluster pattern using alpha-rays derived from neutrons in the combined location (Fig. 4).

③The results of the radiation resistance evaluations confirmed that there would be no incorrect detection of neutrons up to the cumulative gamma-ray dose, or degree of 1000Gy. In addition, the results of irradiating a single neutron revealed no remarkable increase in the count, even with irradiation of more than 6.5e+6n/(cm^2·s)·s.

④The long distance signal transmission properties confirmed that transmission could take place over more than 50m because the neutron count with a 50m long cable was almost the same as that of a 16m cable length.

⑤In confirming the effect of the reaction layer neutrons were irradiated at the sensor without a 6Li coating, which is the reactive layer of the sensor. The results confirmed that neutrons could basically not be detected practically if there were no reaction layer.

⑥The results of measuring the neutron flux with the direction of the sensor normal line and neutron generation in evaluating the directional dependency revealed that the angle of the sensor face provided no significant change up to 45 degrees. However, the neutron flux did decrease beyond that.

2 Other Phase-1 Studies

Phase-1 involves the applicability to Fukushima Daiichi being evaluated after element tests.

①In order to study the capabilities of the feasible neutron detector and the specifications the results of a performance validation via element tests were clarified, and the capabilities and specifications of the neutron detector in actual use considered.

②With respect to the conceptual design of the neutron detector the use of a neutron measurement system was assumed in an investigation of the outside of the Unit 1 pedestal (a method to where a sensor descends from the grating on the 1st floor), and a concept neutron detector designed.

③The study involved the establishment of a neutron detector development plan, and discussing the relevant schedule up to the production period toward practical application, the cost, the delivery due date, and the handling of the developed detector (Availability of measurements by a plant operator and the necessity of preliminary training, etc.) Practical application was thereby determined.

3 Performance Validation of Element Technology

The test production of a small neutron detector was commenced upon based on the results of Phase-1.

①The sensor design and production were commenced upon; and more specifically, the design of a CMOS sensor, the sensor installation, a study on the performance validation method using a single CMOS sensor, and the design of peripheral equipment and software.

②The test production and evaluation of the sensor unit were commenced upon with respect to the basic design of the sensor unit, the design of the peripheral equipment, and the planning of the performance evaluation tests.

►Future Developments

Following Phase-2, the production of the sensor as well as the sensor unit and performance evaluations will be conducted in the completion of a small neutron detector by the end of the second quarter of FY2018. More specifically, a survey of an application in which a smaller neutron detector when compared with the existing one, and the required specifications determined. After completion of this project the decommissioning activities at Fukushima Daiichi NPS, including a detailed investigation inside the PCVs and monitoring during the fuel debris retrieval etc., will be substantiated for application in the project.

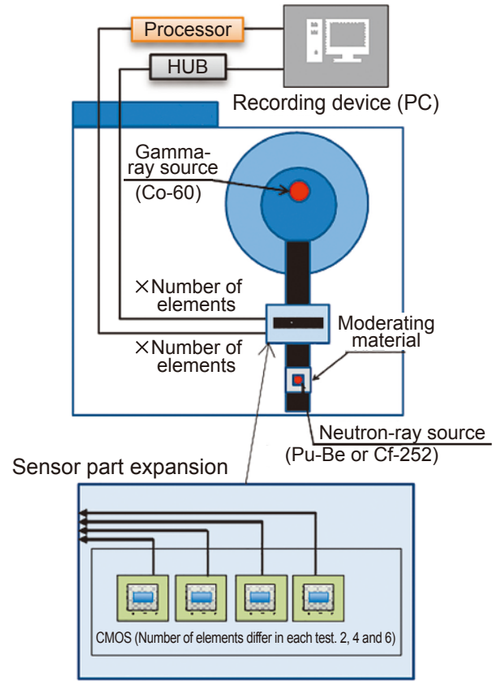


Fig. 1: Layout of Performance Validation Test

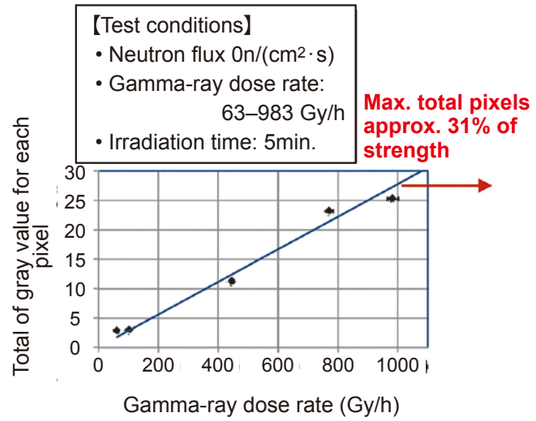


Fig. 2: Detection Performance at Single Gamma-ray Location

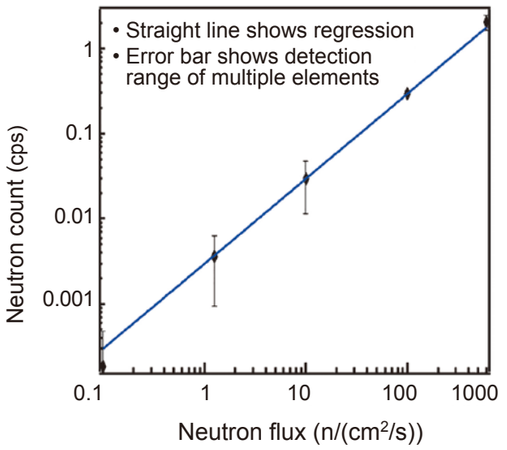


Fig. 3: Detection Performance with Single Neutron Location

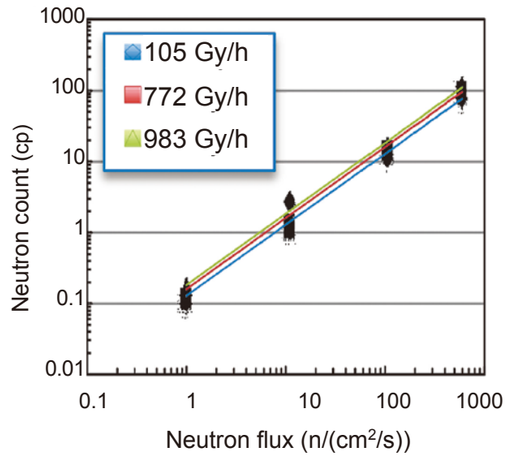


Fig. 4: Detection Performance with Gamma-Ray/ Neutron-Ray Combined Locations

R&D for Fuel Debris Retrieval

Development of Technology for Criticality Control Methods

►Background

The assumption is that the fuel debris has not currently reached criticality. The development of a criticality control method is underway in thereby ensuring criticality can be prevented in which the shape of the fuel debris and the change in the amount of water are estimated for during the fuel debris retrieval work in the future, as well as the termination of any criticality in a safe manner, even if it does occur.

►Purpose

An impact evaluation method for use with criticality shall be established via the formulation of criticality scenarios and by developing a behavior evaluation method during a criticality situation. Moreover, criticality prevention technology using neutron-absorbing material with soluble/insoluble properties and criticality monitoring technology, including technology for criticality approach detection and recriticality detection, will be developed and their technical feasibility confirmed.

►Major Approach and Results

1 Establishment of Criticality Evaluation Method

Based on the estimated information on the fuel debris distributions obtained from the results of evaluations and investigations inside the reactor, and muon measurements, the relative importance of criticality control while the fuel debris is being retrieved from each unit was evaluated (Table 1). The results will be used in the studying the concrete deployment of technologies for use in both monitoring and preventing any criticality from occurring.

A behavior evaluation method during criticality via an exposure evaluation model was developed, and an evaluation method that could be used to evaluate the behavior from the occurrence of criticality through to its termination and the impact of any exposure to the public and workers established (Fig. 1). They will be utilized in studying the procedures to use to mitigate any impact in the case criticality occurs and safety measures to use at facilities in the future.

2 Development of Criticality Approach Monitoring Method

The development of subcriticality measurement technology that is based on neutron measurements has been promoted. Operational verification tests of the B-10 neutron detector in a radiation environment were performed in FY2016 in order to confirm its feasibility with the site environment, with the discrimination of neutron-rays and gamma-rays confirming their feasibility when used with appropriate shielding. A reactor core, which simulates the various fuel debris conditions, was configured at the Kyoto University Critical Assembly (KUCA) laboratory in FY2017, and the degree of subcriticality evaluated using the reactor noise method then confirmed the estimate from the neutron signals obtained (Fig. 2). The feasibility of the criticality approach monitoring technology was thus confirmed by the neutron measurements.

3 Development of Recriticality Detection Technology

The gas control system used to monitor slight amounts of FP gas concentrations present in the Primary Containment Vessel (PCV) (Fig. 3) was improved for use in detecting any recriticality in the early stages, and Kr-88 detection technology, which can be used for prompt responses during criticality in addition to the Xe-135 technology that is currently being used in monitoring, is being developed.

This technology is based on gamma-ray measurements using a germanium (Ge) detector and the gamma-ray energy measurement range was increased to 3MeV in order to be capable of collecting gamma-ray data at the Fukushima Daiichi Unit 1 which is equipped with a Ge detector. The results confirmed that the objective nuclides had no impact in the high gamma-ray energy regions and the peak of Kr-88 (Fig. 4). This study confirmed the possibility of early criticality detection using the enhanced gas control system.

4 Development of Criticality Prevention Technology

Neutron absorbing materials for use in preventing criticality from occurring that are of the water soluble/non-soluble type have been developed.

With respect to the non-soluble absorbent material nuclear characteristic verification tests at the KUCA, dissolution tests with long-term exposure, and performance workability tests (Fig. 6) took place using candidate materials selected by their fundamental physical properties and radiation resistance performance tests (Fig. 5), and a prospect absorbent material candidate obtained.

In addition, the soluble neutron absorbent material (sodium pentaborate) confirmed the required boron concentration estimate to be about 6,000ppm as a conservative assumption. This estimate exceeds the concentration proven to exist at the power generation reactor and hence a nuclear characteristic verification test was performed at the KUCA in thereby confirming that the nuclear properties could be evaluated with the same accuracy as previous. Moreover, the basic specifications of the boron concentration maintenance facility were examined. Herewith, the prospect of boron concentration evaluations and the technical feasibility of the necessary facilities, including the concentration maintenance facility, were obtained.

►Future Developments

Prospective establishment of a criticality evaluation method for use with the fuel debris retrieval and feasible criticality control technology were obtained, and the results will be utilized in studying the optimal practical implementation of a fuel debris retrieval device and relevant systems, and thus ensuring greater safety in the future.

Sections	Major shape change	Unit 1	Unit 2	Unit 3
Reactor core	• Submerging of remnant fuel	Minimal (almost no remnant fuel)	Medium (Fuel may remain in/around the reactor core.)	Low (Fuel may remain in periphery)
RPV lower part	• Submerging of debris • State variation during retrieval	Submerging: Low Retrieval: Minimal (Small remnants)	Submerging: Medium Retrieval: Low (Large remnant, exposure)	Submerging: Medium Retrieval: Low (Large remnant, exposure)
CRD Housing	• Submerging of attached debris	Low ~ Minimal (attached shape and amount)	Low ~ Minimal (attached shape and amount)	Low ~ Minimal (attached shape and amount)
PCV bottom part	• Submerging of exposed debris • State variation during retrieval (including curling)	Submerging: Low Retrieval: Low (large residue, small exposure)	Submerging: Medium Retrieval: Low (Large remnant, large exposure)	Submerging: Low Retrieval: Low (Large remnant, small exposure)

Table 1: Degree of Importance for Criticality Control by Units and Sections (relative evaluation)

The concrete deployment of criticality prevention and criticality approach detection technologies are being studied depending on their degree of importance in controlling criticality.

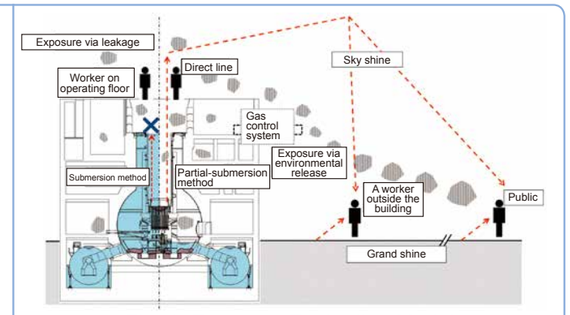


Fig. 1: Exposure Evaluation Model

These models are used in studying the specifications of the safety measure facilities and are reflected in designs in thereby avoiding any excessive exposure in the case of criticality occurring

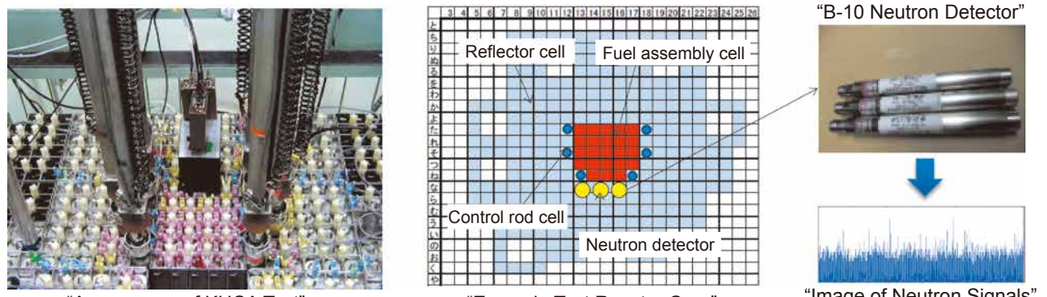


Fig. 2: Criticality Approach Test at Kyoto University Criticality Assembly (KUCA) Laboratory Device

KUCA can be used with variable amounts of fuel and moderator according to the purpose of the test and to simulate various fuel debris conditions and hence was used in the criticality approach detection and nuclear characteristic tests.

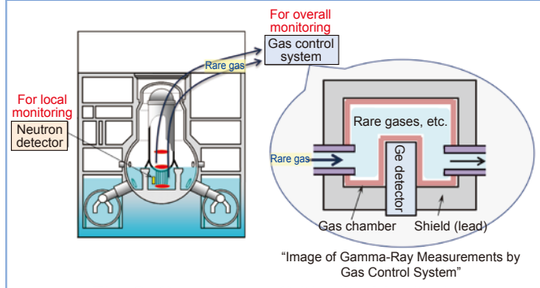


Fig. 3: Overview of Criticality Monitoring

Localized criticality will be monitored by the neutron detector and entire PCV monitored by the gas control system (Gamma-ray monitoring of rare gases).

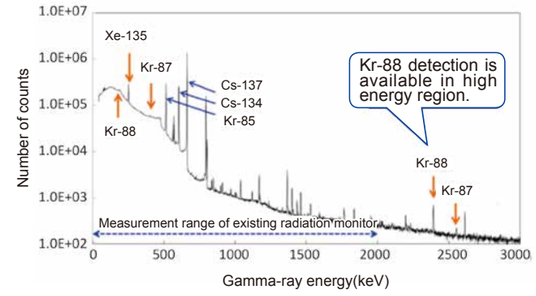


Fig. 4: Result of Gamma-Ray Measurement Tests by Gas Control System

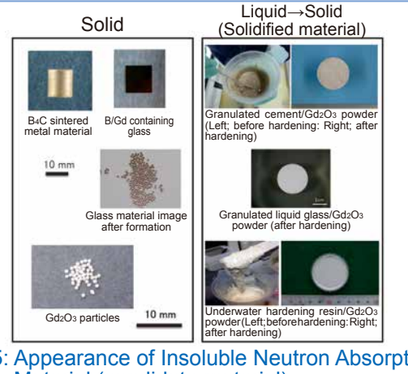


Fig. 5: Appearance of Insoluble Neutron Absorption Material (candidate material)

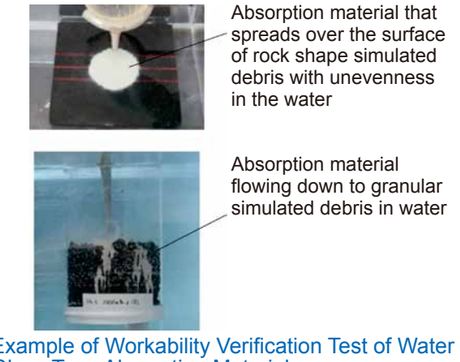


Fig. 6: Example of Workability Verification Test of Water Glass Type Absorption Material

R&D for Fuel Debris Retrieval

Development of Seismic Resistance and Impact Evaluation Methods for RPV / PCV

►Background

Due to the severe events caused by the Great East Japan Earthquake the Reactor Pressure Vessel (RPV) and Primary Containment Vessel (PCV) at the Fukushima Daiichi NPS were affected by high temperatures, seawater, and falling fuel debris and thus concerns about the material further deteriorating. Measures to maintain the structural integrity of the PCV/RPV are thus required over the long term that retrieving the fuel debris from the reactor core will take.

►Purpose

This project aims at clarifying what important equipment in RPVs/PCVs got damaged in the event of the large-scale earthquake and the spread of the impact on the water levels in the PCVs that can be assumed during the debris retrieval work and installation of important equipment in the building. Countermeasures to prevent or suppress that impact will be developed and its efficacy confirmed through seismic assessments.

►Major Approach and Results

1 Establishment of Safety Scenarios during Large-Scale Earthquakes

Safety scenarios (safety functions that maintain or can be used in responding to restoration after accidents have occurred) were established based on countermeasures for the facility which will be performed before the start of any fuel debris retrieval and as a swift preparatory response to the potential risk resulting from any damage to major equipment due to a large-scale earthquake.

2 Development of Seismic Resistance/Impact Evaluation Methods in Establishing Safety Scenarios

The development of seismic resistance and impact evaluation methods has been promoted based on the flow and feedback shown in Fig. 1.

① Development of Seismic Resistance/Impact Evaluation Methods for Suppression Chamber (S/C) Support Column

In order to evaluate seismic resistance while stopping the water in the downcomer by injecting filling into the S/C coupled analysis model (Fig. 3) connected with the vent pipes and the S/C systems in Units 2–3 was created and time-based history seismic response elastic analysis performed. The important evaluation parts: the column support, the seismic resistance support, and the vent header were all evaluated via elastic analysis as well as a detailed FEM model created in confirming the downcomer burial conditions.

② Development of Seismic Resistance/Impact Evaluation Methods for Pedestals

The data obtained uses assumptions about the pedestal temperature history and its distribution in the development of the following evaluation method for erosion impact evaluation from the fuel debris and material data.

- Simplified evaluation where the amount of erosion is a parameter and the detailed evaluation method uses the 3D FEM elastic analysis model shown in Fig. 5.
- The earthquake response impact evaluation method uses the building/large equipment system coupled model (Fig. 2) in which the stiffness degradation is a parameter that assumes the erosion in the RPV pedestal.
- High temperature erosion and strength degradation amounts for use in assuming the strength degradation of reinforcing steel in concrete.

3 Upgrading of Safety Scenarios

A confirmation method that includes analysis and tests was studied for the upgrading of the evaluation method above 2. The following detailed analysis and material tests were conducted.

- Evaluation via time history elastic seismic response analysis of the S/C support column in Unit 1.
- Acquisition of PCV material test data through taking the temperature history at the time of the accident into consideration.

►Future Developments

The safety scenarios will be reviewed according to the progress status of related projects (fuel debris retrieval system, PCV internal survey, etc.).

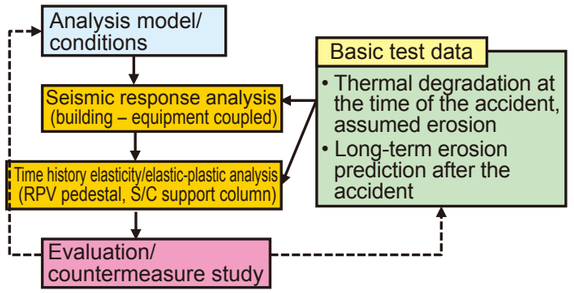


Fig. 1: Overall Development Flow of Seismic Analysis Method

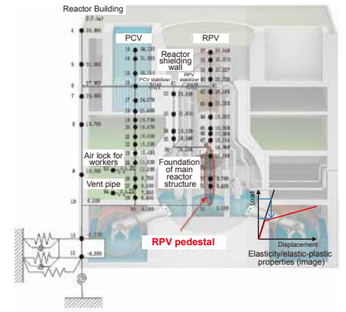


Fig. 2: Reactor Building/Large Equipment System Coupled Model

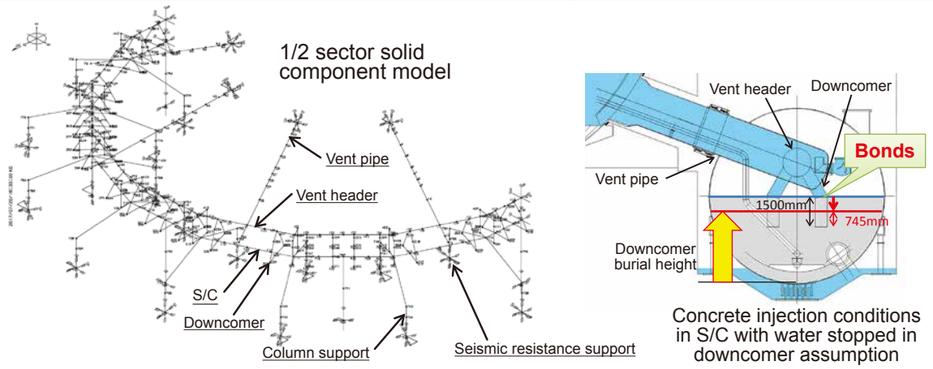


Fig. 3: Vent Pipe–S/C System Coupled Analysis Conditions and Time History Seismic Response Analysis Model (Unit 2–3)

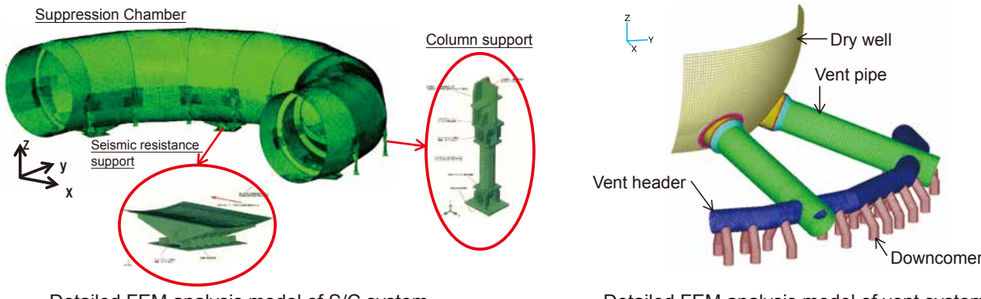


Fig. 4: Detailed Analysis Model of Vent Pipe for Elastic-Plastic Analysis and S/C System (Unit 2–3)

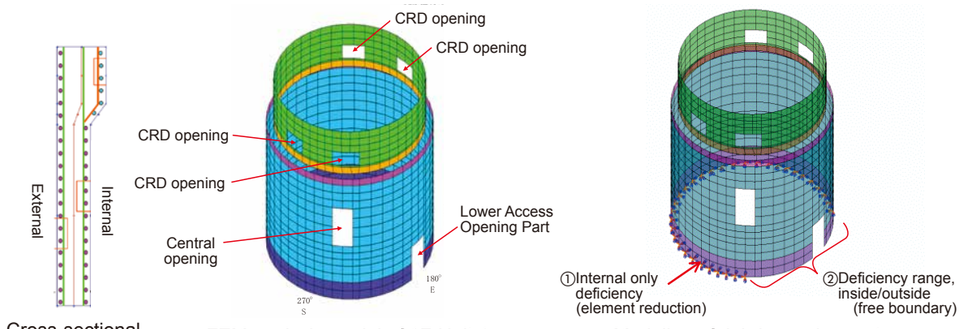


Fig. 5: Development of Seismic Evaluation Method for Pedestal due to Debris Erosion

R&D for Treatment and Disposal of Radioactive Waste

R&D for Treatment and Disposal of Solid Radioactive Waste

►Background

The fuel debris will be retrieved from the Fukushima Daiichi NPS in addition to the debris etc. that has already been stored and hence a large amount of waste can be estimated to be generated in the future. Because of this situation, methods to store, treat, and dispose of the waste in the implementation of the project will need to be developed in parallel with their characterization.

►Purpose

This project aims at developing technology for the safe treatment and disposal of the solid waste generated in the accident by integrating the results of Research and Development (R&D) resulting from characterization of an inventory evaluation based on waste analysis and a study of solidification technology, the stabilization of secondary waste generated from the water treatment, and concepts of the treatment and safety evaluation method used.

►Major Approach and Results

1 Characterization

Analysis of the rubble, contaminated water, and secondary waste generated from the water treatment continues to takes place in amassing data. In addition, the concentration of various nuclides is compared to Cs-137 in thus investigating contamination behavior using the analysis data obtained so far. The results revealed that the Sr-90 and Cs-137 concentrations indicate a correlation with the rubble samples in the reactor building, regardless of the unit (Fig. 1), with the same behavior being observed with the other nuclides. Furthermore, the contamination frequency distribution of radioactive nuclides indicates the normal logarithmic distribution used with the amount of radioactivity (inventory), including the radioactive waste, and which is being estimated (Fig. 2).

2 Preliminary Management

① Applicability Evaluation of In-Drum Type Glass Solidification Technology

As part of the stabilization technology required for the preliminary management of the secondary waste generated in the water treatment in-drum type glass solidification technology was focused upon from the aspect of contamination dispersion prevention and equipment size. The solidification results from simultaneous melting with zeolite being used for the contaminated water treatment and other simulated waste from the secondary waste generated by the water treatment (Fig. 3). Basic data, which includes chemical analysis and a leaching test from the solidification, was collected, and the composition and conditions of the solidification thus provided.

② Study on Decontaminant Device Sludge Stabilization (including sample collection)

The internal conditions of reservoir tank D in the main process building where sludge generated from the decontaminant device has been stored were surveyed in collecting some actual sludge (Fig. 4). An underwater camera revealed the thickness of the accumulated sludge layer to be approximately 40cm, and hence its volume was estimated to be 37m^3. In addition, basic data related to fluidity was obtained using simulated sludge in the study on the sludge retrieval.

3 Study of Concepts of Disposal Applicable to Solid Waste and Safety Evaluation Method

A detailed survey (Fig.5) of overseas repositories: the U.K. Low Level Radioactive Waste Repository (LLWR), the Swedish Final Repository for low and intermediate level short-life radioactive waste (SFR), the U.S. Waste Control Specialist (WCS) for low level radioactive waste disposal, among others, was conducted in the development of information to use with the concepts of applicable solid waste disposal and safety evaluation method, as well as the applicability to the solid waste at the Fukushima Daiichi NPS being studied based on various case scenarios and with domestic disposal cases and the characterization of the solid waste taken into consideration.

4 Integration of R&D Results

The waste stream was reflected in the latest results obtained from existing research and the establishment of a method of ensuring consistency in the progress made, results, and remaining issues commenced upon.

►Future Developments

Analysis will be continued to be reflected in improving the inventory estimation model as well as tests related to the stabilization of the secondary waste generated by the water treatment. In addition, a detailed survey of overseas' disposal concepts and the evaluation method, and evidence and background will continue, and applicability to the solid waste treatment at the Fukushima Daiichi NPS reviewed. The above results will then be examined with respect to the waste stream.

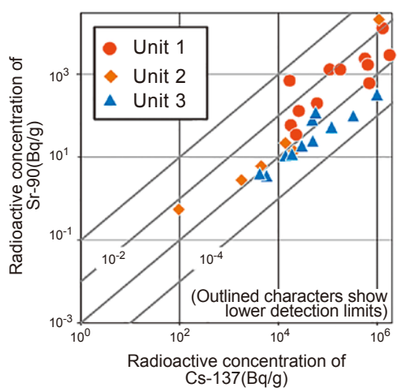


Fig. 1: Correlation of Sr-90 and Cs-137 in Rubble in R/B

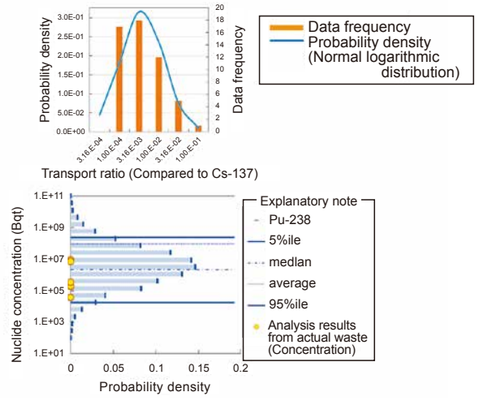
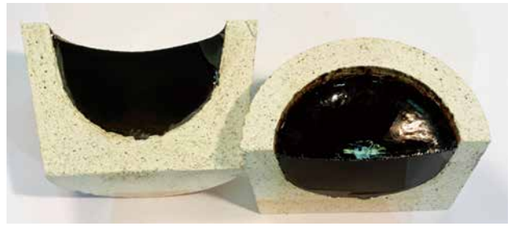


Fig. 2: Examples of Analysis Value Distribution (Upper Drawing) and Inventory Assumption (Lower Drawing)



- Production of glass solidification of secondary waste generated in the simulated water disposal (mixed zeolite, sludge from the decontamination device, and additives such as B_2O_3)

Fig. 3: Glass Solidification Tests Using Simulated Waste

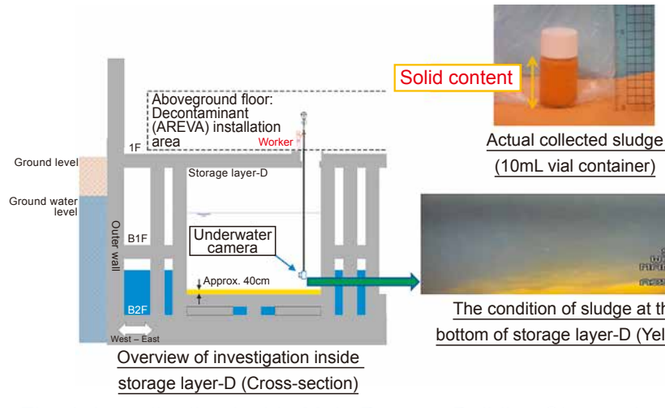


Fig. 4: Investigation inside Main Process Building Storage Layer-D and Collection of Sludge from Decontamination Device

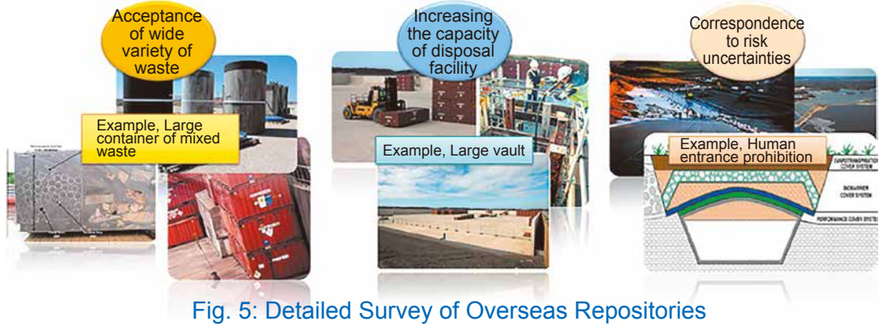


Fig. 5: Detailed Survey of Overseas Repositories

Measurement and Evaluation of Fuel Debris Distribution inside Reactor at Fukushima Daiichi NPS Unit 3

►Background and Purpose

As an approach to identifying the conditions inside the reactor and toward retrieving the fuel debris muon transmission measurements* have been made in thereby identifying the distribution of substance quantities in the Reactor Pressure Vessel (RPV) using the penetration rate of muons that could penetrate the reactor as a method of obtaining information on the fuel debris distribution at the Fukushima Daiichi NPS Units. The same measurements and evaluations were conducted for Unit 3.

* The measurements were developed using technology of the High Energy Accelerator Research Organization

►Major Approach and Results

1 Measured Results at Unit 3

Muon measurements, which can penetrate the reactor building, confirmed major structures such as the shielding concrete of the Primary Containment Vessel (PCV) peripheral, the spent fuel pool, and the reactor building wall.

2 Evaluation Results of Unit 3

The results of evaluating the fuel debris distribution in the RPV through measurements made with the muon penetration method are as follows.

① No mass of fuel debris is present in the original reactor core region.

② Fuel debris may remain at the bottom of the RPV, although uncertain.

3 Summary

The results of the evaluation will be utilized in the approach used with the fuel debris retrieval in the future in addition to other expertise obtained from investigations made inside the PCV.

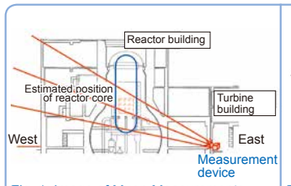


Fig. 1: Image of Muon Measurements Penetrating Reactor Building (East-West Cross Sectional Drawing)

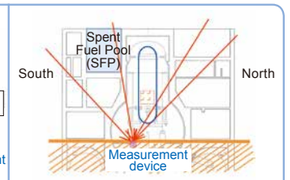


Fig. 2: Image of Muon Measurements Penetrating Reactor Building (South-North Cross Sectional Drawing)

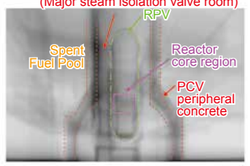


Fig. 3: Evaluation of Distribution of Substance Quantity (density length) via Simulation (Case of fuel debris being present at the reactor core and at the bottom of the reactor)

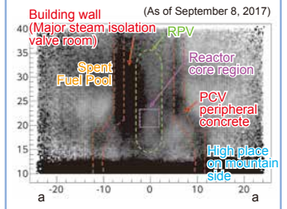


Fig. 4: Evaluation of Distribution of Substance Quantity (density length) using Muon Measurements

Development of Remote Collaboration Motion Control System

►Background and Purpose

The dry ice blast decontamination device for high places and decontamination device for the upper floors that were developed using the FY2013 supplementary budget consist of multiple crawlers, with each of the carts being operated by operators.

This research aims at developing the technology of an automatic tracking vehicle that following carts can automatically use with respect to the route to take in order to reduce the number of required operators.

►Major Approach and Results

1 Operational Test of Route Tracking

Testing of the route tracking on a test course that was a simulation of the reactor building 1st floor (straight, narrow areas, avoiding obstacles, cornering, and searching for the lead cart) confirmed that the route tracking operation had no problems.

2 Future Developments

In the case of use of decommissioning devices that consist of multiple carts on-site a remote collaboration motion control system will be developed in thereby reducing the number of necessary operators.

Photo 1: Decontamination Device for Upper Floors

Photo 2: Testing of This Research

Major Research Results in FY2017

No.	Presented at / by	Date	Details
1	The 50th JAIF Annual Convention 2017	Apr. 11, 2017	Robotics Technology Utilization
2	Special Lecture on Nuclear Reactor Decommissioning, Tokyo Institute of Technology	Apr. 21, 2017	Current State of Fukushima Daiichi NPS and Road to Reactor Decommissioning
3	2017 International Congress on Advances in Nuclear Power Plants (ICAPP 2017)	Apr. 26 – 28, 2017	Robot Exhibition Lecture: Overview of IRID R&D - Focusing on Debris Investigation
4	Societe Francaise d'Energie Nucleaire, Les accidents graves (French Nuclear Society, The severe accidents)	May 10, 2017	Fukushima Daiichi: Clarification of the accident progression, current plant status and R&D programs in Japan
5	Electrical Review 2017, Summer Special Issue	May 12, 2017	Development of Inside Survey Equipment for Nuclear Reactor Containment Vessel – Shape Variation Type Robot [PMORPH] –
6	[The contemporary Science and Technology Giant Seminar "The Inspiration of Knowledge"], Kyoto University	May 17, 2017	Working for Radioactivity
7	NSC2017 (Chernobyl Workshop)	May 18, 2017	Fuel debris and MCCI product characterization for Fukushima Daiichi NPS
8	The 42nd Task Team Meeting for Decommissioning / Polluted Water Control / Secretariat Conference	May 25, 2017	Analysis of Solid Waste Sample, Fukushima Daiichi NPS (Accomplishment report to the present situation), etc. 2 cases
9	Robotics Consortium, Shibaura Institute of Technology	May 26, 2017	Future of Decommissioning and Robotics Technology
10	National Institutes for Quantum and Radiological Science and Technology (QST)	Jun. 1, 2017	Impact Evaluation of Gamma-Ray Exposure Exerting the Local Erosion of Carbon Steel in the Diluted Artificial Seawater in which Rust-Proof Agent is Added, etc. 2 cases
11	NPO Japan Association for Automation Advancement General Meeting	Jun. 3, 2017	Future of Decommissioning and Robotics Technology
12	Professional Meeting for Basic Study Related to the Reliability Keeping of Containment Vessel / Building and Waste Disposal for Decommissioning Action and Core Human Resource Cultivation Program	Jun. 12, 2017	Proof Strength Evaluation of Severe Accident Experienced Reinforced Concrete Structure
13	JOURNAL OF NUCLEAR SCIENCE AND TECHNOLOGY	Jun. 12, 2017	Development of the model for advection and diffusion of eroded concrete into debris in molten core-concrete interactions
14	The 30th Regular Seminar of [Water Chemistry Committee], Atomic Energy Society of Japan	Jun. 23, 2017	Impact Evaluation on Rust-Proof Agent Exerting the Local Erosion of Carbon Steel in the Diluted Artificial Seawater
15	FY2017 Summer Special Issue, [Electrical Review]	Jun. 30, 2017	Front Line of Disaster Corresponding Robot – Prospect at Flammable Gas Generation and Approach to the Firefighting Activity at Large-Scale Fire –
16	Knowledge Innovation Research Group Meeting, Knowledge Management Society of Japan	Jun. 30, 2017	Overview of Activities of International Research Institute for Nuclear Decommissioning
17	ACTINIDES 2017, Sendai Progress in Nuclear Science and Technology	Jul. 2017	Characterization of the VULCANO test products for fue debris removal from the Fukushima Daiichi Nuclear Power Plant
18	International Trade Fair [1 FPEX 2017] Hosted by Japan Fluid Power Association	Jul. 2017	Water moves machine! Safety of food! Safety of person! Safety of town! Safety of Country!
19	The Second International Forum of the Fukushima Daiichi Decommissioning	Jul. 2 – 3, 2017	Estimation of Situation inside the Reactor Core and PCV Fukushima Daiichi NPS
20	International Conference Actinides 2017; and Progress in Nuclear Science and Engineering	Jul. 10, 2017	Chemical state analysis of simulated corium debris by EXAFS, etc. 2 cases
21	The 16th Materials Division Summer Seminar, 2017; Atomic Energy Society of Japan	July 12, 2017	Development of Technology for Corrosion Control of RPV/ PCV in 1F
22	The 14th Academic Conference, Japan Society of Maintenology	Aug. 2, 2017	Development and Verification of Investigation Device inside PCV – Basement Survey by Shape Variation Type Robot [PMORPH] –
23	IRID Symposium 2017 in Iwaki	Aug. 3, 2017	Conceptual Description of Element Technology for upgrading Fundamental Technology
24	[The 14th Nuclear Power Technology Summer Seminar], Nuclear Power Group Meeting	Aug. 4, 2017	Approach to Domestic and Foreign Nuclear Power ①
25	Technical Information Center Seminar	Aug. 22, 2017	The Latest Technique Development of Nuclear Power Plant Robot toward Decommissioning/ Convergence Support
26	Study on Characterization of Fuel Debris and Human Resource Cultivation Conference (ConFDeC2017)	Sep. 6, 2017	Current Status of Fukushima Daiichi NPS and R&D for Fuel Debris Retrieval
27	Creative Human Resource Cultivation Program through Basic Study on Decommissioning – Transdisciplinary Challenge from Fukushima Using Inter-College Network – FY2017 Section Meeting and the 1st Research Report Meeting	Sep. 6, 2017	R&D Status of International Research Institute for Nuclear Decommissioning

No.	Presented at / by	Date	Details
28	Decommissioning Study / Human Resource Cultivation Enhancement Program, FY2017 Summer School, University of Tokyo	Sep. 6, 2017	Remote Technology for Decommissioning and its Design Methodology, etc. 2 cases
29	The 3rd Asian Nuclear Fuel Society	Sep. 8, 2017	A study of cesium chemisorption onto surface of Stainless Steel
30	The 35th Japan Robotics Society	Sep. 11, 2017	Robotics Technology for Decommissioning and Expectation to Academy, etc. 3 cases
31	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Filling Water Stop in S/C (1) Overview Related to 1/1 Scale Actual Size Filling Test (2) Relationship between Stiffening Ring Trans-lesion and Concrete Mix (Mix-A, Mix-B) (3) Placing up State and Finishing State regarding 1/1 Full Scale Filling Test (4) Concrete Core regarding 1/1 Scale Full Scale Filling Test (5) Water Stopping Performance of Damaged Hole, Quencher and Strainer regarding 1/1 Full Scale Filling Test
32	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Fuel Debris Criticality Control Technique (29) and Criticality Control Policy, etc. 12 cases
33	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Chemical Reaction Evaluation on Cs and Steel Member at Light-Water Reactor Serious Accident (1) Evaluation on Speed of Reaction between Cs and Steel Member toward Modeling
34	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Housing-Can for Fuel Debris (1) Colledtion/ Transfer/ Storage Techniques for Fuel Debris, etc. 10 cases
35	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Study on Identifying of Conditions inside Reactor by Severe Accident Analysis Code MAAP (17) Detailed Analysis on the Accident Progression of Fukushima Daiichi Unit 2 by MAAP, etc. 2 cases
36	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Poly-Nuclear Species Analytical Method by ICP-QQQ-MS Development of simultaneous measurement for multi isotopes by ICP-QQQ-MS
37	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Review on the Preprocessing for Dry Type Storage of Retrieved Fuel Debris – Evaluation on the Drying Property Focused on the Shape of Fuel Debris – Pre-treatment of defueling Fuel Debris for drying storage – Evaluation of Drying Characterization focused on form for Fuel Debris –
38	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Inventory Evaluation Method for Fukushima Daiichi Accident Waste (11) Review on Analytical Estimation Technique for Contamination State in Nuclear Reactor Building
39	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Analysis/ Evaluation on Indentification of Conditions inside Reactor Fukushima Daiichi NPS, TEPCO (91) Evaluation on Debris Spreading State by Actual Machine Sensitivity Analysis for In-Core State Assumption
40	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Analysis on Inside Temperature Distribution of Fukushima Daiichi Unit 3 by Using CFD Tool
41	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Compact Dosimeter toward the Inside Survey of PCV
42	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Development of Water Stop Technique in S/C by Underwater Inseparable Concrete Filling (11) Overview of Filling Property/ Water Stop Property Confirmation Tests by Inseparable Concrete Using Full Scale S/C Model
43	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13, 2017	Evaluation on Long-Term Integrity of Fuel Assemblies Retrieved from Spent Fuel Pool (4) Evaluation on Fuel Soundness at Wet Type Storage
44	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 13 – 14, 2017	Development of Inside Survey Equipment for PCV [PMORPH]
45	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 14, 2017	Development of Multi Nuclides Analysis Method by ICP-QQQ-MS
46	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 14, 2017	Review on Preprocessing for Dry Type Storage of Retrieved Fuel Debris – Evaluation on Dry Property Focusing on the Shape of Fuel Debris –
47	2017 Fall Meeting, Atomic Energy Society of Japan	Sep. 15, 2017	Current State of Technical Development by IRID toward the Decommissioning of Fukushima Daiichi NPS
48	The 3rd Strategical Workshop Related to the Decommissioning of Fukushima Daiichi NPS	Sep. 16, 2017	Recommendation to the Decommissioning from Perceptions of Large MCCI Test at CEA
49	6th Asia-Pacific Symposium on Radiochemistry (APSORC17)	Sep. 17, 2017	Application of ICP-MS to analytical methods for samples from 1F site at Okuma Analysis and Research Center
50	HOTLAB2017 (Annual Meeting on Hot Laboratories and Remote Handling)	Sep. 17 – 19, 2017	International collaborations at JAEA/CLADS toward decommissioning of Fukushima Daiichi NPS, etc. 4 cases

No.	Presented at / by	Date	Details
51	Decommissioning Technique, Radioactive Waste Management and Nuclear Facility Decommissioning Technology Center	Sep. 20, 2017	Current State of R&D for Fuel Debris Retrieval Technique toward the Decommissioning of Fukushima Daiichi NPS – Overview of R&D Approached by International Research Institute for Nuclear Decommissioning (IRID) –
52	[Introduction to Nuclear Decommissioning Engineering/ Special Topics], Intensive Course of Tohoku University	Sep. 23, 2017	Development of Robot Technique Associated with Decommissioning Work and State of Site Application
53	Kansai Nuclear Conference [Research Committee on the Upgrading Technique of Atomic Fuel]	Oct. 11, 2017	IRID R&D State toward Fuel Debris Retrieval
54	Academic Journal; The Institute of Systems, Control and Information Engineers (ISCIE)	Oct. 15, 2017	Introduction to ROS for Control Researchers
55	The 34th Japan-Korea Nuclear Experts Meeting	Oct. 16, 2017	Overview of IRID R&D Focusing on Debris Retrievel
56	The 2nd Committee on Decommissioning Ground Engineering, 2017	Oct. 16, 2017	R&D on Treatment and Disposal of Solid Wastes from Fukushima Daiichi NPS
57	MIT-Tokyo Institute of Technology Innovative Nuclear Event System (MT-INES) Program	Oct. 19, 2017	R&D activityes for Fukushima Daiichi Nuclear Power Station Decommissioning
58	The 64th Materials and Environmental Discussion Session (Japan Society of Corrosion Engineering)	Oct. 24, 2017	Criticality Prevention Measures at Fuel Debris Retrieval by Using Neutron Absorption Material, and Impact on Erosion
59	MIT-Tokyo Tech workshop on Innovative Nuclear Energy Systems (TM-INES)	Oct. 27, 2017	Restoration and decommissioning activities for Fukushima Daiichi Nuclear Power Station by Toshiba
60	2017 IEEE/SICS International Symposium on System Integration (SII 2017)	Oct. 30, 2017	Outcome of [Cooperative Movement Control of Multiple Carts]
61	The University of Tokyo-IRID workshop	Oct. 30, 2017	Current State and the Issues of R&D toward Fukushima Daiichi Decommissioning, etc. 2 cases
62	The 64th Materials and Environmental Discussion Session, Japan Society of Corrosion Engineering	Nov. 8, 2017	Development of RPV/PCV Erosion Suppression Technique for Fukushima Daiichi NPS: About Selection Result and Management Procedures of Rust-Proof Agent, etc. 3 cases
63	Robot Festival Fukushima, 2017	Nov. 9, 2017	State of R&D Approached by IRID [Survey/ Retrieval of Fuel Debris by Robot]
64	[Outcome and Issues of Robot Technique] Hosted by Expert Committee of Production and Management Knowledge, The Japan Society for Precision Engineering	Nov. 13, 2017	Decommissioning of Fukushima Daiichi and Robot Technique
65	Vol. 35, Number 9; Japan Robotics Society	Nov. 15, 2017	Development of Fuel Debris Shape Measuring Device
66	The 26th Polymer Materials Forum, The Society of Polymer Science, Japan	Nov. 16, 2017	Current State of Technical Development by IRID toward the Decommissioning of Fukushima Daiichi NPS
67	The 10th International Symposium on Nuclear Science and Technology	Nov. 23, 2017	Numerical Analysis for Fulushima-Daiichi Unit 2
68	[Conference on the Erosion Prediction and Mitigation of Major Components in Fukushima Daiichi NPS], the 4th Fukushima Research Conference FY2017	Nov. 27 – 28, 2017	Preliminary Evaluation of Radiolytic Hydrogen Amount in Fuel Debris Canister (Provisional Calculation of Hydrogen Generation Amount by the Radioactive Degradation in Fuel Debris Containment Can), etc. 4 cases
69	Discussion Session on X-Ray Material Strength, The Society of Material Science, Japan	Dec. 1, 2017	Nondestructive Inspection of Imaging by Muon Scattering Method
70	QST Takasaki Science Festival 2017	Dec. 12, 2017	Evaluation on Hydrogen Gas Generation Associated with Gamma-Ray Irradiation Targeted at the Cement Solidification Sample of Contaminated Water Treatment Secondary Waste
71	The Society of Instrument and Control Engineers Lecture Presentation, Systems Integration Category	Dec. 20, 2017	Development of Operation Training System Related to the Fukushima Daiichi NPS by Using VR
72	Lecture Presentation on the Measures for Decommissioning and Polluting Water	Dec. 20, 2017	Survey Robot Technique Development at IRID
73	Decommissioning Technology and Human Resource Cultivation Forum, Tokyo Institute of Technology; 2017	Jan. 10, 2018	Review on Realistic Criticality Risk Evaluation Method
74	Journal of Japan Electrical Manufacturers' Association [DENKI]	Jan. 24, 2018	Current R&D State of International Research Institute for Nuclear Decommissioning (IRID) toward the Decommissioning of Fukushima Daiichi NPS
75	Research Chronology 2016 (brochure), Takasaki Advanced Radiation Research Institute	Feb. 2018	Investigation of Hydrogen Gas Generation by Radiolysis for Cement-Solidified Products of Used Adsorbents for Water Decontamination
76	Journal of Nuclear Engineering and Radiation Science	Mar. 2018	Mechanical properties of cubic (U, Zr) O2

List of Joint Research/Contract Research in FY2017

No.	Project name	Category	Subject	Partner	Period
1	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	MELCOR Analysis Related to Event Transition at Reactor Core Substance Slumping	WASEDA University	Apr. 1, 2017 – Feb. 28, 2018
2	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	Piping Deformation Analysis at Reactor Core Substance Slumping	University of Tokyo	Apr. 1, 2017 – Feb. 28, 2018
3	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	Inverse Problem Evaluation by Virtual Nuclear Reactor	University of Tokyo	Apr. 1, 2017 – Feb. 28, 2018
4	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	Study on Cesium Supplementary Reaction and Diffusion Behavior	Osaka University	Apr. 1, 2017 – Feb. 28, 2018
5	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	Study on the Thermodynamic Amount Evaluation of Cs-Si-(Fe)-O System Chemical Compound	Tokyo Institute of Technology	May 1, 2017 – Feb. 28, 2018
6	Upgrading the Comprehensive Identification of Conditions inside Reactor	Contract Research	Research on Silicon Behavior in Material	Tohoku University	May 1, 2017 – Feb. 28, 2018
7	Upgrading of Fundamental Technology for Retrieval of Fuel Debris and Internal Structures	Contract Research	Evaluation on Trajectory Generation Considering the Avoidance of Interference with the Environment of Robot Multiple Degrees of Freedom	Kobe University	Jun. 15, 2017 – Feb. 15, 2019
8	Upgrading of Fundamental Technology for Retrieval of Fuel Debris and Internal Structures	Contract Research	Survey on the Estimation/ Control of Hydraulic Driven Manipulator Finger Load Force	Osaka University	Aug. 1, 2017 – Feb. 15, 2019
9	R&D for Treatment and Disposal of Solid Radioactive Waste	Contract Research	Review on the Accuracy Improvement of Analytical Evaluation Method	Central Research Institute of Electric Power Industry	Jul. 1, 2017 – Jan. 31, 2018
10	R&D for Treatment and Disposal of Solid Radioactive Waste	Contract Research	Co-Operation in Waste Management Technology Fields on Gas Generation	National Nuclear Laboratory Limited (NNL) in UK	Sep. 27, 2017 – Feb. 28, 2018
11	Development of Technology for Criticality Control Methods	Contract Research	Verification Test of Criticality Approach Detection System to be Applied to the System Including Fuel Debris and Neutron Absorption Material (Part-2)	Kyoto University	Oct. 20, 2017 – Jan. 31, 2018
12	Development of Repair Technology for Leakage Points inside PCV	Contract Research	Liquidity Improvement of Self-Compacting Concrete	Kochi University of Technology	Oct. 1, 2017 – Mar. 20, 2018

Major Research Facility/Equipment

Over 1 Million Yen

No.	Project name	Details
1	Full-scale test of repair and water stoppage technology for leakage points inside the Primary Containment Vessel	Heating/ Water Supply Facility
2	Full-scale test of repair and water stoppage technology for leakage points inside the Primary Containment Vessel	Muddy Water Treatment Facility
3	Full-scale test of repair and water stoppage technology for leakage points inside the Primary Containment Vessel	Working Floor
4	Full-scale test of repair and water stoppage technology for leakage points inside the Primary Containment Vessel	Test Sample Mitigation Rail
5	Full-scale test of repair and water stoppage technology for leakage points inside the Primary Containment Vessel	Full scale Mock-up Facility
6	Development of Technology for Investigation inside PCV	B1 Survey Equipment
7	Development of Technology for Investigation inside PCV	Scattering Prevention Facility for B1 Survey Equipment
8	Development of Technology for Investigation inside PCV	Ancillary Facility for B1 Survey Equipment
9	Development of Technology for Investigation inside PCV	Simulated Object for B1 Survey Equipment Mockup Test
10	Development of Technology for Investigation inside PCV	Shielding Block Removing Device
11	Development of Technology for Investigation inside PCV	Fuel Debris Shape Measuring Device
12	Development of Technology for Investigation inside PCV	Element Test Device for Fuel Debris Shape Measuring Device
13	Development of Technology for Investigation inside PCV	A2 Survey Equipment (Chamber and Guide Pipe included)
14	Development of Technology for Investigation inside PCV	X-6 Penetration Hole Punch: 1 set
15	Development of Technology for Investigation inside PCV	In-Penetration Advanced Check Device: 1 set
16	Development of Technology for Investigation inside PCV	Sediment Removing Device: 1 set (Chamber included)
17	Development of Technology for Investigation inside PCV	Ancillary Facility for A2 Survey Equipment: 1 set
18	Development of Technology for Investigation inside PCV	In-Pedestal preliminary Confirmation Device: 1 set
19	Development of Technology for Investigation inside PCV	In-PCV Structure Simulated Mockup Body: 1 set
20	Development of Technology for Investigation inside PCV	A3 Survey Component Test Equipment: 1 set
21	Development of Technology for Investigation inside PCV	Hatch Opening Device Associated Machine: 1 set
22	Development of Technology for Investigation inside PCV	B2 Survey Equipment
23	Development of Technology for Investigation inside PCV	Scattering Prevention Equipment for B2 Survey Equipment
24	Development of Technology for Investigation inside PCV	Ancillary Facility for B2 Survey Equipment
25	Development of Technology for Investigation inside PCV	Simulated Object for B2 Survey Equipment Mockup Test
26	Development of Technology for Investigation inside PCV	Underwater Swimming Type Equipment Trial Model : 1 set
27	Development of Technology for Investigation inside PCV	X-6 Penetration Hole Remote Punch: 1 set
28	Fuel Debris Characterization	Large Capacity Thermogravimetric Scales and Simultaneous Thermal Analyzer
29	Fuel Debris Characterization	4-Component Piezoelectric Cutting Dynamometer
30	Fuel Debris Characterization	Elemental Analyzing System for SEM
31	Fuel Debris Characterization	Hydraulic Type Automatic Embedded Equipment
32	Fuel Debris Characterization	Inverted Metal Microscope
33	Fuel Debris Characterization	Carbon Coater
34	Fuel Debris Characterization	Vacuum Replacement Arc Melting Furnace
35	Fuel Debris Characterization	Fuel Debris Compression Test Equipment
36	Fuel Debris Characterization	Fuel Debris Sonic Speed Measurement Device
37	Fuel Debris Characterization	Metallographic Image Analyzer
38	Fuel Debris Characterization	Dynamic Micro Hardness Tester
39	Fuel Debris Characterization	Simultaneous Thermal Analyzing System
40	Fuel Debris Characterization	Gas Piping Valve Heater
41	Fuel Debris Characterization	Sample Cutting Machine
42	Fuel Debris Characterization	Sample Polishing Machine
43	Fuel Debris Characterization	Core Sampling Collection Unit
44	Fuel Debris Characterization	Laser Diffraction Type Grain Size Distribution Measuring Apparatus
45	Fuel Debris Characterization	Dry Automatic Density Meter
46	Fuel Debris Characterization	Heating Furnace for Thermal Analyzer
47	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Full Scale Test Device
48	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Full Scale Test Facility
49	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Equipment for 1/4 Scale Test
50	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Facility for 1/4 Scale Test
51	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	1/4 Model Test Facility
52	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	1/4 Scale Reactive Force Retaining Mechanism Combination Test Sample
53	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Test Sample of PRV Upper Part Water Shielding
54	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Flexible Structure Arm: 1 set
55	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Flexible Structure Arm Control Device
56	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Facility for Mockup in PCV
57	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Facility for Equipment Hatch Carry-In Test
58	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	1/1 Scale Hydraulic Type Reactive Force Retaining Mechanism
59	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	1/1 Scale Electrically-Assisted Type Reactive Force Retaining Mechanism
60	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Laser Gouging Power Measurement Unit
61	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Laser Gouging Head
62	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Access Equipment Component Test Equipment
63	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Robot Arm
64	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	Access Rail
65	Development of Fundamental Technologies for Retrieval of Fuel Debris and Reactor Internals	PCV Welding Device
66	R&D for Treatment and Disposal of Solid Radioactive Waste	Chamber for Alpha Nuclide Analysis
67	R&D for Treatment and Disposal of Solid Radioactive Waste	Digital Spectrometer
68	R&D for Treatment and Disposal of Solid Radioactive Waste	Efficiency Calculation Program for Gamma-Ray Measurement
69	R&D for Treatment and Disposal of Solid Radioactive Waste	Aerosol Mitigation Observation Instrument
70	R&D for Treatment and Disposal of Solid Radioactive Waste	Well-Type Ge Detector
71	R&D for Treatment and Disposal of Solid Radioactive Waste	Core Data Collection Unit
72	R&D for Treatment and Disposal of Solid Radioactive Waste	Zeolite Sample Collection Test Equipment
73	R&D for Treatment and Disposal of Solid Radioactive Waste	Compact Core Sample Collection Test Model

* R&D completed major research facility/equipment have been deleted from the list, FY2017 version.