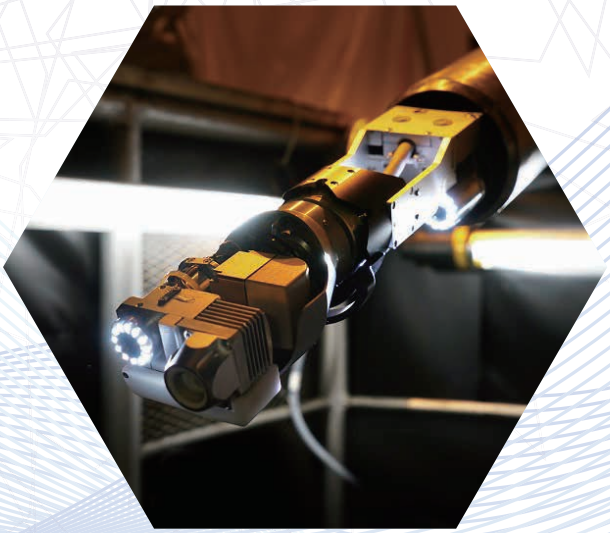
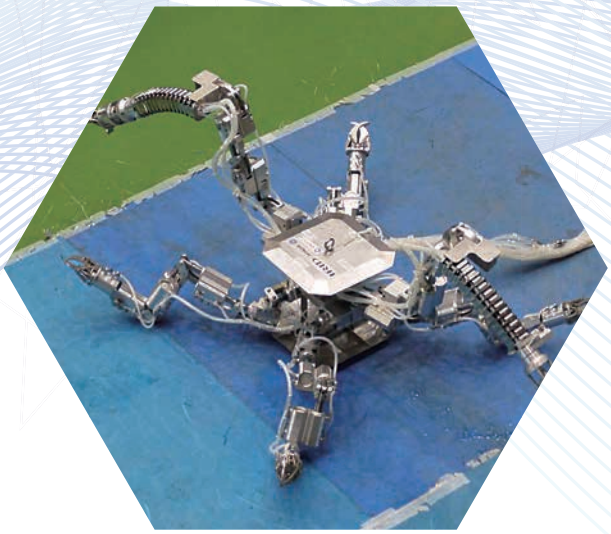
Annual Research Report 2018





IRID
International Research Institute
for Nuclear Decommissioning

Greeting

The “Mid-and-Long-Term Roadmap toward the Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS), Tokyo Electric Power Company (TEPCO) Holdings Co., Inc.” was revised by the government. It is based on the updating of the Technical Strategic Plan for 2017 Decommissioning of Fukushima Daiichi NPS, TEPCO Holdings Inc., by Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) in September 2017. It indicated that retrieving fuel debris at the bottom of the primary containment vessel (PCV) shall be performed in advance by focusing on the “Partial submersion side-access” retrieval method as “Fuel Debris Retrieval Policy”, and decide the fuel debris retrieval method for the initial unit in fiscal year 2019.

The International Research Institute for Nuclear Decommissioning (IRID) has been engaged in the research and development (R&D) of 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 nuclear reactor being clarified upon as well identifying the technical issues to be overcome by using the development of technology for investigating inside the PCV and detecting the fuel debris using cosmic rays.

The Annual Research Report 2018 is intended to summarize the achievements of the R&D projects (15 subsidized projects and 2 in-house research) undertaken by the IRID in FY2018. We would appreciate if this report helps to understand the R&D achievements and what IRID has been responsible for.

Eight years have now passed since the accident that occurred at the Fukushima Daiichi NPS after the Great East Japan Earthquake. 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 efficient nuclear decommissioning in thereby fulfilling our responsibilities.

We sincerely appreciate your kind guidance and continued support.

March 2019

Hideo Ishibashi

President of International Research Institute for Nuclear Decommissioning

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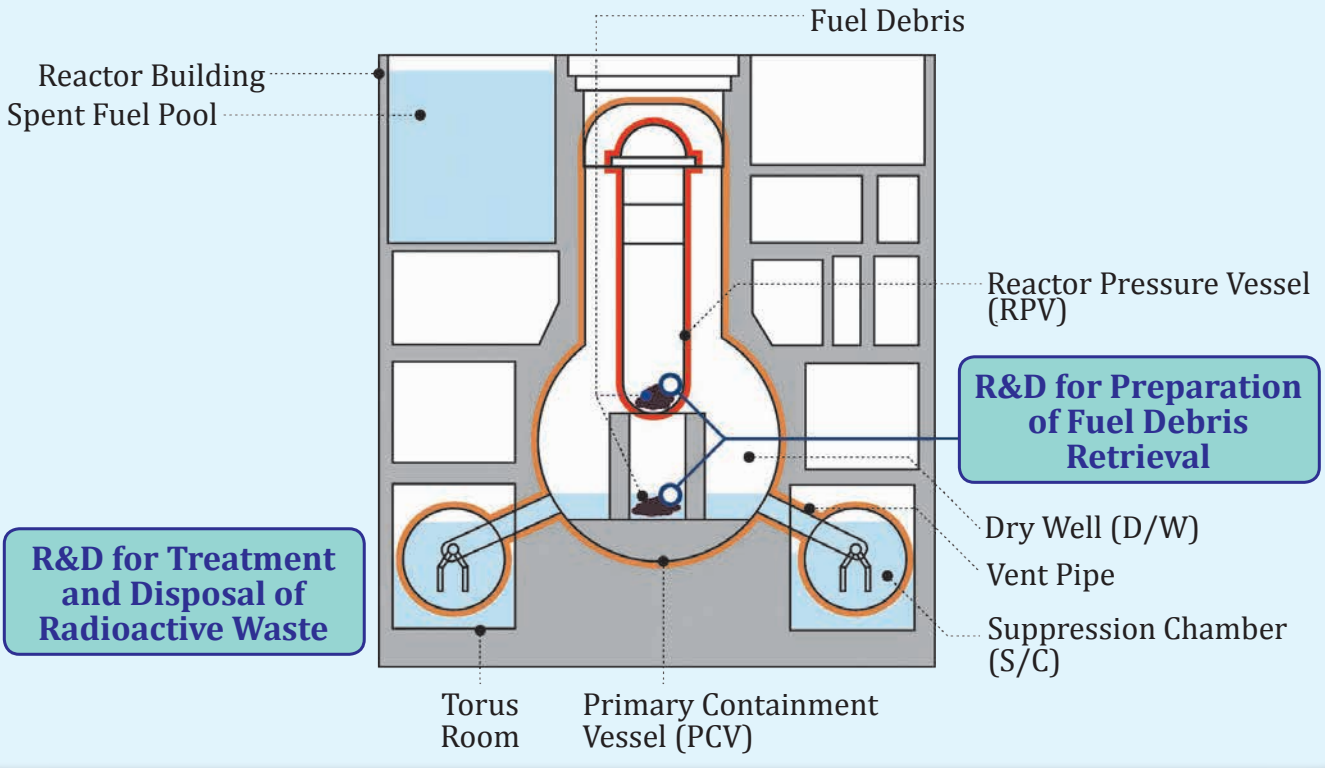
In-House Research (2 projects)

1F: Fukushima Daiichi NPS

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



R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Detailed Investigation inside PCV

Background

Melted fuel debris are considered to have fallen into the pedestal at Fukushima Daiichi Nuclear Power Station (NPS) Units 1-3. Valuable information was obtained from investigation of the pedestal inside and outside in Units 1-3 until so far, however, the needs for fuel debris retrieval were not satisfied due to dimensional restrictions of the existing penetration opening.

Purpose

The project of the "Detailed Investigation inside PCV" is amed to enlarge the size of access device and to upgrade the measuring technology for the device to meet the needs of fuel debris retrieval. Additionally, this project is intended to develop the device to perform more detailed investigation through a newly established larger access route.

Major Approach and Results

1 Investigation and Development Planning

A submersible access device that can move a wide range of the basement floor by accessing through X-2 penetration into PCV was selected for Unit 1 as planned based on the latest situation and investigation results of the pedestal inside and outside of Unit 1 and 3. An arm type access device whcih can move in the air by accessing through X-6 penetration into PCV was selected for Unit 2 based on the investigation results of the Unit 2 pedestal . Additionally, the investigation results for Unit 1 and 2, and measuring technology for access device were studied to update and to concrete the plan.

2 Development of Access and Investigation Device

① Establishing Access Route into PCV via X-6 Penetration

An isolation room that will be the PCV boundary when opening the X-6 penetration hatch was designed and produced, and a combination test of the isolation room and the remote-operated hatch opening device was conducted. In addition, the design and production of connecting tubes with isolation valves to be connected with X-6 Penetration by the remote operation in the isolation room (Reference: Fig.1 "X-6 Penetration Connection Structure") were performed to confirm various functions (connections to X-6 penetration, flange gripping, PCV boundaries (airtight), isolation functions of isolation valves and remote self-driving).

② Establishing Access Route into PCV via X-2 Penetration

The PCV access route device such as extension tubes, isoation valves and guide pipes to connect a double door opening hole of X-2 penetration, which will be a new boundary, were designed and produced. In addition, equipment that is required for opening holes for inside/outside of double doors and the grating in PCV, and guide pipe installation separated from PCV inside was designed and produced. The performance, retrieval methods and the construction conditions were confirmed to extract issues and countermeasures (Reference: Fig.2 "In-plant Validation Status of Opening Hole in X-2 Penetration Inner Door").

③ Access/ Investigation Device

The investigation device for Unit 1 that is to carry in/out access device separated from PCV and 6 kinds of submersible type access device were designed and produced. The performance, methods and combination operation were confirmed to extract issues and countermeasures (Reference: Fig.3 "In-plant Validation Status of Submersible Type Access Device").

The arm type access device (the arm and its enclosure) which has access to PCV inside from X-6 penetration was produced for Unit 2 (Reference: Fig.4 "Production Status of Arm Type Access Device").

3 Applicability Validation of Element Technology

The design and production of the systems for the deposit 3D shape measurement, the deposit thickness, fuel debris detection and identification of the access device were performed for Unit 1. The performance, measurement operations, measurement disturbance of a single and combination device were confirmed to extract issues and countermeasures. (Reference: Fig.5 "Status of Compatibility Validation for Measurement of Deposit 3D Shape").

For the contribution to the fuel debris estimation for Unit 2, sensors were produced to gether information of the shape and dimension, and dose rate in PCV under high radiation environments, and the compatibility validation were confirmed (Reference: Fig.6 "Status of Campatibility Validation for Laser Scanner").

Future Development

This project developed the access route establishment, a mockup test with the device for the detailed investigation inside PCV, operation training and the on-site verificaiton in Unit 1 and 2, which will be followed under the projects for FY2018 and FY2019 ("Project of Development of Technology for Detailed Investigation Inside PCV (On-site demonstration of technology for detailed investigation considering management of deposits and on-site demonstration of technology for detailed investigation through X-6 penetration).

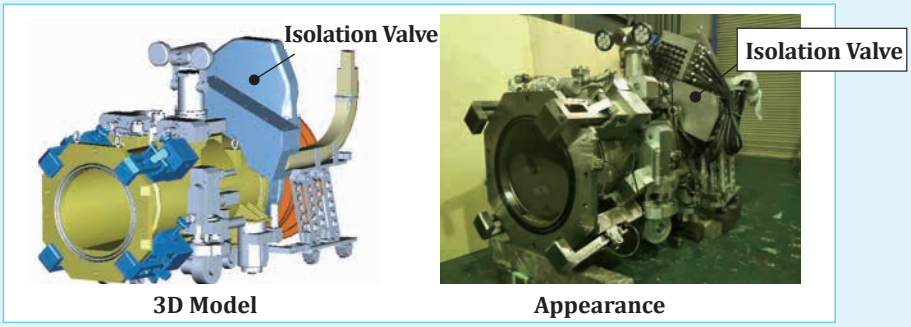


Fig. 1: X-6 Penetration Connection Structure

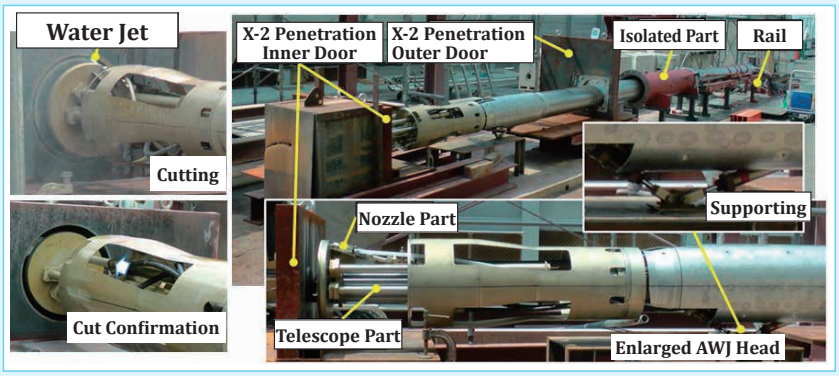


Fig. 2: In-plant Validation Status of Opening Hole in X-2 Penetration Inner Door

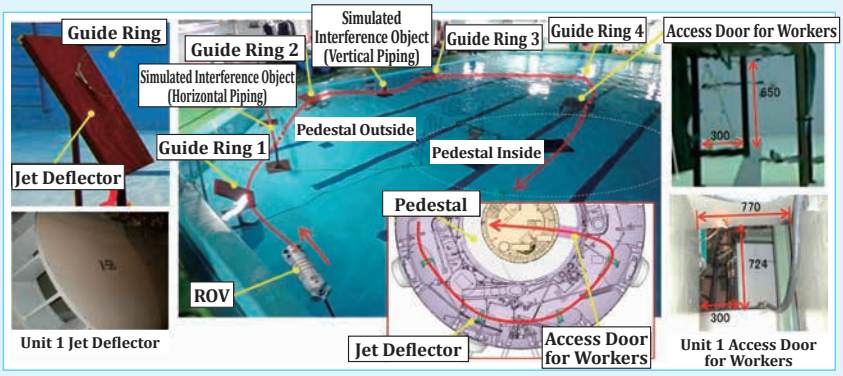


Fig. 3: In-plant Validation Status of Submersible Type Access Device

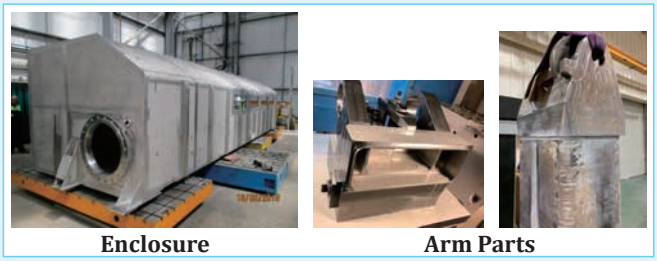
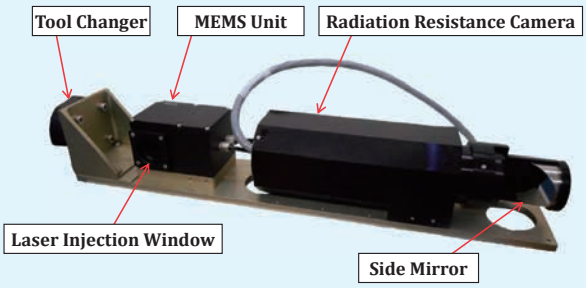


Fig. 4: Production Status of Arm Type Access Device



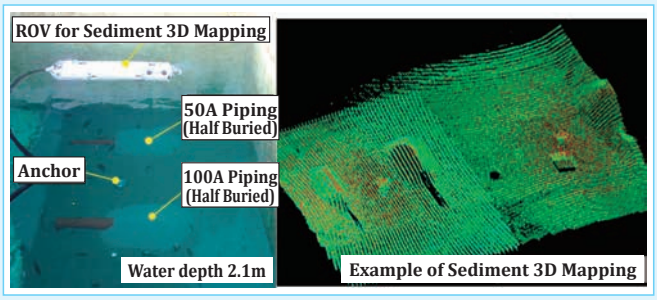


Fig. 5: Status of Compatibility Validation for measurement of Deposits 3D Shape

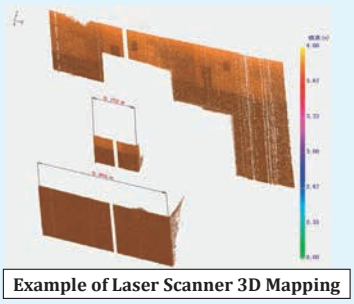


Fig. 6: Status of Compatibility Validation for Laser Scanner

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Detailed Investigation inside PCV
(On-site demonstration of technology for detailed investigation considering management of deposits)

Background

Fuel debris in the Fukushima Daiichi NPS Unit 1 exists under the deposits located inside/outside of the pedestal. To retrieve the fuel debris, the information on the deposits and the situations in the pedestal is necessary.

Purpose

The purpose of the project is to establish an access route through X-2 penetration into PCV inside and to perform the site verification in Unit 1 using a submersible investigation device with measuring technology.

Major Approach and Results

1 Investigation and Development Planning

A mockup test plan and the test facility design for Unit 1 were performed. Working hours and radiation exposure were calculated from the mockup test results of the access route establishment to review on-site verification plan. In addition, the sequence of 6 kinds of submersible investigation device for the detailed investigation was reviewed.

2 Development of Access and Investigation Device

① **Establishing Access Routes in PCV**
The mockup test for new boundary connections with X-2 penetration, cutting of inner/outer doors and interference objects, and guide pipe installation confirmed that work under the isolated state from PCV inside can be conducted. After operation training, the preparation of the site verification was started. (Fig. 1: "Status of AWJ Mockup Test for 350A").

② **Development of Access and Investigation Device**
The mockup test facility simulated a work area and the half circle of the inside-outside pedestal was produced to start the test.

Future Development

The access route establishment and the site verification for detailed investigation will be performed in FY2019. The guide ring installation and detailed visual inspection will be performed for detailed investigation, and subsequent investigation sequence will be decided. The deposits thickness measurement, fuel debris detection, the deposits sampling and the deposit 3D mapping measurement will be performed.

Development of Technology for Detailed Investigation inside PCV
(On-site demonstration of technology for detailed investigation through X-6 penetration)

Background

As a result of internal investigation performed in Fukushima Daiichi NPS Unit 2, the deposits that were assumed to be fuel debris were confirmed at the bottom of inside the pedestal.

Purpose

This project aims to insert the access and investigation device through a large opening of X-6 penetration and to verify technology for the detailed investigation inside PCV.

Major Approach and Results

1 Investigation and Development Planning

Based on the investigation results of Unit 2 inside PCV and the design achievements of access and investigation device, the study on the access from X-6 penetration and the access procedure of investigation device, obstacle removal, accessible ranges (measurable ranges), data acquisitions and schedule for investigation were studied to establish the investigation plan.

2 OnSite Verification of Access Device and Investigation Technology

① **Mockup Test Considering Site Situation**
The test procedure for the mockup test of the arm type access and investigation device was reviewed to concrete the test plan based on the test plan studied by the project of the "Development of Technology for Detailed Investigation inside PCV." In addition, a part of the test facility for the mockup test was produced.

② **Operation Training**
The Virtual Reality (VR) system which reflects the design results of access, investigation device (specifications, dimensions, movable ranges of each arm joint) and the PCV internal shape were established for simulation operation training (Fig.1: VR System for Access and Investigation device).

③ **Test for Establishing Access Route to PCV and Onsite Operation Training**
Operation training for the hatch opening was conducted. In addition, a combination test of the isolation room and connecting tubes with isolation valves (X-6 penetration connection structure) that will be connected with X-6 penetration by remote operations was conducted to test cable handling and emergency separation action in case of failure (Fig.2: Status of Combination Test).

④ **On-site Verification**
The specifications for the neutron detection system (detectors, the sheilding facility, neutron mederators, etc.) that is designed to estimate the range and distribution of nuclear fuel existance during on-site verification, were established. Furthermore, a validation test plan for the neutron detection system was developed as well as the design and production were started.

Future Development

On-site applicability of the arm type access and investigation device will be confirmed and evaluated by combination and mockup tests, and the operation training will be performed. After the completion of the mockup test and operation training, the device installation for Unit 2 PCV and on-site validation (site survey) will be performed.

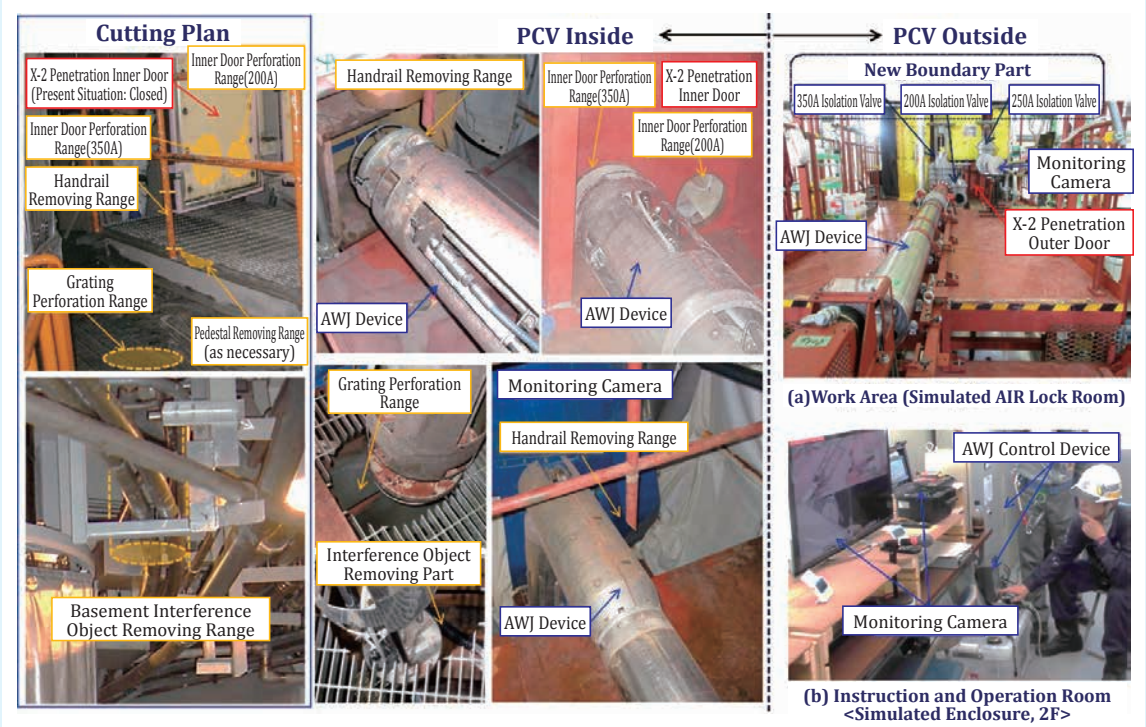
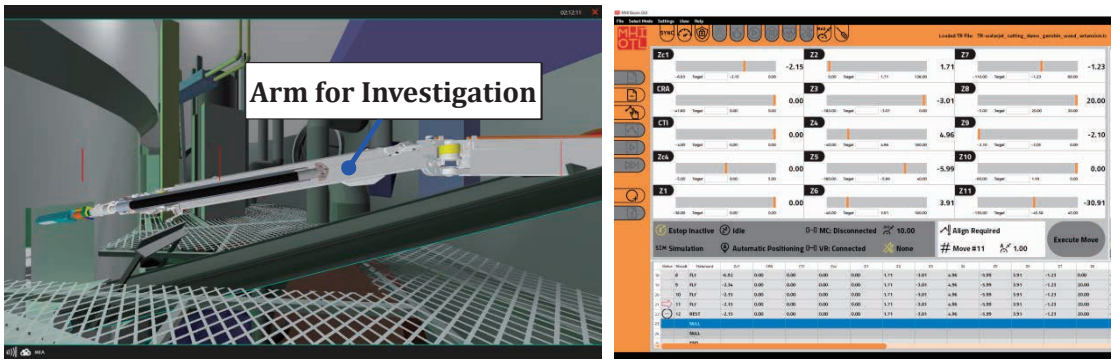


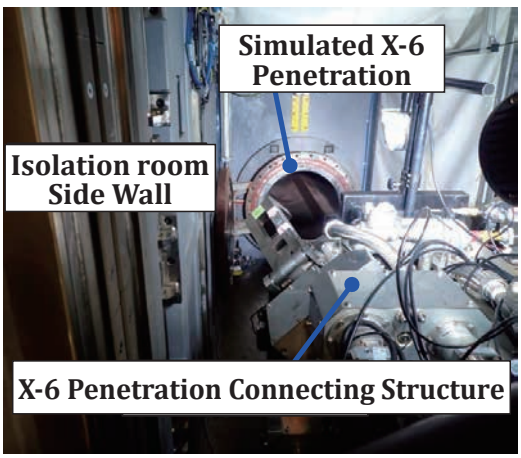
Fig. 1: Status of AWJ MockupTest for 350A



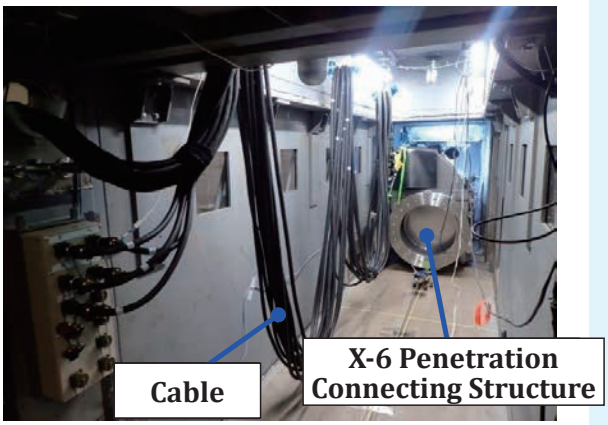
Display Image (Arm is accessing PCV internal.)

Input Screen

Fig. 1: VR System for Access and Investigation Device



Isolation room (near X-6 Penetration)



Isolation room (cable layout)

Fig. 2: Status of Combination Test

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Investigation inside RPV

Background

Fuel debris and the reactor internals remain in the Reactor Pressure Vessels (RPVs) and therefore advance information on those location, the shape and the conditions is necessary. However, it is difficult to directly access RPV to obtain the information due to the complicated structures and extremely high radiation rate.

Purpose

The decommissioning work including fuel debris retrieval is required to gather information on unclear situations to ensure a safe and efficient work. This project is intended to clarify the investigative target, and to develop required investigation technology by the reactor core drilling method of accessing from the top or side of the RPV.

Major Approach and Results

1 Investigation and Development Planning

The information on fuel debris retrieval was organized and updated, and as the result, the requested information was resulted into the appearance and dose rate as before. Accordingly, development of device that is assumed to establish access routes and to insert the investigation device up to the reactor core was planned. The investigation plan was reflected from the updated step-by-step plan to acquire the information; (1) The next step of investigation inside RPV, and (2) Study on the fuel debris retrieval method.

2 Investigation Method Planning

The concepts for the safety conditions during investigation was examined to study the safety evaluation method. Furthermore, the contamination level of the structure to be processed was estimated based on the results of the accident progress analysis. A simplified model of radiation exposure using airflow analysis in PCV was established to estimate the impact on radioactive dusts during processing.

3 Study on Investigation Auxiliary System

Maintaining negative pressure in PCV requires gas control, nitrogen supply systems, dust monitoring, criticality control sysytems, water treatment sysytems and the auxiliary system which will be required from the aspect of safety and investigation. These requirement specifications were extracted.

4 Development of Access and Investigation Device

① Development of Investigation Device for Top Access Method

The device specifications were established by desk analysis and partial tests based on the achievements and remained issues in FY2017. In addition, the plan for element tests (confirmation tests for small-diameter drilling for PCV/RPV heads, the RPV heat insulator removal method, workability and accessibility for processing the reactor internals, and accessibility for investigation device) was concretized to confirm the validity of the device specifications.

The study on the structure changes considering effective working procedures for the device to be handled in a work cell which is established as the prevention system of the spreading contamination, and the simplified work in a work cell were performed from the aspect of radiation exposure reduction to reflect the device specifications. In addition, the appearance simulation was performed based on the result of visuality test for investigation device which simulates fog environments.

② Development of Investigation Device for Side Access Method

The test plan for element tests required for device specifications (cutting ability test with hybrid waterjet tool, compressed seal test, collection and drainage test for treated water, and strength test of chemical resin joint parts) was concretized to prepare for the test facility and the device for element tests.

Future Development

Accepting the progress of FY2018, the radiation exposure evaluation required for the safety evaluation and element tests by using the partial test model of each device will be conducted in FY2019. Based on the results, the device will be designed to establish the device and facility specifications. In addition, investigation procedures and the maintenance method will be examined to concrete the investigation plan.

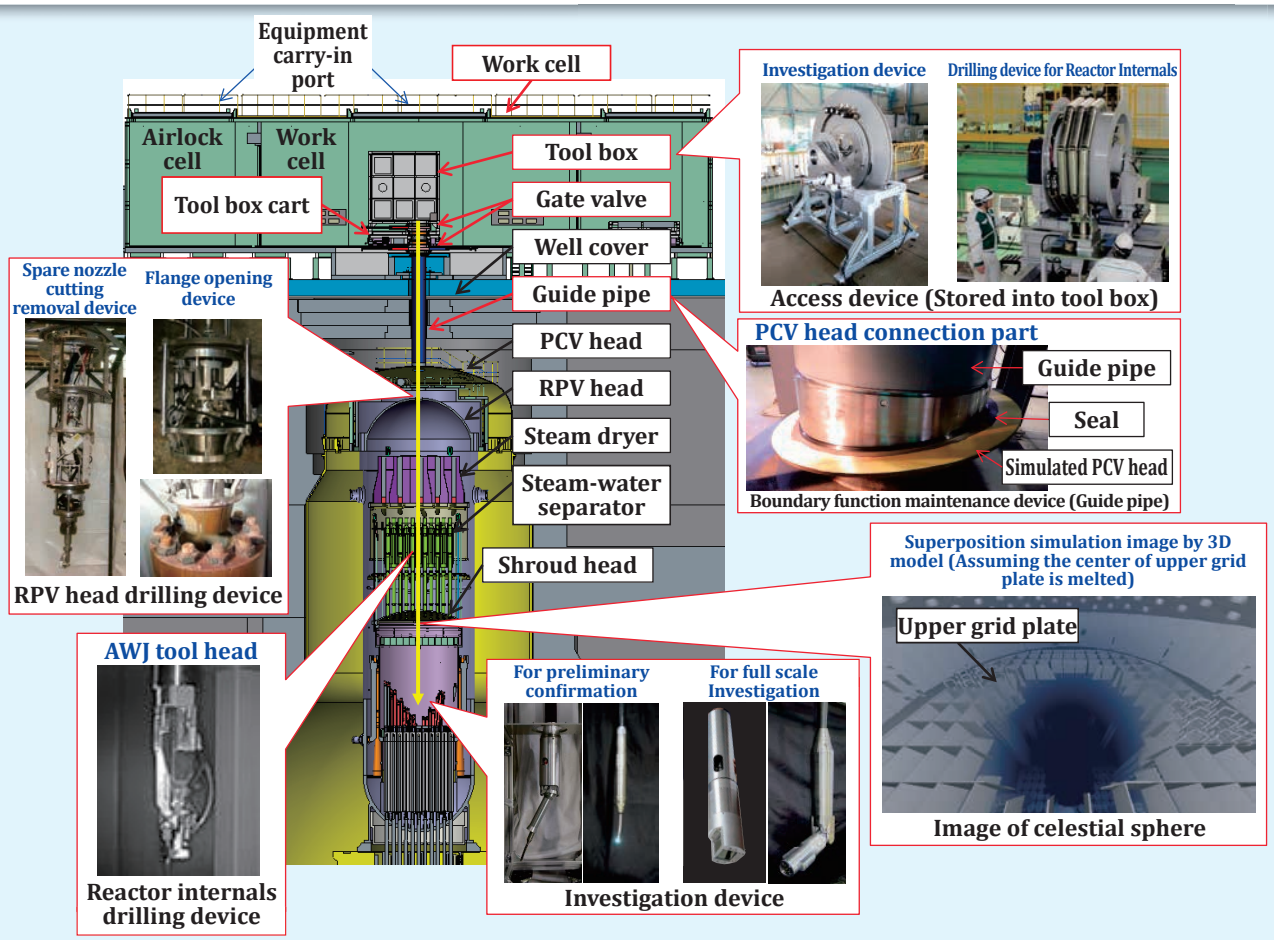


Fig. 1: Overview of the Top Access Investigation Method

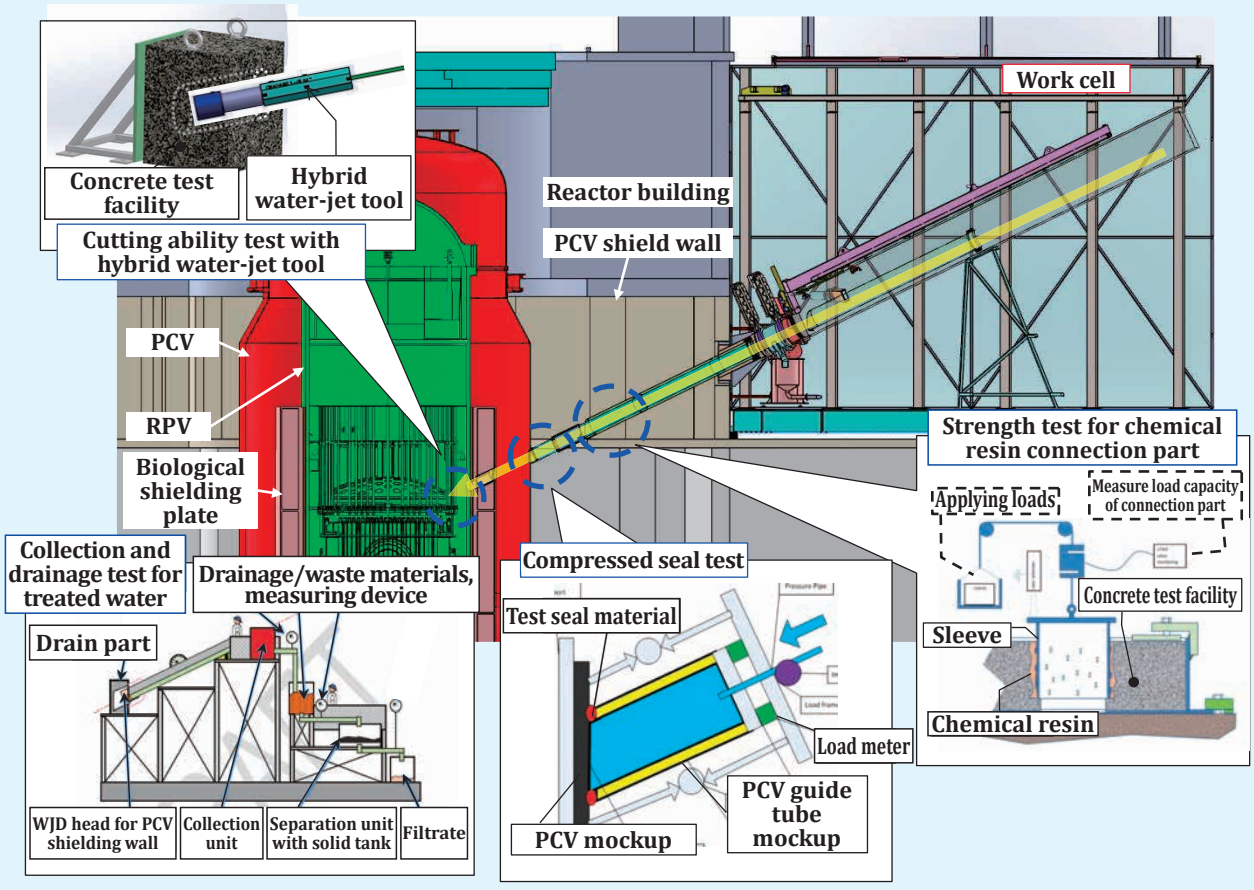


Fig. 2: Overview of the Side Access Investigation Method

R&D for Preparation of Fuel Debris Retrieval

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

Background

Identifying the component and mechanical properties of fuel debris is important to ensure the appropriate safety management and the facility design during retrieving fuel debris which will be collected as a sample from the lower part of Primary Containment Vessel (PCV) and the reactor. Therefore, the sampling method that collected debris sample is taken out to the analysis facility has been studied to obtain information that cannot be taken by a camera.

Purpose

This project aims at obtaining the debris information in a safe and prompt manner. The sampling scenario is established to promote the design and test production of sampling device, safety studies and study on sampling device while utilizing the investigation results of inside PCV and development results of the arm for detailed investigation inside PCV.

Major Approach and Results

1 Development of Fuel Debris Collection and Sampling Scenario

The total scenario and development plan of collecting fuel debris were reviewed and updated based on the following points.

① The phased sampling steps were reviewd considering the balance between analytical needs and analysis facility capability.
② A feasible sampling method of retrieving small amount of fuel debris was established without using special facilities during investigation inside PCV.
③ The countermeasures for troubles with having access dificulities by PCV interference objects were extracted.

2 Fuel Debris Sampling System for PCV, and Design and Test Production of Device

The design and trial production of specific technologies required for fuel debris sampling were promoted.

① Basic Design of Fuel Debris Sampling System

The structure and specifications for the remote-operated debris sampling system for transporting from the high-dose sampling site, and neutron monitors to detect re-criticality symptoms due to crack occurrence when cutting debris were established. In addition, the feasibility of the remote-operated transport system for debris sampling was confirmed.

② Design and Trial Production of Fuel Debris Accessing Device

The performance enhanced measures were established to apply the arm type access device for detailed investigation inside PCV to collect debris sample. Specifically, the enclosure structure considering the radioactive materials confinement was reviewed, and the additional joints which can avoid the pedestal structures that is difficult to handle with the above arm type access device were designed.

③ Design and Trial Production of Fuel Debris Sample Collection Device

The device specifications for the sample collection device structure developed last fiscal year were concretized based on the element test to improve handling ability considering transporting debris sampling to the analysis facility, and accessing into PCV with the arm type access device as well as easy-to-retrieve fuel debris.

3 Conceptual Study of Sampling System for Fuel Debris in Reactor Pressure Vessel (RPV)

The device specifications for the sample collection device structure developed last fiscal year were concretized based on the element test to improve handling ability considering sampling transport to the analysis facility, and accessing into PCV with the arm type access device as well as easy-to-retrieve fuel debris.

4 Trial Production of Small-Amount Sampling Device for Detailed Investigation inside PCV

Two kinds of collection devices which can be connected to the arm type access device for detailed investigation inside PCV and carried out sealed samples from the sampling site were produced toward the completion of small-amount sampling.

Future Development

- Focusing on technology required for fuel debris retrieval, validation items, design specifications and development schedule were examined. The device development will be promoted to complete early-stage fuel debris sampling since next fiscal year.
- This project will develop to complete small-amount sampling in cooperation with on-going project of “Development of Technology for Detailed Investigation inside PCV.”

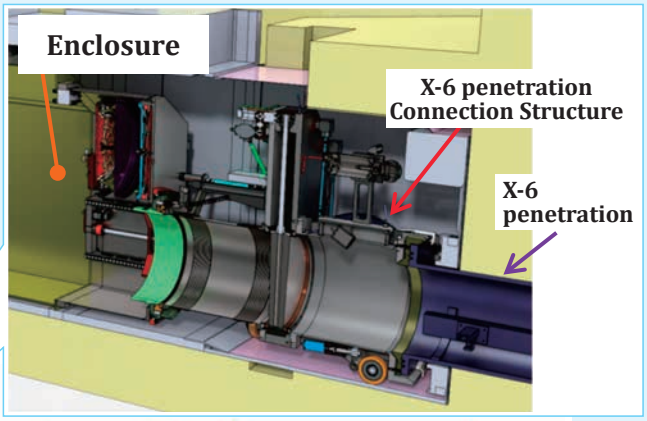


Fig. 2: Enclosure and X-6 Penetration Connection Structure Considering Radioactive Material Confinement

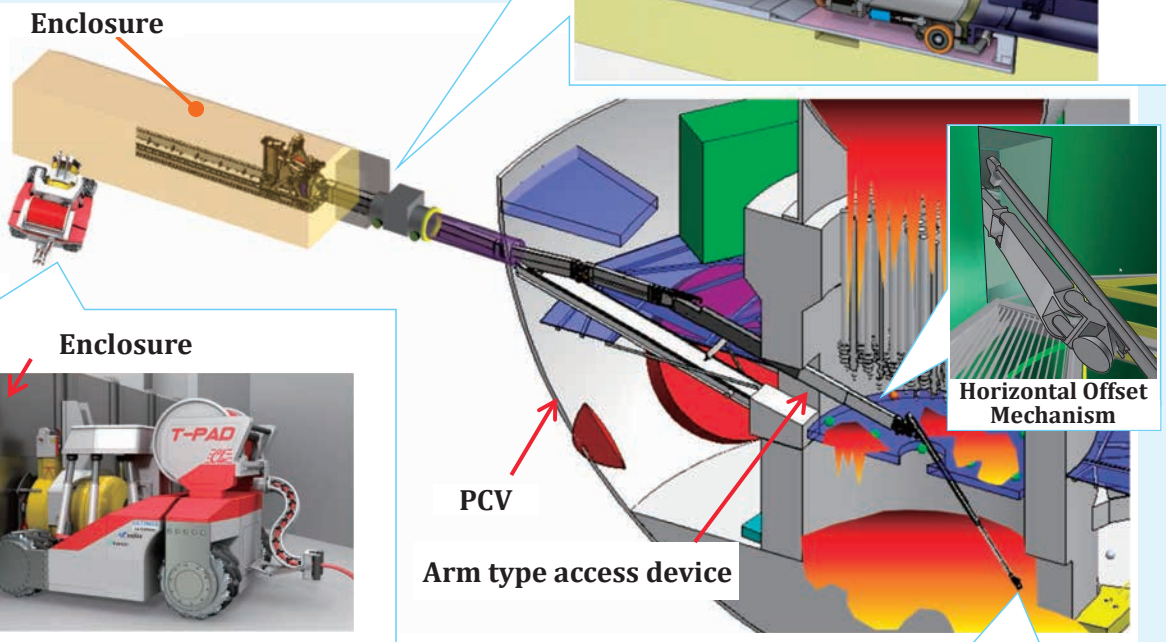


Fig. 1: Concept of Fuel Debris Sampling in PCV

Carry-out debris sample from high-radiation sampling site

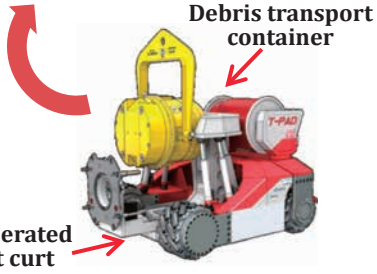


Fig. 3: Debris Remote Transportation System

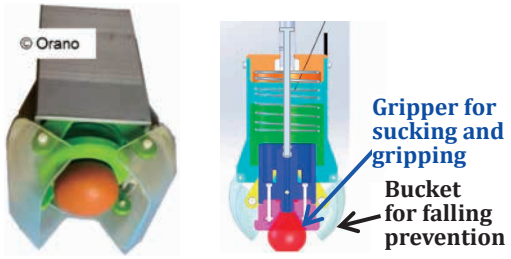


Fig. 4: Concept of Pebble-like and Sand Shape Debris Collection Device

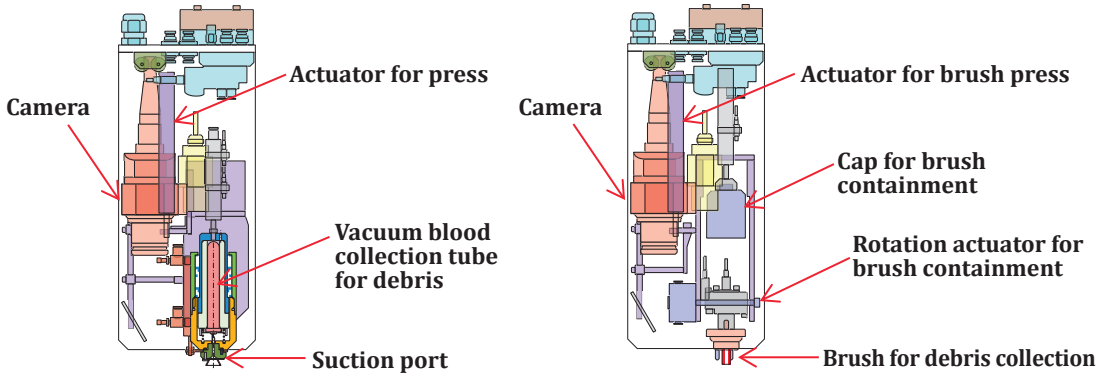


Fig. 5: Example of Small-Amount Debris Collection Device

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Fuel Debris Analysis/ Characterization

Background

The nuclear decommissioning requires retrieval, collection, transfer and storage of fuel debris in safe and effective manners. Therefore, it is necessary to understand fuel debris properties for decommissioning work. In addition, technology development is necessary to analyze fuel debris sampling in the future.

Purpose

This project aims to estimate fuel debris properties through deposit analysis and a basic test with simulated fuel debris materials, and to provide the information to the project for the decommissioning work. In addition, the development of element technology for fuel debris analysis and investigation of transportation technology will be performed for the preparation of the future fuel debris sampling.

Major Approach and Results

1 Estimation of Fuel Debris Characterization

As part of fuel debris characterization, the surface dose rate was continuously estimated, and besides, the behavior of radioactive airborne particles was studied and the deposits (the reactor internals deposits) during investigation inside PCV were analyzed.

Firstly, the evaluation formula for the surface dose rate established in FY2017 was modified considering the apparent burnup and radio-activation source to improve the applicability of various fuel debris while representative cases were evaluated.

Data for the radioactive airborne particles generated by dismantling the Globe Box (GB) at the existing facility was gained and evaluated (Fig.1) to understand the behaviors of radioactive airborne particles that may be an issue during fuel debris retrieval. In addition, powder having various diameters and non-organic materials were selected as test samples, and the property data for the transportation and migration behavior in air, in water and air-liquid interface was obtained from the test.

As for the deposit samples collected from the internal investigations for each Unit including investigation inside the Unit 3 pedestal (Fig.2), the surface of the deposits was observed, and elements and nuclides were analyzed to confirm the consistency of the estimation on the situation of the reactor internals.

These findings are summarized as the “List of Fuel Debris Property.”

2 Property Evaluation by Using Simulated Debris

Emission Behavior Evaluation of Fission Products (FP) during Dry Heat Treatment

The dry treatment is studied as one of the pretreatments for storage of the retrieved fuel debris, and therefore, the volatile FP was evaluated as a basic data for the off-gas treatment of facility. Focusing on the FPs among severely evaluated nuclides that were selected based on environmental emission evaluation in FY2017 and considered that the vulnerability may change due to the treatment conditions, their chemical compounds were experimentally evaluated for temperature andemission start temperature/ emission temperature as emission behaviors. In addition, the change of surface area and the impact of air pressure for the migration of volatile FP off-gas during the dry treatment of fuel debris were confirmed.

3 Development of Element Technology for Fuel Debris Analysis

For the preparation of fuel debris sample analysis, the analysis instruction for all of twenty two items was prepared since FY2017. A series of a work flow from the acceptance of test samples up to the disposal and return was reviewed by considering the consistency and efficiency of the analysis results.

As for development of the analysis method that multi-nuclides are analyzed with the new type ICP-MS (Inductively Coupled Plasma Mass Spectrometry)simultaneously and promptly, the types and flow rates of the reaction gas that sufficiently reduces nuclides impact hindering during the nuclides measurement were studied. As the result, it was confirmed that original nuclides to be measured and hindering nuclides can be sufficiently separated excluding a part of nuclides. Excluded nuclides which are insufficient to separate from hindering nuclides are found out to be separeted from hindering nuclides before the system installation.

Hearing investigation was conducted at the existing facilities in Ibaraki Prefecture where will accept a candidate facility for transport containers. Prior to acceptance, issues were clarified whether the containers can be accepted without a large scale of construction.

Future Development

Preparing analysis for a small amount of fuel debris sample will be continuously conducted for the plan of transporting collected sample to Ibaraki area by using containers. The fuel debris properties will be obtained from actual fuel debris data. Furthermore, the behavior of radioactive airborne particles will continue to be studied for collecting the behavior data of fine articles generated during fuel debris retrieval work in cooperation with domestic and international research institutes.

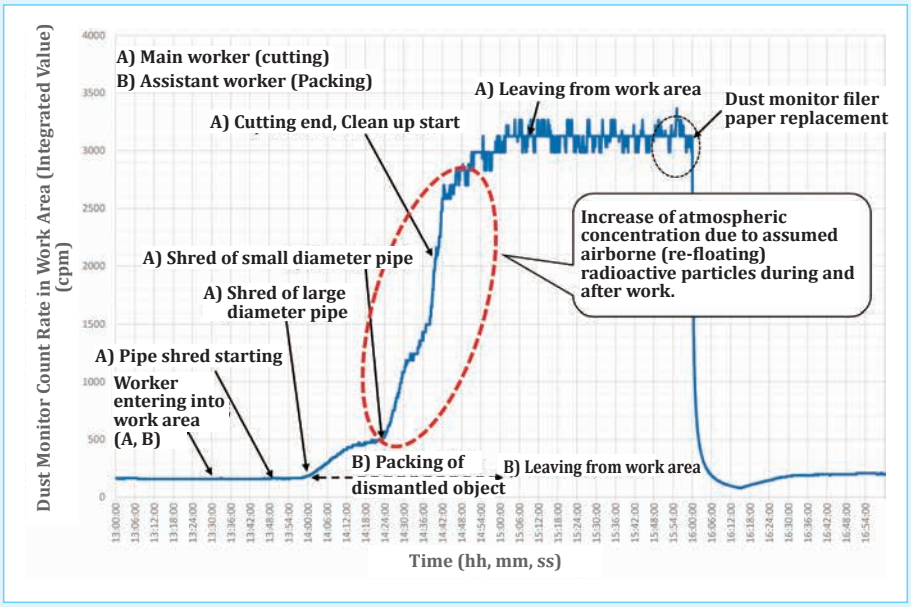


Fig. 1: Example of GB Demolition Work at Existing Hot Facility

Radioactive particles will be dispersed during various work at contaminated areas. This project studies dispersed radioactive particles generated by fuel debris retrieval based on the data of particles generated from the GB demolition work.

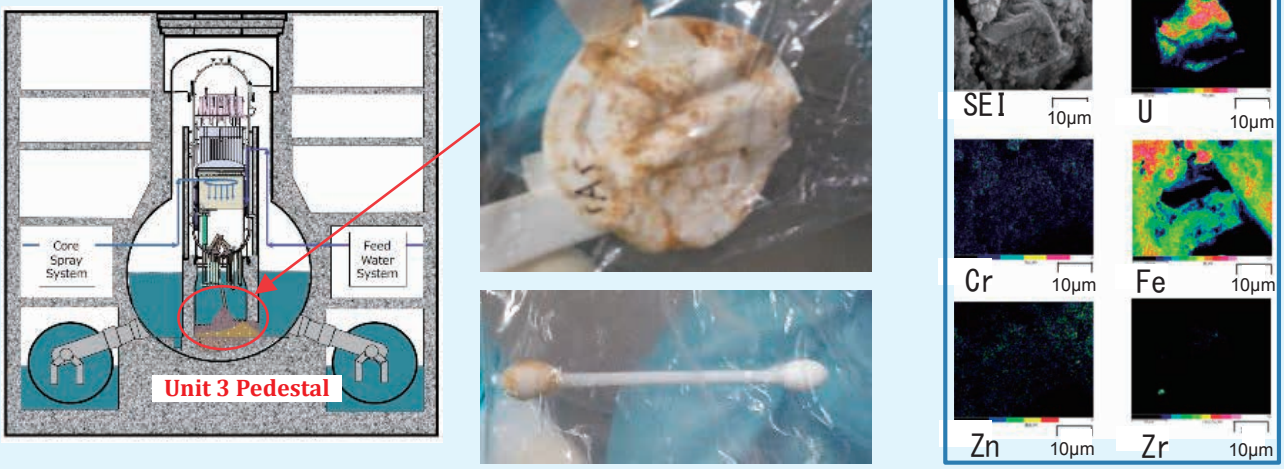


Fig. 2: Wiping Deposits (photo in the center) and Analysis Result by Field Emission Type Electron Scanning Microscope (Figure in right)

The deposits attached to the investigation robot that was returned from the pedestal inside of Unit 3 was wiped off with smear filter paper and cotton-tipped stick. Element analysis for the surface of the wipped deposits which was observed. The data showed that the reactor internal condition was consistent with the analysis results.

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Water Circulation Systems in PCV
Development of Technology for Water Circulation Systems in PCV (Full-scale Test)

Background

The project of "Upgrading of Approach and Systems for Retrieval of Fuel Debris and Internal Structures" is also promoted to improve environment for the risk reduction and to ensure safety of fuel debris retrieving work toward the decommissioning of the Fukushima Daiichi NPS. Therefore, the establishment of the water intake structure is needed as the water circulation system of Primary Containment Vessel (PCV).

Purpose

Water intake parts of the water circulation system has challenging issues to be addressed for the confinement function of gas phase and liquid phase, achieving a long-term integrity and on-site remote workability during installation and operation under high radiation environments. This project aims to develop applicable technologies for accessing and connecting to PCV to intake water in the water circulation system.

Major Approach and Results

1 Clarification of Technological Specifications, Work Plan Study and Development Plan for Upgrading Water Circulation System in PCV

① Study on Water Circulation System and Technology Using Drywell (D/W)

- Based on various investigation results so far, access route establishment technology for the D/W and the suppression chamber (S/C) water intake was studied and clarified for environmental dose rates on the first floor of the reactor building (R/B) inside/outside of of PCV, estimation results of the reactor internal situations, deposits in PCV and water levels in PCV (current situations, during construction and operating the water circulation systems) for each Unit.
- In addition to these results, the technological specifications (in common with D/W and S/C) for the access route establishment in PCV and the D/W water intake design were examined based on the study results of the water circulation system developed by the project of "Upgrading Approach and System for Retrieval of Fuel Debris and Internal Structures,"and the candidate penetration of the D/W water intake port was selected considering the site environment.
- As a result of study on existing technologies, technology for establishment of the access route from outside to inside PCV, provided a perspective on applicability of existing technologies including access methods into PCV which was proved by another project, and thereby, issues of the access route establishment, a route up to a water intake point, were clarified that; 1) The remoteoperated pump (piping) suspension method, 2) The remote operated connection and replacement method for piping.

② Study on Water Circulation System and Technology Using S/C

- Design specifications of the S/C water intake part structure were clarified based on the common study results of (1). In addition, the candidate location of the S/C water intake part structure considering the site environment was selected for each Unit.
- The function requirements of the S/C water intake part were examined based on the study results by the project of "Upgrading Approach and System for Retravel of Fuel Debris and Internal Structures." The S/C water intake structure and maintenance program were established to satisfy the requirements.
- Existing technologies were studied based on establishment and maintenance of the S/C water intake part. The study result showed that a main development issue is a connection method of extended pipes, and therefore, a policy was determined that the applicability was confirmed by element test.
- The project development items were summarized among applicable device during construction and maintenance.

2 Development and Validation of Element Technology for Access and Connection to PCV

- The access and connection in the D/W and S/C will be verified by eleement tests in FY2019.

3 Full-scale Validation of Technologies for PCV Access and Connection

- As part of cooling water management flowed out from the D/W of to the Unit 1 S/C inner side of torus room, the validation test plan of the water circulation system boundary at the inside of torus room was developed, which utilized the full-scale test facility of Naraha Center for Remote Technology Development, Japan Atomic Energy Agency (JAEA Naraha Development Center). This test is to confirm the possibility of utilizing the space of the S/C inner side of torus room as the boundary of contaminated water and fuel debris powder.
- As the test preparation of the JAEA Naraha Development Center, operation and maintenance of the heating and water supply facilities, and the turbid water discharge facility were performed.

Future Development

A development plan of the project will be established. The element tests will be conducted to verify a remote-operated pump (piping) suspension required for the D/W water intake part establishment, pipe connection methods, replacement methods during maintenance, and connection methods of extension pipes required for the S/C water intake part establishement. In addition, tests will be conducted to confirm workability for the S/C water intake part establishment by full-scale remote operation and to verify the water circulation system boundary.

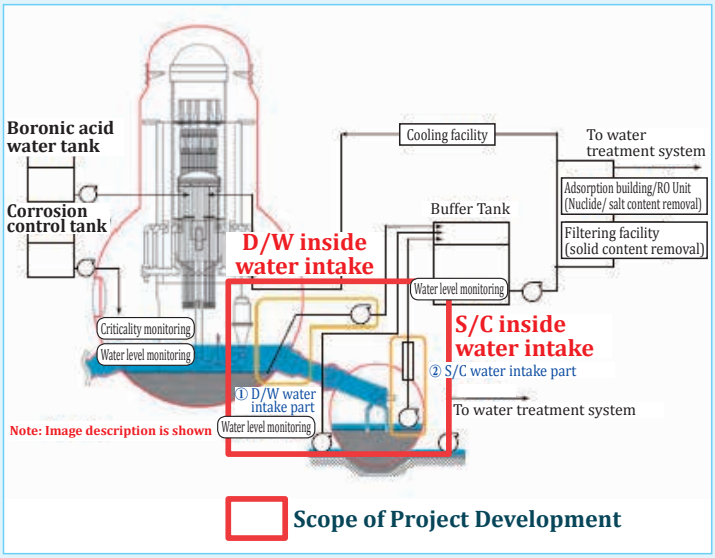


Fig. 1: Water Circulation System during Fuel Debris Retrieval

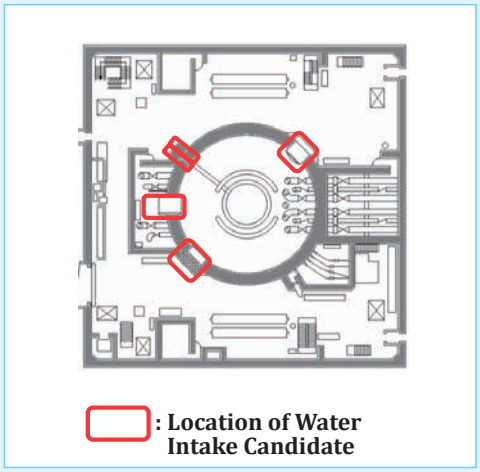
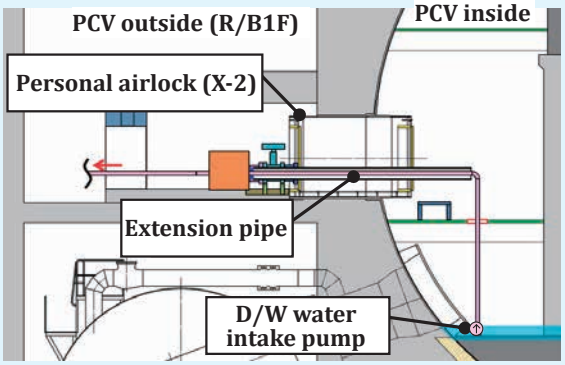


Fig. 2: Selection Result of the D/W Intake Candidate Penetration (Example: Unit 3)



A used penetration part will be selected as the D/W water intake port depending on requirements of the water circulation system layout. This figure shows the example of the airlock for staffs (X-2) as a water intake port.

Fig. 3: Image of Water Circulation System Using D/W

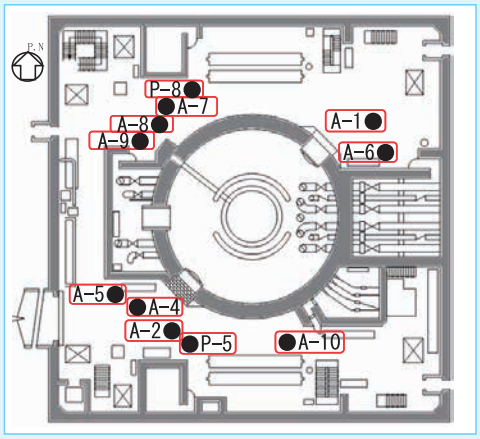


Fig. 4: Selection Result of the S/C Water Intake Structure Candidate Locations (Example: Unit 3)

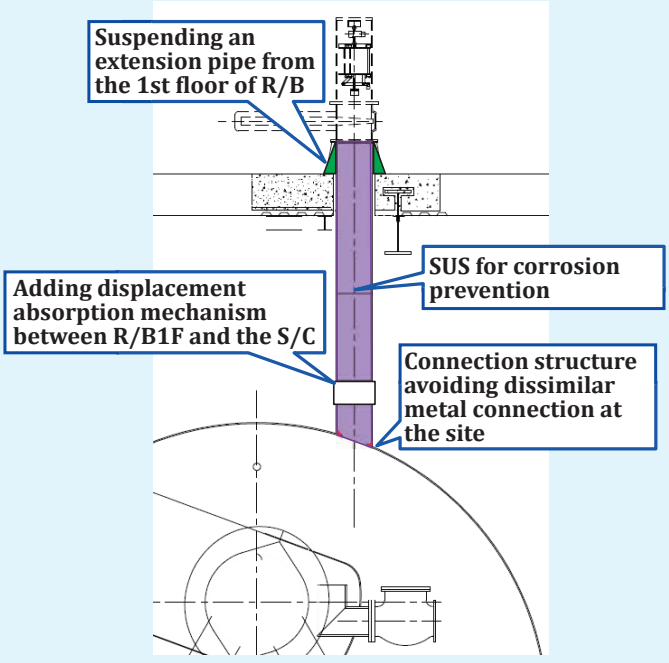
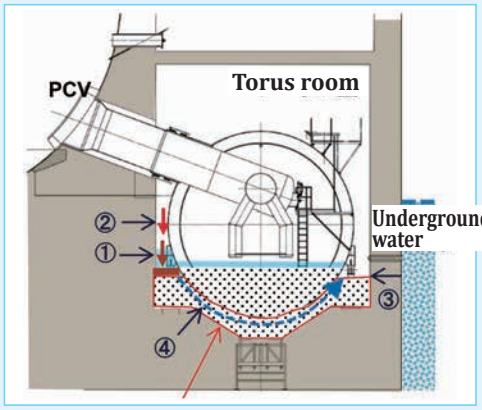


Fig. 5: S/C Water Intake Structure



Strengthen support columns
→ Separation of underground water and contaminated water
① Injection of repairing materials
② Injection of contaminated water and simulated fuel debris powder
③ Confirmation for the leaking situation of contaminated water and simulated fuel debris powder
④ Confirmation for the immersion state of contaminated water and fuel debris powder simulation body due to the S/C cutting

Fig. 6: Overview of Validity Test for Water Circulation System Boundary

R&D for Preparation of Fuel Debris Retrieval

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

Background

Fuel debris in the Reactor Pressure Vessel (RPV) and Primary Containment Vessel (PCV) of Fukushima Daiichi Nuclear Power Station (NPS) has been currently secured a cooling condition. However, the reactor building, RPV and PCV were damaged by the accident and the plant itself is in an unstable situation. This project aims to retrieve fuel debris from the unstable state and to remain the stable condition without spreading radioactive materials.

Purpose

The technology for upgrading the approach and the system for retrieving the fuel debris and internal structures has safety issues; ensuring the confinement functions, capturing and removing the dust generated from fuel debris, and the monitoring of alphanuclides (collective terms for the radioactive nuclides that release alpha rays). This project aims at developing technology to solve these issues and to optimize the methods and systems for ensuring safety.

Major Approach and Results

1 R&D for Confinement Functions

- As the element technology development for securing the confinement function by differential pressure management, analytical methods that can predict airflow distribution , dust spreading prediction (Fig. 1), and hydrogen local accumulation were almost established. Additionally, the differential pressure conditions which can secure the confinement of radioactive dust were set by element test.
- A connection method for the Reactor Building (R/B) outside a work cell and PCV with the Reactor Building (R/B) access tunnel outside a work cell and PCV with the access tunnel having airtight and shielding functions by the partial submersion side accesse method (Fig.2) was studied, and element test (Fig.3) that simulated the connection to PCV with the access tunnel delivered from the R/B outside was conducted to confirm the feasibility.

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

- Element tests for t echnology development of dust collection and removal in the gas phase and liquid phase systems (Fig. 4 and Fig. 5) were performed for the collection and removal methods which have items to be confirmed, and thereby, comparability data that fluid properties containing dust will be available was obtained.
- Assuming the possibility of alpha-nuclides dissolving into water, element tests for technology development of solubility nuclides collection and removal in the liquid phase system were conducted to confirm collection and removal methods. As a result, camparability data that alpha-nuclide behavior of inorganice wate quality will be available was obtained.

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

- The necessity and the purpose of alpha-nuclides monitoring technology during fuel debris retrieval were updated since last fiscal year, as well as the required measurement range for the gas phase and liquid phase systems were clarified.
- Investigation for the existing technologies of the gas phase and liquid phase systems alpha-nuclides monitoring was performed, and issues of feasible applications were clarified.

4 Optimization Study on Ensuring Safety of Methods and Systems

- The methods was updated focusing on the partial submersion side access method since last fiscal year.
- The safety and function requirements for fuel debris retrieval based on the defense in depth was reclarified, and the monitoring parameters required for the installation was clarified.
- The radiation exposure evaluation method for publics and workers during fuel debris retrieval were studied and the trial test calculation was performed to expand the requirement items for the equipment design.
- Prerequisites for insufficient information shortage of the safety system required for fuel debris retrieval were set and the required system configurations were established under the conservative conditions.

Future Development

This project will promote effective and reasonable work for fuel debris retrieval and the reactor internals and concretize the best retrieval method. It will be necessary to undertake a detailed study of the safety system established in FY2018 for feasible applications based on on-site situations, and therefore, the operator of the NPS will take over the responsibility of engineering.

As for part of the confinement functions, and collection and removal technology of the liquid phase system, development of applicable technology is continuously planned.

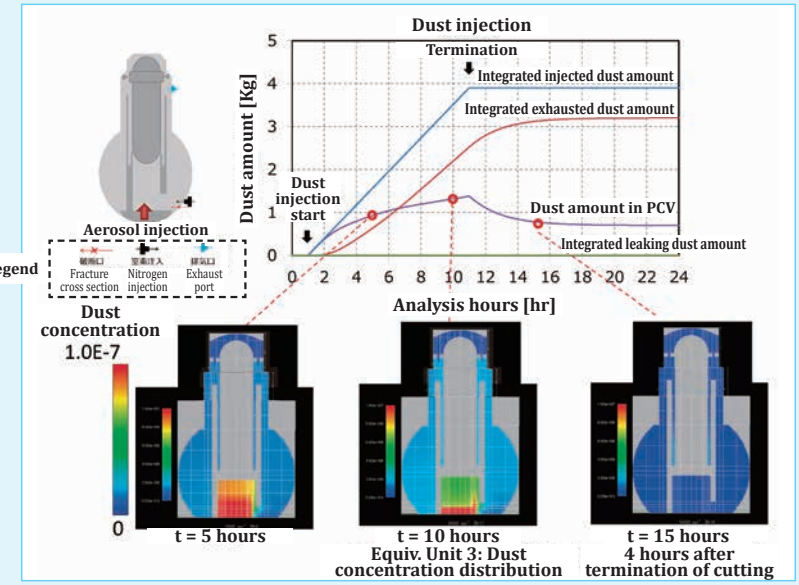


Fig. 1: Example of Technology Development of Confinement Functions (Dust spreading prediction)

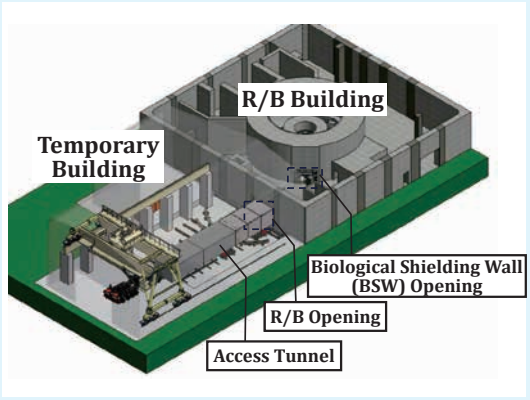


Fig. 2: Access Tunnel Installation Method

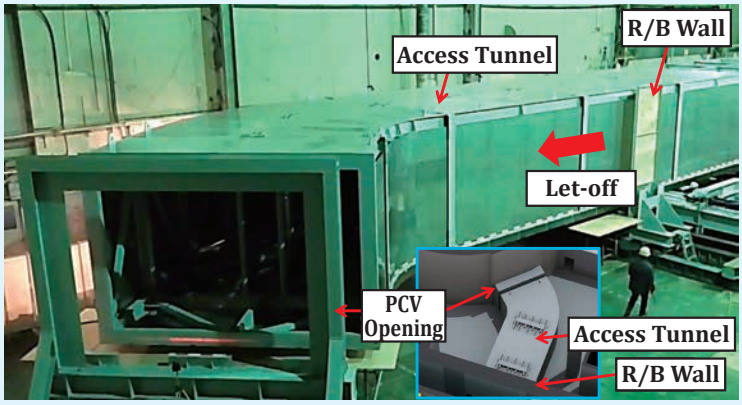


Fig. 3: Access Tunnel Element Test

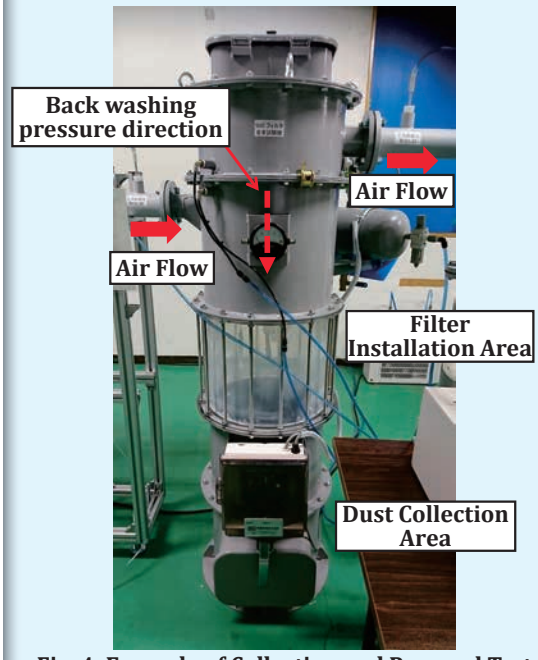


Fig. 4: Example of Collection and Removal Test Back washing Filter Testing Device

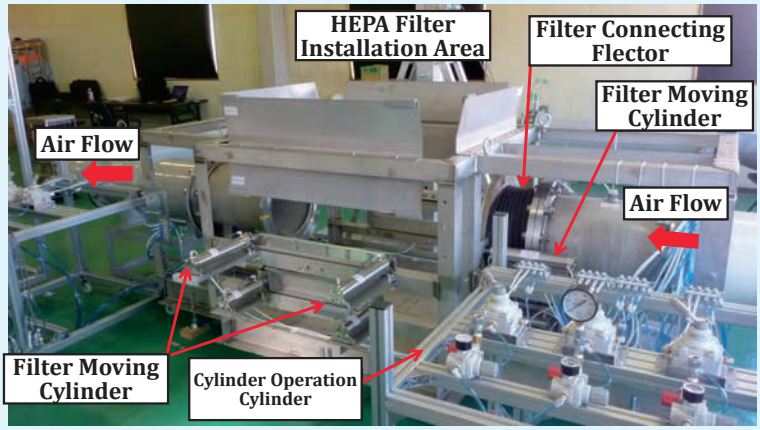


Fig. 5: Example of Collection and Removal Test Testing Device for Remote replacement HEPA

R&D for Preparation of Fuel Debris Retrieval

Upgrading of Approach and Systems for Retrieval of Fuel Debris and Internal Structures (Development of Technology for Establishment of Criticality Control Method)

Background

It is assumed that fuel debris has not currently reached criticality, while a criticality control method has been developed to ensure the criticality prevention despite change of the shape and water amount of fuel debris during fuel debris retrieval work in future, and to safely terminate criticality even if criticality occures.

Purpose

This project aims to confirm the feasibility of each element technology based on the site situation, study the application of retrieval device and systems, and optimize the criticality control method from the aspect of ensuring safey for the entire retrieval work based on the site situation.

Major Approach and Results

1 Technology Development for Subcriticality Measurement and Criticality Approach Monitoring

The development of the subcriticality estimation approach method based on neutron measurement is promoted. In the current fiscal year, various experimental systems composed of two reactor cores were configured by the Kyoto University Critical Assembly (KUCA) to confirm the feasibility of subcriticality measurement technology in case of assuming a widely spread fuel debris system based on images obtained from investigation inside primary containment vessel (PCV). (Fig. 1). As the result, it was confirmed that the change of local subcriticality approach can be captured by neutron signal analysis (noise method).

In addition, for the application study of criticality monitoring removal device, the concept of nuetron detector to be installed on fuel debris (Fig.2) and cable handling methods were studied, and the basic plan and issues for a practical application of the device size, weight and handling performance were clarified.

2 Development of Recriticality Detection Technology

Technology development for early detection of recriticality occurrence is promoted by upgrading of the radioactive gas control system. In the current fiscal year, criticality event evaluation based on the operation condition of the negative pressure control system during fuel debris retrieval was performed. It was confirmed that early criticality occurrence can be detected by monitoring Kr-88 which responds faster than currently monitoerd Xe-135 (Fig. 3).

In addition, radioactive gases such as Kr-88 was generated by using neutron irradiation piles (Fig. 4) in the National Physical Laboratory (NPL) to reduce the radioactive concentration measurement errors of a gas radiation detector and to improve the criticality detection accuracy, and calibration technology for a gas radiation detector was established.

3 Development of Criticality Prevention Technology

Development of water-soluble/non-soluble type of neutron absorbing materials to prevent criticality occurance. In this fiscal year, , a long-term irradiation test was performed to evaluate the impact of insoluble absorbing materials (B4C metal sintered material, Gd2O3 particle) during fuel debris retrieval, and it was confirmed that the impact on hydrogen generation and water quality (Fig. 5) was small.

In addition, the fuel debris injection and crushing test (Fig. 6) was conducted to study the workability of insoluble absorbing materials and fuel debris, and the conceptual study of absorbing material injection device was performed for on-site application.

4 Optimization Study of Ensuring Safety in Methods and Systems (for Criticality Control)

Based on the safety and the site applicability, the most applicable criticality control method have been studied. As the result of investigation inside PCV and a practical criticality risk assessment by statistical assessment, there is no significant change in criticality risks, and the tendency of criticality risk increase was not seen from the past assessment.

In addition, fuel debris retrieval plan including the criticality control method for the fuel debris retrieval expansion phase and the defense in depth of criticality control that is consistent with the safety concepts for the entire debris retrieval work were developed.

Future Development

On the basis of the feasibility study of criticality control technology and the study results of practical application of the retrieval device and systems, study on the validation test and the site applicability will be performed, aiming at the completion of element technology for criticality prevention and monitoring.

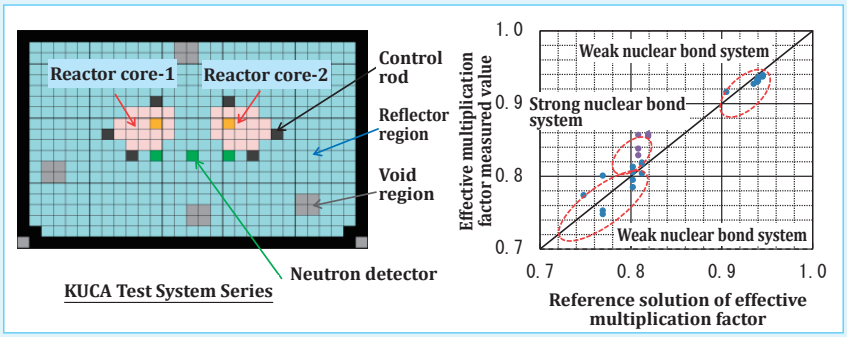


Fig. 1: Subcriticality Measurement Test and Measured Results of Kyoto University Critical Assembly (KUCA)

In case of largely expanded fuel debris, there is a possibility of having strong and weak bound atomic nucleus in the regions. Even in these cases, it was confirmed that the degree of local subcriticality can be estimated.

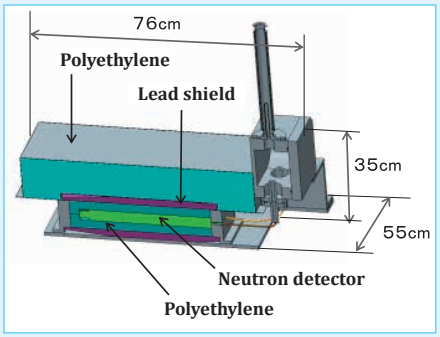


Fig. 2: Design Concept of Neutron Detection Unit

A neutron shielding plan is being studied to shield Gamma-ray with lead and neutron in the other area with wrapping polyethylene for around a neutron detector.

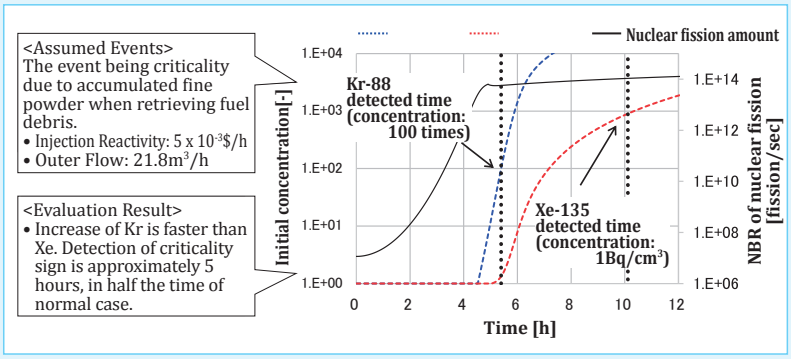


Fig. 3: Evaluation Result of Criticality Detection Performance in case of Criticality Event (Example of Minor Criticality due to Fine Powder Accumulation)

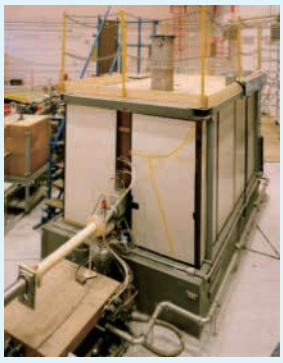


Fig. 4: Neutron Irradiation Pile in the NPL, UK

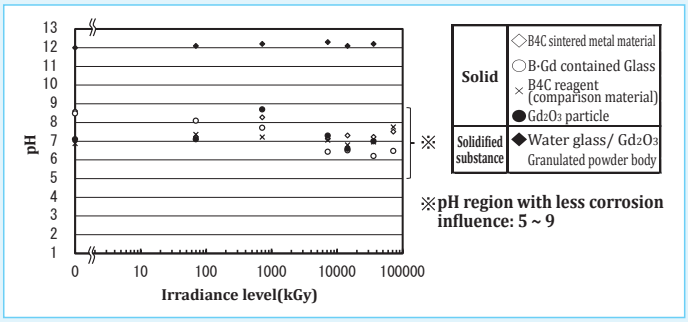


Fig. 5: Test Result for Water Quality Impact Evaluation by Long-term Irradiation of Insoluble Absorbing Materials

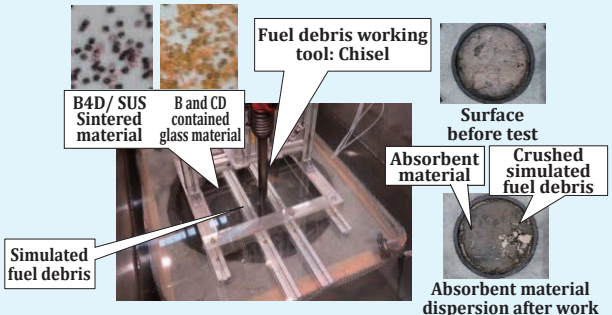


Fig. 6: Insoluble Absorbing Material Injection and Crushing Test for Fuel Debris

This is an experiment test to investigate how fuel debris and insoluble neutron absorbing materials are mixed or unevenly distributed during fuel debris processing.

R&D for Preparation of Fuel Debris Retrieval

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

Background

A fuel debris retrieval policy was determined and thereby the partial-submersion side access method is focused on. This project aims to acquire the necessary data and information by performing element tests and a conceptual study to evaluate 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" has studied theoretical retrieval methods. This project aims at increasing the feasibility of the project 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 issues.

Major Approach and Results

1 Development of Technology for Prevention of Fuel Debris Spreading

① Development of Fuel Debris Collection System

- Assuming the fuel debris collection process for the bottom of Primary Containment Vessel (PCV) and the technology information on the collection system of powder-shaped fuel debris was clarified.
- As to processed fuel debris and pebble-like fuel debris, the technology information on an effective collection work tool was clarified.

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 of the fuel debris would be, and the most effective processing method and the collection method.
- A workability test for chisel processing and ultrasonic core boring against the MCCI (Molten Core Concrete Interaction) products was conducted to confirm processing properties and their speed.
- The components of the MCCI products and the trial production method as simulated fuel debris were studied. The trial product was processed by a processing test to analyze processed waste liquid, and thereby the grain size data was obtained.

③ Development of Prevention Method of Fuel Debris Spreading

- To prevent fuel debris at the PCV bottom spreading into the vent pipes, the suppression chamber (S/C) and other area associated with fuel debris retrieval work, element tests were conducted assuming the weir installation in PCV, which provided the feasible prospect of the remote installation.

2 Development of Element Technology for Retrieval Device Installation

① Development of Element Technology for Work Cells

- Technology for the cell confinement and connecting to the PCVs were compared and clarified.
- The element test for inflate seals which can seal for cells and PCV connections was conducted, thereby confirming the feasibility of work steps and extracting issues. (Fig. 1)

② Development of Interference Object Removal during Fuel Debris Retrieval

- Interference objects are required to be removed until fuel debris at the PCV bottom is reached by the partial submersion side access method, and thefore processing methods were clarified.
- The element test for the interfering object removal was performed based on the clarification results of the interfering objects, and the feasibility of the work steps was confirmed and issues were extracted. (Fig. 2)
- The element test for removing interfering objects at the reactor bottom by the partial submersion side access method was performed, and basic cutting means of the CRD (Control Rod Driving Mechanism) housing and the fragment collection method were confirmed. (Fig. 3)
- The element test of interfering objects removal for inside and outside the pedestal by the partial submersion side access method was performed, and the feasible prospect was obtained for a basic cutting and collection work at narrow parts. (Fig. 4)
- The combination element test of the robot arm and the access rail was conducted to extract issues, and the feasibility for basic action of the removal of fuel debris and interfering objects were confirmed. (Fig. 5)

3 Development of Remote Maintenance Technology for Fuel Debris Retrieval Device

- Basic concepts of remote maintenance, for example equipment in the cell of the partial submersion side access method, were studied to clarify the maintenance classification and facility.

Future Development

- Based on issues extracted by the element tests including a simulated fuel debris processing test and interfering object removal, a development plan will be established to contribute the feasibility study of the method.
- Fuel debris retrieval work will be promoted in a reasonable manner which is necessary for effective methods, and the study of the most feasible method will be promoted.
- Considering the transportation and storage method for the retrieved fuel debris and wastes, the feasible carry-out process of fuel debris and wastes will be proceeded in the cooperation with relevant other projects.

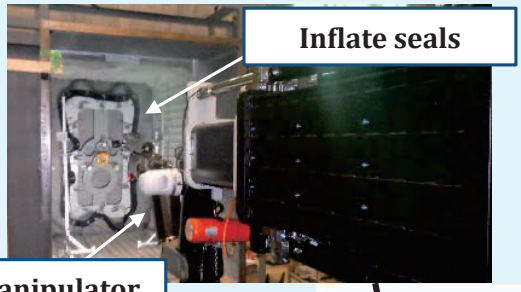
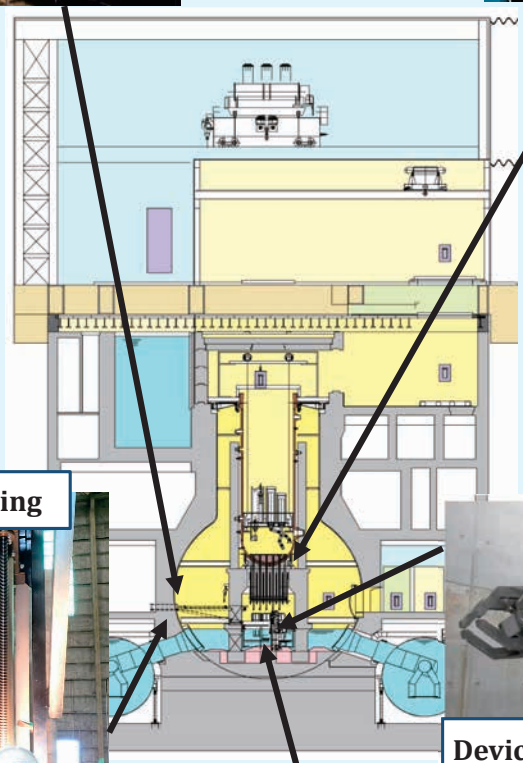


Fig. 1: Partial Submersion Side Access Method: Inflate Seal Element Test

Fig. 3: Partial Submersion Side Access Method: Element Test of Interfering Object Removal



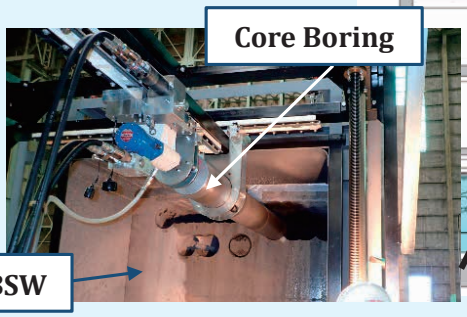


Fig. 2: Partial Submersion Side Access Method: Element Test of Biological Shielding Wall (BSW) Removal

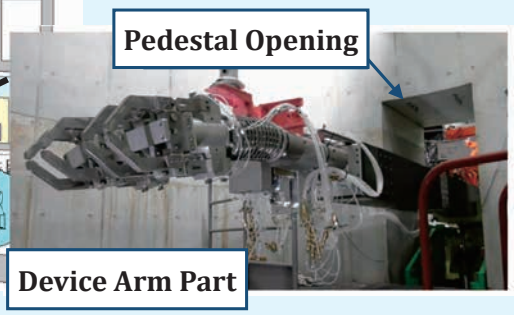


Fig. 4: Partial Submersion Side Access Process Method: Element Test of Interfering Object Removal

Fig. 5: Partial Submersion Side Access Method: Element Test for Combination of Robot Arm and Access Rail

R&D for Preparation of Fuel Debris Retrieval

Development of Fundamental Technology for Retrieval of Fuel Debris and Internal Structure (Development of Small Neutron Detectors)

Background

Retrieving fuel debris necessitates identifying the location and amount of fuel debris. One of the method for identifying fuel debris is the neutron measurement method that is to measure neutrons generated by spontaneous nuclear fissions in the fuel debris. However, existing sensors may not be capable of being used due to the dimensional restrictions, thus making a smaller sensor necessary.

Purpose

For fuel debris detection, it is necessary to install a detector in the vicinity of fuel debris and measure weak neutrons under high gamma ray dose. The access route to the vicinity of fuel debris is narrow, therefore a compact type sensor is required. This project aims at developing a small neutron detector to satisfy those requirements.

Major Approach and Results

1 Specifying the Feasible Neutron Detection Technology for Fuel Debris Retrieval and Results of Element Tests for Feasibility Investigation (Phase-1) for Fukushima Daiichi NPS

Element test of the CMOS type neutron detector was performed to confirm the neutron flux detection at a single neutron location, gamma-ray detection at a single gamma-ray location, and detection performance under the complex irradiation environment of gamma-ray and neutron ray. The identification of cluster patterns using alpha-rays derived from neutrons in the combined location was confirmed (The Fig. 1 principle was confirmed.). It was also confirmed that there is no false detection of neutrons until gamma-ray cumulative dose reaches up to the degree of 1000Gy.

2 Development of Neutron Detector (Phase-2)

A prototype of the small neutron detector was produced based on the study results of Phase-1. The study of the sensor layout, the design of the sensor unit, and the detection software production and the performance validation were performed.

The sensor unit was designed considering the sensitivity secured by stacking three sensors and heat radiation performance (Fig. 2). In addition, the neutron detection software was installed into the PC, which is transmitted images and comprised the display of neutron counts in real-time.

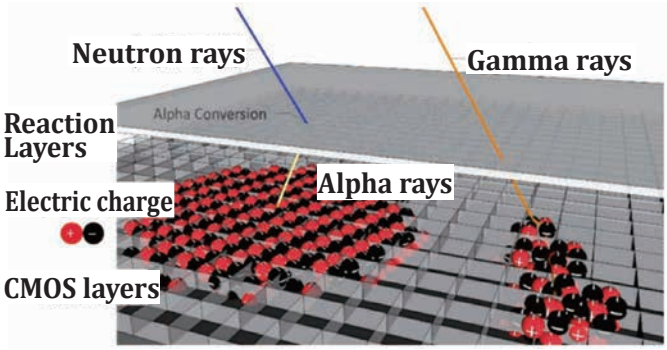
As the result of the evaluation test, the following performance were confirmed (Fig. 3 and 4). 1. The neutron detection sensitivity was able to detect 2.3 neutrons per hour in average after 7 hour measurement against the requirements that can count neutrons within 1 hour for the neutron flux on 0.1n/ (cm^2·s). 2. It was confirmed that the measuring range of the neutron flux can measure more than 0.1n/ (cm^2·s) and less than 1,000n/ (cm^2·s). 3. Neutrons can be discriminated up to the accumulated dose of 1000Gy as radiation resistance. 4. The detection capability was the same as normal temperature even under the environment of 40°C as heat resistance. 5. The water resistance capability was confirmed as it was able to operate even under water without water immersion.

In addition, the conclusions below were obtained from the test assumed practical application; 1. The study on the shielding structure using neutron absorbing materials is necessary if the neutron source is located around the area of use (within 200 ~ 300mm) in underwater environment. 2. A neutron moderator installed around the CMOS sensor is necessary for the promotion of thermalization because neutrons are not thermalized in the aerial environment. For the effective nuetron detection, the change of the collimator shape and the moderator size in the collimator depending on the purpose of use are assumed to enhance the feasibility.

Requirement specifications of this sensor differ depending on the application destination, therefore, the sensor requires to meet the design and production.

Future Development

A small neutron detector completed in this study is smaller than a conventional neutron detector,therefore, this project aims at promoting the application to utilize the profits. Specifically, the application of the detector will be promoted for on-going projects of decommissioning of the Fukushima Daiichi NPS including the project of investigation inside PCV and the monitoring technology for fuel debris retrieval. In addition, a wide range of matching needs will be promoted because these technologies are possible to be utilized in general industries and medical industries other than nuclear decommissioning.



When neutrons enter into the reaction layers applied on the CMOS layers, heavy-charged particles are generated and charged on the CMOS layers as charge, and bright patterns are displayed. On the other hand, since gamma-ray is displayed relatively small patterns, this is discriminated from neutron entering.

Fig. 1: Principle of CMOS Type Neutron Detector

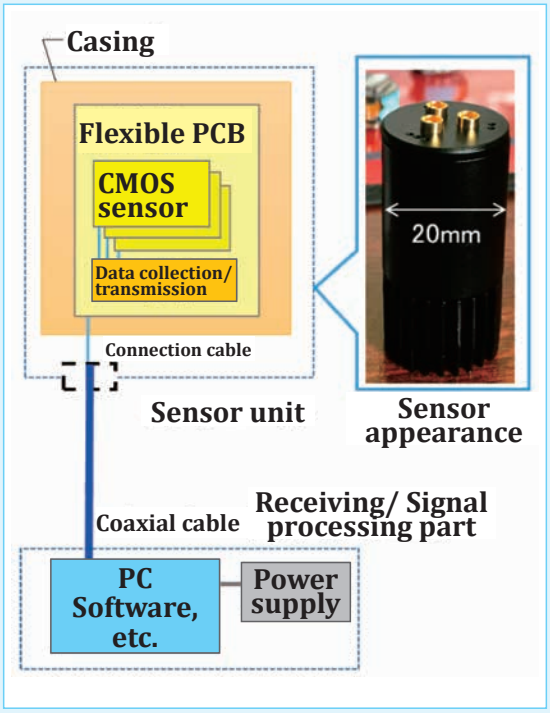


Fig. 2: Overview of CMOS Type Neutron Detection System

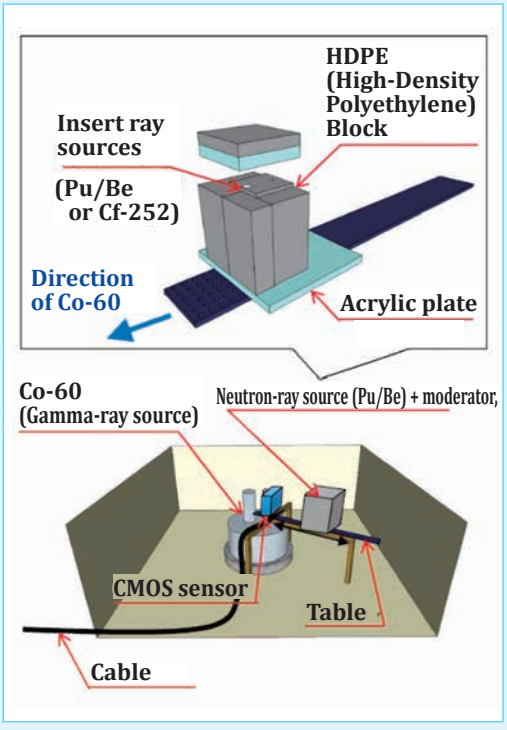


Fig. 3: Mockup System of Element Test

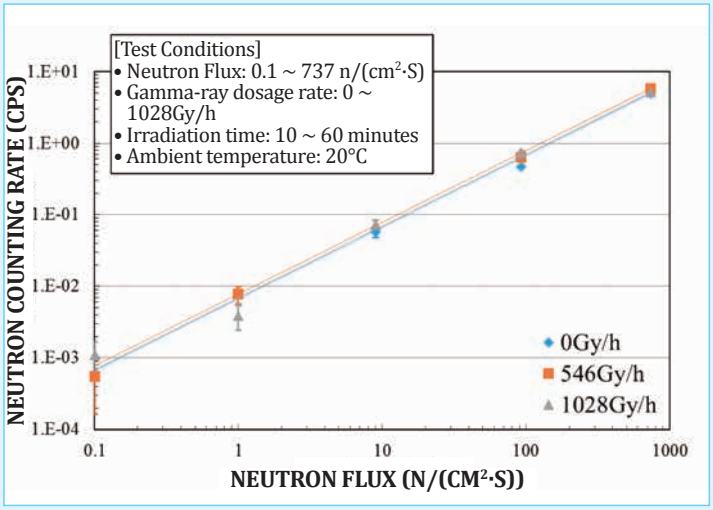


Fig. 4: Neutron Flux Detection Performance (under radiation environment)

R&D for Preparation of Fuel Debris Retrieval

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

Background

According to the Mid-and-Long-Term Roadmap plan toward the Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS) of Tokyo Electric Power Company (TEPCO) Holdings Co., Inc., fuel debris will be retrieved from the primary containment vessel (PCV) and then stored in the storage building of the Fukushima Daiichi NPS until the treatment and disposal methods are determined. Therefore, it is necessary to establish the fuel debris collection, transfer and storage system.

Purpose

Based on the experience of the Three Mile Island Nuclear Power Generation Station Unit 2 (TMI-2) in the United States, and proven technologies for transport and storage of spent fuel, this project aims at development of fuel debris canister (hereinafter referred to as "canister") and the canister handling device for safe and efficient collection, transfer, and storage. The project mainly develped the appropriate specifications, and the shape of the canister and its handling device for the fuel debris retrieval method in FY2018.

Major Approach and Results

1 Investigation and Research Planning for Transfer and Storage

As for the safety evaluation and validation of the canister for Fukushima Daiichi NPS, the project team exchanged information with overseas engineers having decommissioning experiences and knowledge, and thereby, confirmed the applicability of basic specifications for the canister.

2 Study on Safety Requirements, Specifications and Storage System for Transfer and Storage for Fuel Debris Canister

A process flow plan and the throughput (including the required amount of wastes, the number of canisters, and the storage area) for fuel debris retrieval, collection, transfer and storage (including drying treatment) were updated, while requirements from the projects of the fuel debris retrieval, and waste disposal and treatment, were clarified to revise the scenario. In addition, based on the scope of the safety function of canister and the building facility, the function scope was refined. Furthermore, , the specification plan for drying facility design was provided from the aspect of hydrogen gas generation reduction.

3 Development of Safety Evaluation Method and Safety Validation

Unlike the TMI-2 case, fuel debris and the Molten Core Concrete Interaction (MCCI) possibly contain sea water components in the Fukushima Daiichi NPS. For safety collection, transfer and storage of fuel debris and the MCCI products, it is required to verify the safety for criticality, the structures, material deteriorations and hydrogen generation.

Various safety validation study and tests for the fuel debris canister were performed. For example, the canister lid structure (feasibility verification test considering a handling flow and the safety requirements (Fig. 1 and 2), and hydrogen gas management (measurement test for hydrogen generation amount using spent fuel (Fig. 3 and 4), and efficiency evaluation of hydrogen recombination catalyzer) were studied, and thereby, necessary knowledge was acquired to establish the safety evaluation method.

4 Study on Fuel Debris Storing Type

Based on study of the safety conditions and the safety validation results for the basic specifications of fuel debris canister indicated by above Item 2 and 3, the storage methods were studied considering the properties and the shape of various type fuel debris; lump-like, granular and powderly shaped fuel debris (Fig. 5). As the results, the study revealed that the canister specification plan is currently applicable to the throughput, and fuel debris properties and the shape.

Future Development

A verification test for the canister structure will be planned and conducted for evaluation of storage technology. In addition, the transfer conditions of the canister will be clarified by the hydrogen measurement method and its management. Furthermore, technology for drying treatment and pre-storage treatment evaluation will be studied development of drying technology and its system.

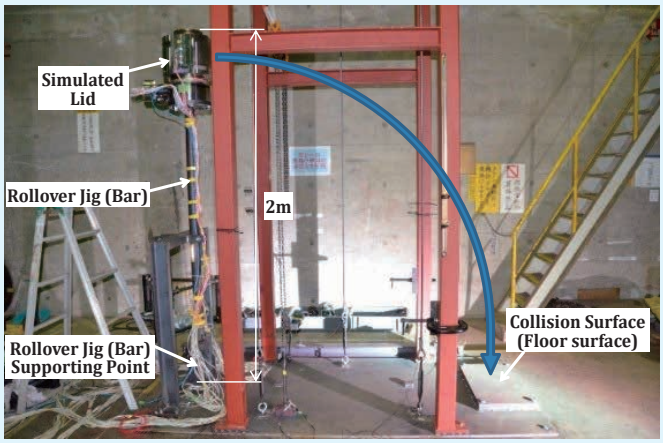


Fig. 1: Appearance of Test Device

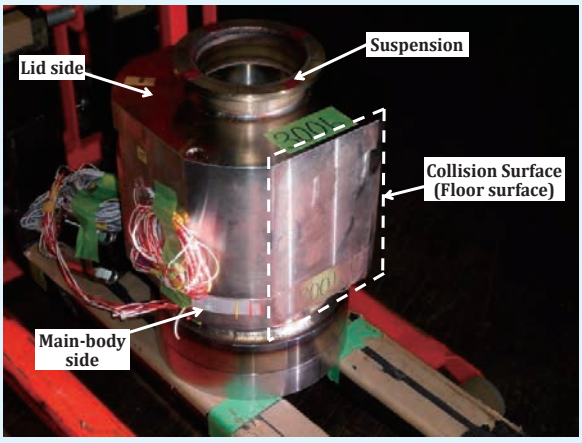


Fig. 2: Example of Simulated Lid after Test

- **The conditions of the feasibility test for the canister lid structure (Canister rollover, Inner diameter of canister: 220mm)**
- **For confirming the feasibility of the canister lid structure, the load test simulating events which may have a large impact on the structure strength evaluation was conducted. As a result, confinement performance of the lid structure was confirmed when shock loads were applied..**

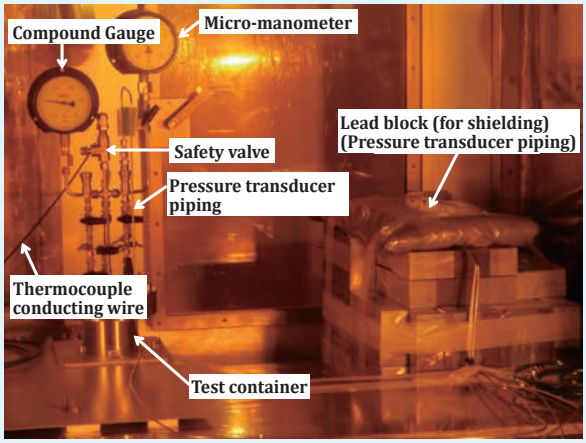


Fig. 3: Appearance of Test Device

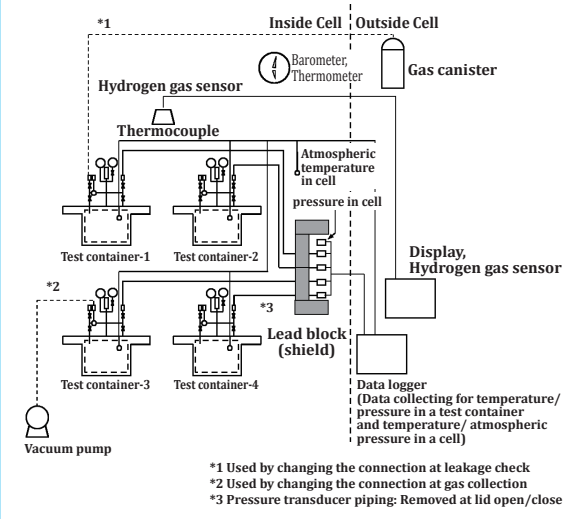


Fig. 4: Test Device Configuration

- For confirming the impact on alpha-ray against hydrogen generation amount, a measurement test for hydrogen generation amount using spent fuel as alpha-ray source will be performed, and the obtained test data will be reflected the hydrogen generation amount evaluation. strength evaluation was performed to confirm the feasibility and the confinement performance of the lid structure was confirmed when shock loads were applied.

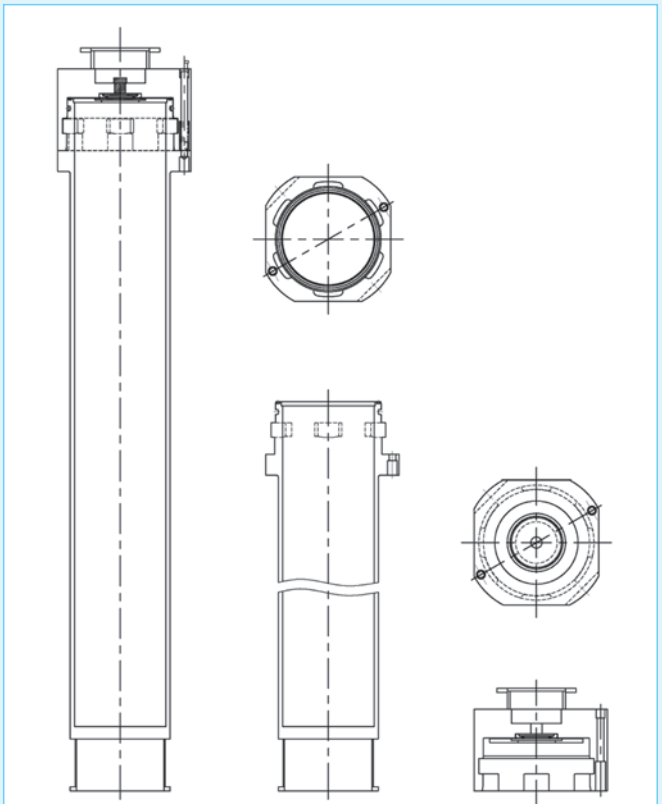


Fig. 5: Basic Plan of Canister Shape

- **This is a connection method by rotating the canister tunk and its lid.**
- **Based on the safety validation results of various studies and confirmation tests for the canister design, the basic shape of the fuel debris canister was studied.**

R&D for Treatment and Disposal of Radioactive Waste

R&D for Treatment and Disposal of Solid Radioactive Waste

Background

As fuel debris retireval work proceeds, a large amount of wastes will be generated in the Fukushima Daiichi Nuclear Power Station (NPS) while fallen trees and rubbles have already been stored. Therefore, it is necessary to develop waste management methods of storage, treatment and disposal and to implement the project while clarifying the properties of the wastes.

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); characterization of inventory evaluation based on waste analysis, and study on solidification technology the stabilization of secondary wastes generated by water treatment, and concepts of the treatment and the safety evaluation method.

Major Approach and Results

1 Waste Characterization

The analysis of rubbles, the secondary waste generated by water treatment, and contaminated water continues to be performed. The analysis revealed that local contamination of rubble samples is distributed unevenly (Fig. 1). In addition, the data repository with accumulated analysis data was released on website to contribute the decommissioning (Fig. 2). The amount of radioactive wastes was estimated that the distribution of contamination frequency caused by radioactive nuclides was the normal logarithmic distribution, and thereby, the estimation method considering the increase of analysis data was studied (Fig. 3). The radioactivity inventory of the wastes by using the improved evaluation approach was calculated and a computation tool was also improved.

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 by water treatment, in-drum type glass solidification technology was focused upon, and the solidification (crucible test and engineering scale test) that melted simultaneously with zeolite used for the contaminated water treatment and other simulated waste from the secondary waste generated by water treatment was produced (Fig. 4). Based on the results of the glass composition study and a crucible melting test, an engineering scale test under the manufacturing conditions was conducted to evaluate solidification properties, the nuclide transition to the off-gas system and chemical durability of solidification.

② Study of Storage Measures for High-dose Waste (Hydrogen Generation Measures)

Differences and reasons between Japan and overseas in the concepts , the evaluation methods nd countermeasures of hydrogen generation and specifications of canister were investigated, which provided the knowledge of the hydrogen gas generation evaluation method and requirements for vents. In addition, as for the slurry-shape waste and the reactor internals (metal wastes), a series of hydrogen generation measures for storage, process and disposal were studied to clarify the evaluation method and issues of hydrogen gas generation measures.

3 Study of Disposal Concepts and Safety Evaluation Methods for Solid Wastes

Focused on case studies of overseas repositories, solid wastes in the Fukushima Daiichi NPS were clarified about their applicability and issues. In addition, the methods of the disposal concepts considering properties of the wastes were examined (Fig. 5). The case study of multiple disposal concepts was performed with this method. It was confirmed that a policy of the waste treatment and disposal can be studied depending on the waste properties.

4 Integration of R&D Results

The waste stream was reflected in the latest results obtained from the existing research. The establishment of an integration method started for the progress, consistency of results and remaining issues, and the operational issues were clarified through trial operations.

Future Development

The project will continuously perform analysis on waste characterizations, as well as the sample collection, efficient analysis and improvement of the inventory estimation method. In addition, in preparation for high-dose waste segregation and storage methods, will be studied. Advanced disposal technology will be continuously selected for the stable treatment of the secondary wastes generated by water treatment. The wastes will be estimated more specifically and multiple disposal methods will be studied.

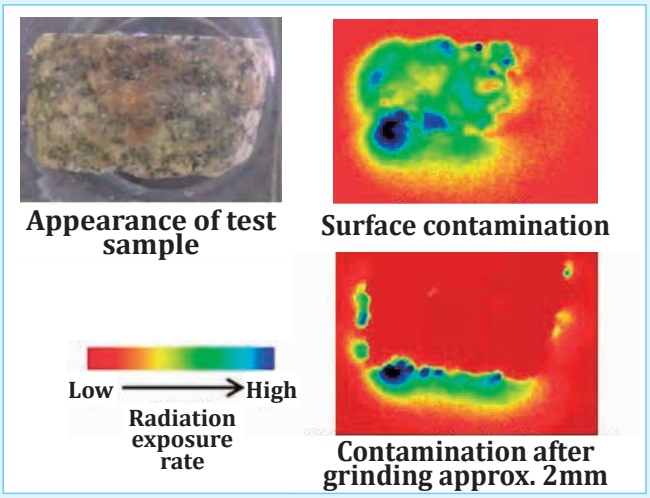


Fig. 1: Appearance of Locally Inhomogeneous Contaminated Rubbles (by imaging plate measurement)

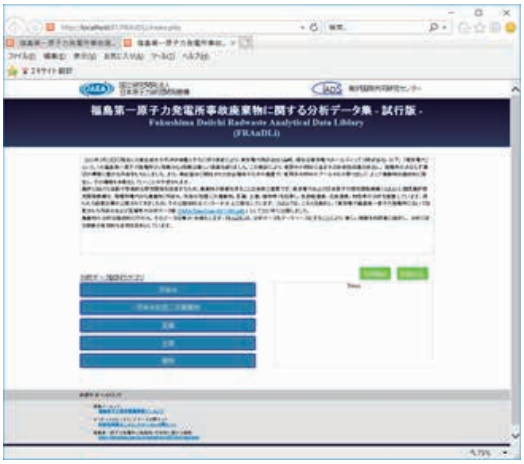
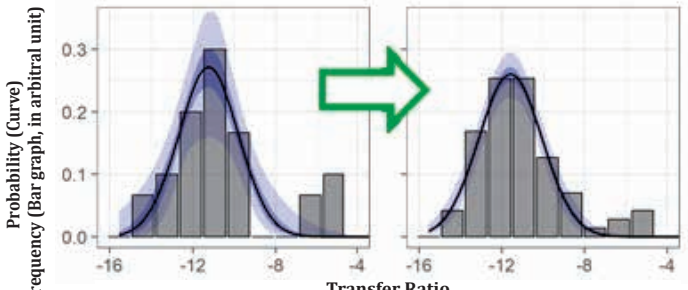


Fig. 2: Released Analysis Datasheet

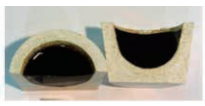


Improvement of Analysis Data

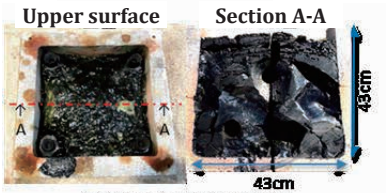
The uncertainty of normal logarithmic distribution parameters (average and deviation) is decreased, which shows the validity of the assumptions.

Fig. 3: Example of the Uncertainty Decrease of Distribution Parameters Associated with Analysis Data Increase

Engineering Scale Test Device



Solidified material (crucible test)



Solidified material (Engineering Scale Test)

Fig. 4: Test Facility of In-Drum Type Glass Solidification Technology and Solidified Materials

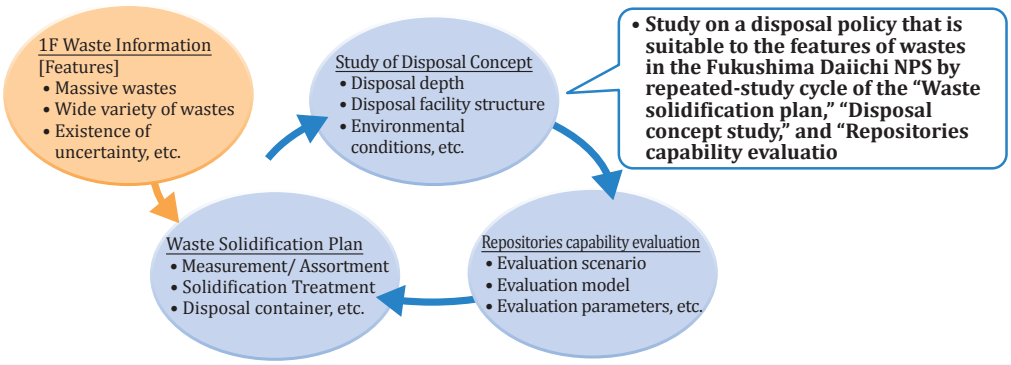


Fig. 5: Study Process of Disposal Concepts Considering Waste Properties

R&D for Treatment and Disposal of Radioactive Waste

R&D for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods)

Background

In the Fukushima Daiichi Nuclear Power Station (NPS), multiple and various kinds of wastes have been already generated, and will increase for a long term in the future. To proceed with the decommissioning, it is necessary to manage the generated wastes in a safe and appropriate manner, while studying the waste treatment and disposal methods and ensuring the consistency.

Purpose

This project aims at developing technologies for safe treatment and disposal of the solid wastes generated in the accident by the integration of results of research and development (R&D); Characterizations of inventory evaluation based on waste analysis, study on solidification technology, stabilization of the secondary wastes generated by water treatment, the concepts of wastes and the safety evaluation method.

Major Approach and Results

1 Prospect Evaluation of Proven Technology for Solid Waste Treatment

① Engineering Scale of Applicability Evaluation on Element Technology for Solid Waste Disposal

This project aims at acquiring information on four treatment technologies (High temperature: Glass solidification and melting, Low temperature; Cement solidification, AAM: (Alkali Activated Materials), solidification) proven both in Japan and overseas, washing out of the selection index (evaluation axis) of applicable treatment technology and clarification of qualitative/ quantitative information (Table 1). Furthermore, necessary information was clarified. In addition, the insufficient data mainly on the low temperature treatment was obtained to complement quantitative information. Properties of the AAM solidiication were discovered; early strength developing property in cement (Fig. 1), the possibility of superior dissolution stability and differences of the setting time depending on composition (Fig. 2).

② Clarification Items Having Impacts on Disposal Safety Evaluation and Study on Analysis Evaluation Method for Disposal Affects Substances

The project extracted six substances (organic materials, sea water components, boronic acid, ferrocyanide, sulfate and carbonate) since they should be confirmed as impact substances, or they are more likely to have impact on the safety disposal evaluation based on the information on nuclide adsorbing behavior and wastes. The insufficient information about the interaction with nuclides was acquired and investigated, provided the quantitative evaluation methods for the influence against nuclide adsorbing behavior depending on the amount of available data. A trial of the adsorption reducing coefficient evaluation (Fig.3)was performed to extract issues.

2 Development of Technology for Solid Waste Storage and Management

① Development of Contamination Evaluation Technology for Solid Waste Segregation

As for alpha contamination measurement technology, the parameters impacting the measurement of environmental temperature and radiation dose rate were clarified, assuming the site environment, the requirement specifications of the measurement device were established based on the measurement needs. Additionally, based on the required specifications, the test device (Fig.4) added enlarged lens and temperature adjustment mechanism were produced, and element tests were conducted to clarify issues for the site application.

The scope of the site application for the penetration alpha contamination measurement technology was studied and the measurement needs were investigated, and thereby, the technological investigation was performed aiming at using the technology under the assumed environmental conditions. Moreover, the measurement method performance of the gamma nuclides penetration depth including Cs-137 which is considered to accompany alpha nuclides (Fig. 5) was evaluated.

② Study of Simple and Rapid Analysis Method

The analysis method for a massive and wide dose rates of waste samples was developed for the safe, and effective analysis while ensuring the reliability of analysis values. Specifically, the methodology with least sample collection was established to ensure appropriate samples. Furthermore, the analysis process (Fig. 6) that was installed a mass analysis to the minimize nuclide separation processes and to improve a detection lower limit was established. In addition, the automation technology of seven-step operations (from the melting phase to the ion exchange/solid-phase extractions) which is the most complicated analysis operation was developed, and confirmed that the system has the same accuracy as skilled workers. The specific methods including the analytical accuracy management to secure the reliability of acquired data and to maintain analyst's skill were systematically developed.

Future Development

This project will perform additional investigations and tests for the insufficient information and data about the applicability evaluation of processing technology and the impact evaluation with toxic substance in parallel with other R&Ds. In addition, technology for contamination evaluation and the analysis methods were established, and technology and management verification of these methods will be promoted for the site application.

Table 1: Major Evaluation Axis and Clarified Information (Example: Superhigh Frequency Molten Solidification)

(Evaluation Axis)		(Qualitative/ Quantitative Information)
Technological Achievements		Verification test of small device in Japan (30L/ batch)
Process performance	• Number of process • Treatment temperature • Treatment capacity • CS volatile rate	14 1450°C 0.4t/ batch/ d CS 10 ~ 70%
Operability	• High impact parameter • Major process link	• Waste composition (Ca concentration, impurity), waste moisture content, molten metal temperature • Solidified substance performance degradation due to internal pressure rise and insufficient melting
Economic Efficiency	• Major facility configuration • Generated secondary waste	• Drying facility, high-frequency power source, water-cooled coil, off-gas system • Bug • HEPA filter, residue and exhaust water scrubber
Solidified Substance Products	• Solidified substance dimensions • Leach rate • G-value	200L drum 10-4kg/m²/d No hydrogen generation

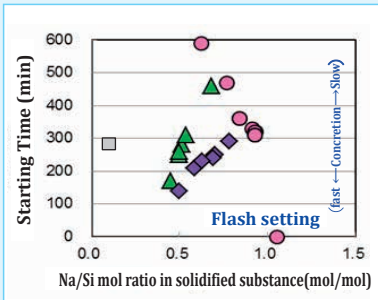


Fig. 2: Relationship between Composition and Concretion Time

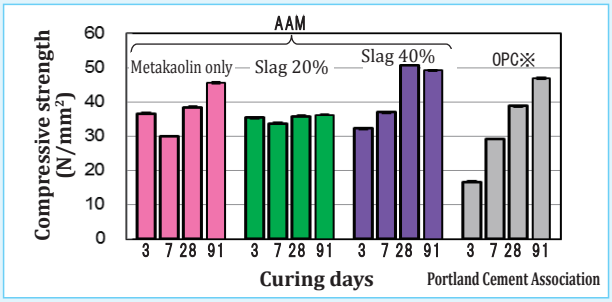


Fig. 1: Relationship between Compressive Strength and Transit Time

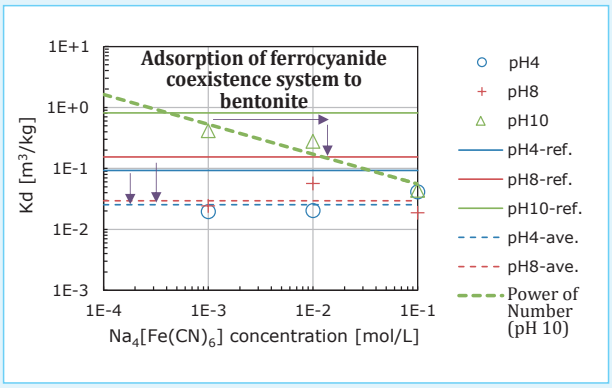


Fig. 3: Evaluation Example of Adsorption Decreasing Factor for Artificial Barriers

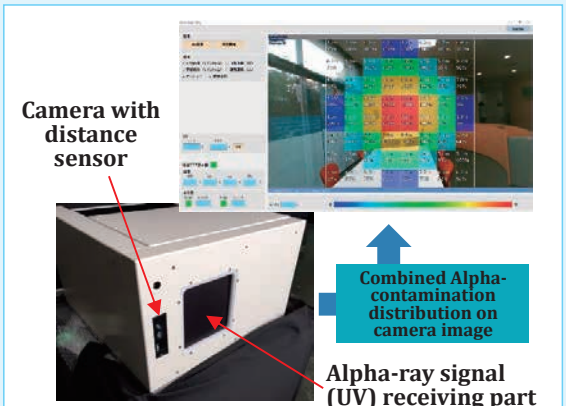


Fig. 4: Surface Alpha Contamination Measurement Device (Alpha Camera)

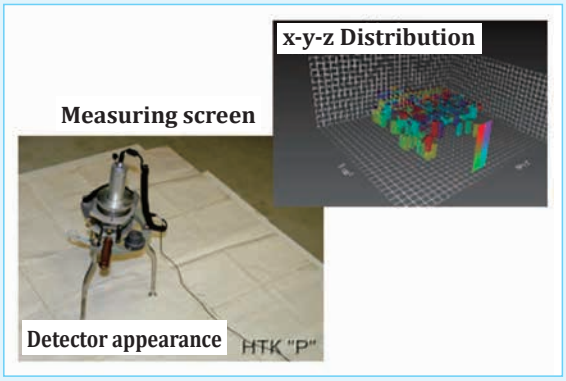


Fig. 5: Example of Investigation Results of Penetration Alpha Contamination Measurement Technology: Detector appearance and image of measured results

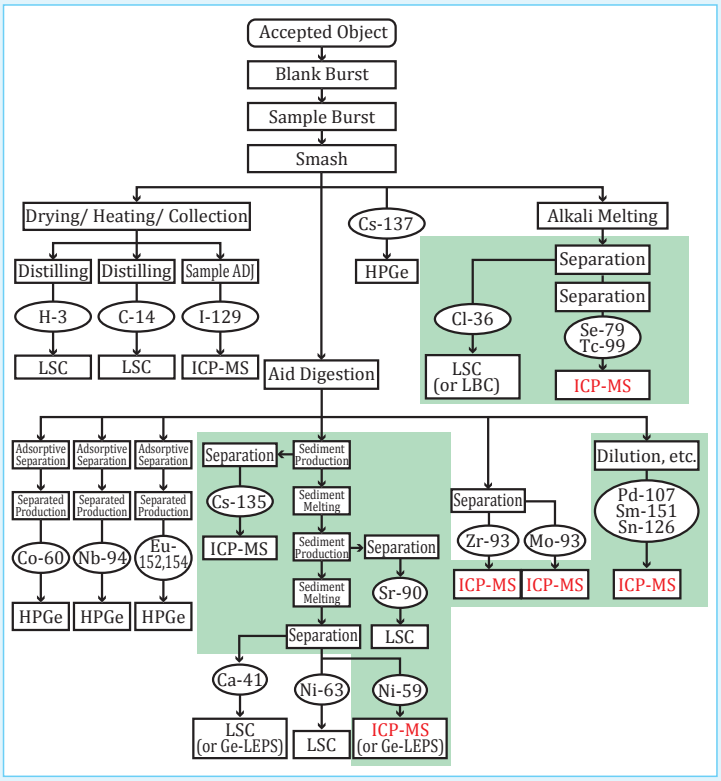


Fig. 6: Developed Analysis Process

Investigation Research on Deposits at the Lower Part of Pedestal in Fukushima Daiichi NPS Unit 2

Background and Purpose

In the Fukushima Daiichi Nuclear Power Station (NPS) Unit 2, the investigation inside the primary containment vessel (PCV) revealed that deposits exist at the bottom of the pedestal. This study aims to confirm the changes of the deposits behavior in contact with the deposits at the lower pedestal based on development of the investigation device for the PCV internals.

Major Approach and Results

The investigation unit that was used for investigation inside the PCV was changed in January 2018, and confirmed the state change of the deposits by applying a mechanical force of the finger structure action. This investigation revealed that pebblelike deposits at the pedestal bottom was movable. In addition, it was confirmed that the deposits on the platform can be gripped and movable.

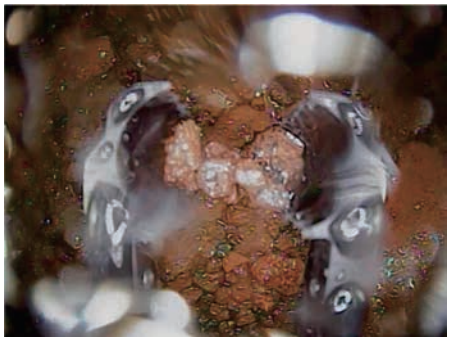


Photo 1: Investigation Result of Pedestal Bottom (In contact with deposits)

Future Development

The useful information on fuel debris retrieval was obtained, therefore, this project continues to study toward determining the fuel debris retrieval method for an initial unit.

Test and Research for the Stable Operation of Advanced Liquid Processing System and Slurry Stabilizing Facility

Background and Purpose

The feasibility of the stabilizing facility with pressurized press filtration (filter press) was confirmed under the subsidized project of supplemental budgets of FY2013 and FY2014. This project aims at verifying the applicability of the treating range by testing for crushing, transfer and filling of dehydration products as well as the system obstructions.

Major Approach and Results

1 Applicability Test of Technology for Crushing and Transfer of Dehydration Products

A dehydrate crushing test using proven wires in general industries was conducted, which provided the prospects of application. In addition, a conveyer transfer test was performed, and it revealed that issues remain in the operation side.

2 Applicability Test of Dehydrate Filling Technology

The bulk density and the scattering condition of the dehydration products after discharge were confirmed, assuming that a container is filled with dehydration products by free fall. In addition, as for the measurement of the water content rate on the dehydration products, the applicability of two patterns calculated from remote measurement and process monitoring data was studied.

3 Applicability Verification for System Obstruction

The removal effect using a detergent was confirmed, assuming that the system was obstructed due to slurry adhesion.

Photo 1: Appearance of Crushing Test by Simulated Dehydration Products

Future Development

The results of the project will be reflected into a basic design of the slurry stabilized treatment facility and develop the practical application.

Major Research Results in FY2018

No.	Presented by	Date	Details
1	Japan Robotics Society (Official English-Language Journal); Advanced Robotics <Research paper >	May 2018	Shape Changing Robot for Investigation Inside PCV named PMORPH
2	The 10th Anniversary Memorial General Meeting for Tohoku and Hokkaido Branch Division Establishment, Japan Society of Maintenology	May 11, 2018	Robot Development toward Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS)
3	Academic Network contributing to Fukushima Reconstruction and Reactor Decommissioning (ANFURD) (Workshop on "Potential Issues on Fuel Debris Retrieval")	May 15, 2018	Current Status of Technology for Fuel Debris Retrieval and Expectation to the ANFURD
4	IAEA Regional train trainer source on NDT for civil infrastructure, Workshop	May 31, 2018	Development of Investigation Equipment for inside PCV (A2, A2', Underwater ROV) and Investigation Results under the Ultimate Environment of Fukushima Daiichi NPS
5	The 35th International Nuclear Air Cleaning Conference by International Society for Nuclear Air Treatment Technologies	Jun. 4, 2018	R&D for Fuel Debris Retrieval at Fukushima Daiichi NPS
6	The 23rd National Symposium on Power and Energy Systems	Jun. 14 ~ 15, 2018	Development of Working Robot under High Radiation Environment for the Decommissioning of Fukushima Daiichi NPS
7			Subsidy Project on Decommissioning and Contaminated Water Management in FY2017 Supplementary Budgets; Development of Technology for Investigation inside PCV in Unit 2-3 of Fukushima Daiichi NPS
8	The 8th Robot Award	Jun. 29, 2018	Subsidy Project on Decommissioning and Contaminated Water Management in FY2017 Supplementary Budgets; Development of Technology for Investigation inside PCV "InvestigationPCV" Investigation inside the Pedestal for Unit 3"
9	The 10th Radiation Measurement Forum, Fukushima	Jul. 4, 2018	Development of Debris Investigation Equipment at Fukushima Daiichi NPS
10	The 26th ATOX Technology Workshop	Jul. 10, 2018	ATOX Approach for National Project
11	Japan Society of Maintenology; The 15th Academic Conference	Jul. 10 ~ 12, 2018	Subsidy Project on Decommissioning and Contaminated Water Management in FY2017 Supplementary Budgets; Development and Results of Technology for Investigation inside PCV in Unit2-3 of Fukushima Daiichi NPS
12	The 26th International Conference on Nuclear Engineering (ICONE 26)	Jul. 22, 2018	Example of R&D on criticality control technique of Fukushima Daiichi Nuclear Power Plants
13	International Conference on Nuclear Engineering (ICONE26)	Jul. 23, 2018	Development of ROV to investigate inside of primary containment vessel at Fukushima Daiichi Unit 3
14	The 56th Team Meeting on Countermeasures for Decommissioning and Contaminated Water Treatment Conference	Jul. 26, 2018	Analytical Results of Waste Sample (rubbles, secondary wastes generated from water treatment faciity contaminated water, treated water, and soil)
15	IEEJ (Institute of Electrical Engineering, Japan) Journal, August Issue	Aug., 2018	Development of Investigation inside PCV
16			Tomography Technology inside the Reactor through Cosmic-ray Muon
17	IRID Symposium 2018	Aug. 2, 2018	Status of IRID's R&D
18			Status of IRID's R&D; Conceptual Design to Enhance Safety and Feasibility, and Future Technological Development
19			Crawler Travel Test in narrow parts
20	The 3rd International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station	Aug. 6, 2018	Application of ICP-MS to analysis of samples from 1F site at Radioactive Material Analysis and Research Facility
21			Core Material Melting and Relocation tests
22			Characterization of the large-scale MCCI test products for fuel debris removal from the Fukushima Daiichi Nuclear Power Plant
23			Progress of 1F PCV contaminant analysis by TEM observation
24			Development of a remote concrete sampling device
25			"NDA System for Fuel Debris Characterization at Fukushima Daiichi"
26			Development of a remote concrete sampling device
27	The 15th "Nuclear Power Technology" Summer Seminar, Nuclear Power Group Meeting; Atomic Energy Society of Japan	Aug. 9, 2018	Estimation of fuel Debris Distribution at Fukushima Daiichi NPS Unit1-3 (Report including Subsidy Project on Decommissioning and Contaminated Water Management in FY2017 Supplementary Budgets (Upgrading the Comprehensive Identification of Conditions inside Reactor.

No.	Presented by	Date	Details
28	2018 Fall Meeting, Atomic Energy Society of Japan	Sept. 5 ~ 7, 2018	Development of Canister for Fuel Debris; (11) Measurement of Hydrogen Generation Amount due to the Water Radioactive Degradation under Gamma-ray Irradiation (Part-2) (12) Analytical Evaluation of Hydrogen Generation Amount due to the Water Radioactive Degradation under Gamma-ray Irradiation (Part-2) (13) Study on Alpha-ray Effect by Hydrogen Generation Test Using Spent Fuel
29			Study on the Element Analysis Method for Fuel Debris in Fukushima Daiichi NPS
30			Results of "Development of Fuel Debris Criticality Control Technology" in FY2017
31			Comparative study of Cs silicates properties between DFT calculation and experimental data
32			(1) Development of the Inventory Evaluation Method for Fukushima Daiichi Accident Wastes, (13) Study on the Introduction of Statistical Approach to Analytical Estimation Technology (2) Development of the Inventory Evaluation Method for Fukushima Daiichi Accident Wastes, (14) The Effect on Nuclide Adsorption to Zeolite due to change of Contaminated Water Quality (3) Establishing Analysis Database of Radioactive Waste Generated from the Fukushima Daiichi NPS Accident
33			(5 topics among the presentations related to the Project of Identifying inside the Reactor as below); Analysis/ Evaluation of Identifying inside the Reactor in Fukushima Daiichi NPS, TEPCO (107) Long-term Corrosion Evaluation of PCV Floor by the Sensitivity Analysis of Debris Deposition Situation (Hitachi-GE) (109) The Difference of Reactor Core Energy in Process of the Reactor Core Materials Transport and its Impact (JAEA) (113) Summary of Comprehensive Analysis/ Evaluation in Unit-3 (TEPCO HD) (114) Summary of Comprehensive Analysis/ Evaluation in Unit-1 (Hitachi-GE) (115) Summary of Comprehensive Analysis/ Evaluation in Unit-2 (JAEA)
34	Summer Seminar, Hokkaido Branch Office, Atomic Energy Society of Japan	Sept. 10, 2018	Approach by Toshiba Energy Systems & Solutions Corporation toward Decommissioning ~ Progress of Investigation inside PCV for Fuel Debris Retrieval and Issues ~
35	JOINT ICTP-IAEA International School on Nuclear Waste Actinede Immobilization	Sept. 10, 2018	Fission Product Behavior under Light Water Reactor Sever Accident in the light of Fukushima Daiichi NPS
36	Geochemical Society of Japan Annual Convention in 2018	Sept. 11 ~ 13, 2018	Study on the Generation Mechanism of Insoluble Cesium Particle, Type-A
37	The 7th Reactor Physics/ Nuclear Data Research Workshop, Tohoku University	Sept. 21, 2018	Introduction of R&D Related to the Fuel Debris Retrieval in Fukushima Daiichi NPS (focused on criticality control technology development)
38	Lecture Meeting on the Decommissioning of NPS, Fukushima Prefectural Centre for Environmental Creation	Sept. 21, 2018	Current Situation of Technological Development involved in the Decommissioning of Fukushima Daiichi NPS
39	Intensive Course "Introduction to Nuclear Decommissioning Engineering/ Special Topics, 2018], Intensive Course of Tohoku University	Sept. 28, 2018	Development of Robotic Technology Associated with Decommissioning Work and Site Application
40	Intensive Course "Introduction to Nuclear Decommissioning Engineering/ Special Topics, 2018", Intensive Course of Tohoku University	Sept. 29, 2018	Characterization and Treatment of Fuel Debris
41	The Nuclear Almanac, 2019	Oct. 2018	Status of R&D for Decommissioning of Fukushima Daiichi NPS conducted by International Research Institute for Nuclear Decommissioning (IRID)
42	2018 International Severe Accident Management Conference (ISAMC)	Oct. 15, 2018	Challenging Issues and International Joint Research Project regarding fuel debris characterization toward decommissioning of Fukushima Daiichi NPP
43	International Conference on Dismantling Challenges: Industrial Reality, Prospects and Feedback Experience	Oct. 22, 2018	The CMMR Program: BWR Core degradation in the CMMR3 Test
44	4th International Conference on Maintenance Science and Technology 2018 (ICMST-Tohoku 2018)	Oct. 23 ~ 26, 2018	Shape-Changing Robot, "PMORPH"
45			Muscular Robot with Flexible Structuring Mechanism
46	NFD Workshop, 2018	Oct. 24, 2018	Development of Robotic Technology Associated with Decommissioning Work and Site Application
47	Journal of Nuclear Science and Technology	Oct. 24, 2018	Fiber optic type compact dosimeter using Nd: YAG for basement investigation inside primary containment vessel

No.	Presented by	Date	Details
48	2018 Fall Lecture Meeting by Fluid Power System, Japan Fluid Power System Society	Oct. 25 ~ 26, 2018	Estimation and Control of Hydraulic Cylinder Output Using System Identification
49	MATLAB EXPO 2018 JAPAN	Oct. 30, 2018	Design Development of Fuel Debris Retrieval Robot for Fukushima Daiichi NPS to utilize MBD
50	The 116th Robotics Seminar, Japan Robotics Society	Oct. 31, 2018	Restoration of Robot Technology in NPS
51	The 2nd Meeting in FY2018; Atomic Energy Society of Japan; "Behavior of Fission Products at Severe Accident," FP Experiment Working Group, Research Expert Committee,	Nov. 2, 2018	Development of Remote-operated Decontamination Technology in Reactor Building; Introduction of Results Involving Investigation of Contamination
52	The 6th Regular Lecture Meeting, Inertial Sensor Application Technology Research Association, NPO	Nov. 9, 2018	Utilization of Inertial Sensor Robot for NPS
53	Research Seminar "Possibility of Nondestructive Analysis through Muon"	Nov. 13, 2018	Three Dimension Analysis by Muon Scattering Method
54	Materiaux, Strasbourg, France	Nov. 19 ~ 23, 2018	First analyses of concrete-corium solids surrogate for the Fukushima Daiichi severe accidents
55	Robot & Aerospace Festival in Fukushima, 2018	Nov. 22, 2018	Subsidy Project on Decommissioning and Contaminated Water Management in FY2015 Supplementary Budgets; Development of Technology for Investigation inside PCV, "Investigation," Investigation inside the Pedestal for Unit 3" Development of Technology for Investigation inside Primary Containment Vessel
56			Status of R&D Conducted by IRID; Investigation and Retrieval of Fuel Debrisl by using Robot
57	E-Journal of Advanced Maintenance Vol.10 No.3	Nov. 25, 2018	Development of a MAV Equipped with Rotatable Attachment Adhesive Mechanism for Movable Observation System
58	The 7th Reactor Physics Professional Study Meeting, Atomic Energy Society of Japan	Nov. 26, 2018	Criticality Behavior Analysis Assuming Fuel Debris Retrieving Work Based on Criticality Scenario; Development of Criticality Approach Monitoring System (1)Validation of criticality approach monitoring system by using KUCA, Development of criticality approach system (2)Validation of MVP2.0.33 Time-list Mode
59	Subcommittee of Building Structure Performance, Decommissioning Study Committee, Atomic Energy Society of Japan	Nov. 28, 2018	R&D Results in FY2017; Development of Seismic Performance and Impact of RPV/ PCV, in Fukushima Daiichi NPS Reinforcement High Temperature Corrosion Test on RPV Pedestal
60	Membership Lecture Meeting; The Japan Machinery Federation, General Incorporated Association	Nov. 30, 2018	Current Situation of Technological Development for the Decommissioning of Fukushima Daiichi NPS
61	"The 11th Radiation Measurement Forum, Fukushima", The 186th Committee Meeting, Japan Society for the Promotion of Science	Dec. 3, 2018	Development of Alpha Contamination Remote-operated Measurement Technology Assuming Fukushima Daiichi NPS
62	The 15th Ibaraki Area Analysis Technology Exchange Meeting	Dec. 7, 2018	Study of Application to New Material Hardness Evaluation Method by the Multiple Spectra Simultaneous Measurement of Laser-induced Breakdown Spectroscopy (LIBS), (1)Physical Properties Evaluation of Test Sample for Hardness Measurement by Using LIBS
63			Study of Application to New Material Hardness Evaluation Method by the Multiple Spectra Simultaneous Measurement of Laser-induced Breakdown Spectroscopy (LIBS), (2) Study of Application to Material Hardness Measurement by LIBS
64	Nuclear Decommissioning Technology/ Human Resource Development Forum and IRID Small Work Shop in FY2018, Tokyo Institute of Technology	Dec. 26, 2018	Current Situation of Technology Development for Fukushima Daiichi NPS by IRID
65			Status of Investigation Inside PCV in Fukushima Daiichi NPS; Development Status of Submersible-type Boat Device
66	Maintenology Academic Journal, Japan Society of Maintenology	Jan. 2019	Subsidy Project on Decommissioning and Contaminated Water Management in FY2015 Supplementary Budgets; Development of Remote-operated Investigation Device for Investigation inside PCV and Situation of inside Pedestal in Fukushima Daiichi NPS Unit-2-3.

List of Contract Research in FY2018

No.	Project Name	Category	Subject	Partner	Period
1	Development of Technology for Fuel Debris Analysis/ Characterization	Contract Research	Research on Radioactive Fine Particle Behavior on Surface of Liquid Phase and Gas Liquid Phase	The University of Tokyo	Apr. 1, 2018 ~ Jan. 31, 2019
2	Upgrading of Approach and Systems for Retrieval of Fuel Debris and Internal Structures (Development of Technology for Establishment of Criticality Control Method)	Contract Research	Verification Test of Criticality Approach Detection System including Fuel Debris to be Applied to the System	Kyoto University	Aug. 6, 2018 ~ Jan. 31, 2019
3	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 Multi-freedom Robot	Kobe University	Jun. 15, 2017 ~ Feb. 15, 2019
4		Contract Research	Investigation for the Estimation/ Control of Hydraulic Driven Manipulator Finger Load Force	Osaka University	Aug. 1, 2017 ~ Feb. 15, 2019
5	R&D for Treatment and Disposal of Solid Radioactive Waste	Contract Research	Study on the Accuracy Improvement of Analytical Evaluation Method	Central Research Institute of Electric Power Industry	Jul. 1, 2018 ~ Jan. 31, 2019
6		Contract Research	Research on Waste Management (Hydrogen Generation)	National Nuclear Laboratory (UK)	Aug. 3, 2018 ~ Feb. 28, 2019
7		Contract Research	Analysis and Evaluation of Highly Contaminated Materials generated from Fukushima Daiichi NPS Accident	Nippon Nuclear Fuel Development Co., Ltd.	Sept. 3, 2018 ~ Jan. 31, 2019
8	R&D for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods)	Contract Research	Research and Study on Evaluation Approach	Central Research Institute of Electric Power Industry	Apr. 1, 2018 ~ Feb. 28, 2019
9		Contract Research	Research and Study on the Solidification of New Material including Recycling Material		Apr. 1, 2018 ~ Feb. 28, 2019
10		Contract Research	Development of Water Containing Component Evaluation Method in New Cement Material	Taiheiyo Consultant Company, Limited	Apr. 1, 2018 ~ Feb. 28, 2019
11		Contract Research	Investigation for the Physical Property Change of Cement based Material		Apr. 1, 2018 ~ Feb. 28, 2019
12		Contract Research	Research on Simple and Prompt Analytical Method for the Treatment and Disposal of Solid Waste in Fukushima Daiichi NPS	Japan Chemical Analysis Center	Jul. 2, 2018 ~ Jan. 31, 2019

List of Major Research Facility/Equipment in FY2018

Over 1 Million Yen

No.	Project name	Details
1	Full-scale test of repair and water stoppage technology for leakage points inside PCV	Heating/ Water Supply Facility
2		Muddy Water Treatment Facility
3		Working Floor
4		Test Sample Mitigation Rail
5		Full scale Mock-up Facility
6	Development of Technology for Investigation inside PCV	B1 Survey Equipment
7		Scattering Prevention Facility for B1 Survey Equipment
8		Ancillary Facility for B1 Survey Equipment
9		Simulated Object for B1 Survey Equipment Mockup Test
10		Shielding Block Removing Device
11		Fuel Debris Shape Measuring Device
12		Element Test Device for Fuel Debris Shape Measuring Device
13		A2 Survey Equipment (Chamber and Guide Pipe included)
14		X-6 Penetration Hole Punch: 1 set
15		In-Penetration Advanced Check Device: 1 set
16		Sediment Removing Device: 1 set (Chamber included)
17		Ancillary Facility for A2 Survey Equipment: 1 set
18		In-Pedestal preliminary Confirmation Device: 1 set
19		In-PCV Structure Simulated Mockup Body: 1 set
20		A3 Survey Component Test Equipment: 1 set
21		Hatch Opening Device Associated Machine: 1 set
22		B2 Survey Equipment
23		Scattering Prevention Equipment for B2 Survey Equipment
24		Ancillary Facility for B2 Survey Equipment
25		Simulated Object for B2 Survey Equipment Mockup Test
26		Underwater Swimming Type Equipment Trial Model: 1 set
27		X-6 Penetration Hole Remote Punch: 1 set

No.	Project name	Details
28	Fuel Debris Characterization	Large Capacity Thermogravimetric Scales and Simultaneous Thermal Analyzer
29		Crystal Piezoelectric Type 4-Component Cutting Dynamometer
30		Elemental Analyzing System for SEM
31		Hydraulic Type Automatic Embedded Equipment
32		Inverted Metal Microscope
33		Carbon Coater
34		Vacuum Replacement Arc Melting Furnace
35		Fuel Debris Compression Test Device
36		Fuel Debris Sonic Speed Measurement Device
37		Metallographic Image Analyzer
38		Dynamic Micro Hardness Measurement
39		Simultaneous Thermal Analyzing System
40		Gas Piping Valve Heater
41		Sample Cutting Machine
42		Sample Abrasive Machine
43		Core Sampling Collection Unit
44		Laser Diffraction Type Gain Size Distribution Measuring Device
45		Dry Automatic Density Meter
46		Heating Furnace for Thermal Analyzer
47	Development of Technologies for Fuel Debris Characterization and Analysis	Alpha Particle Aerosol Basic Test Device
48		Particle Measuring Instrument
49	Development of Fundamental Technology for Retrieval of Fuel Debris and Internal Structure	Full Scale Test Facility
50		Full Scale Test Facility
51		1/4 Scale Test Facility
52		1/4 Scale Test Facility
53		1/4 Scale Model Test Facility
54		1/4 Scale Reactive Force Retaining Mechanism Bonding Test Sample
55		Test Facility of PRV Upper Part Water Shielding
56		Flexible Structure Arm: 1 set
57		Flexible Structure Arm Control Device
58		Facility for Mockup in PCV
59		Facility for Equipment Hatch Carry-In Test
60		1/1 Scale Hydraulic Type Reactive Force Retaining Mechanism
61		1/1 Scale Electric Reactive Force Retaining Mechanism
62		Laser Gouging Power Measurement Unit
63		Laser Gouging Head
64		Equipment for Access Equipment Element Test
65		Robot Arm
66		Access Rail
67		PCV Welding Device
68	R&D for Treatment and Disposal of Solid Radioactive Waste	Chamber for Alpha Nuclide Analysis
69		Digital Spectrometer
70		Efficiency Calculation Program for Gamma-Ray Measurement
71		Aerosol Migration Observation Instrument
72		Well-Type Ge Detector
73		Core Data Collection Unit
74		Zeolite Sample Collection and Test Equipment
75		Small Core Sample Collection Test Model
76		Portable X-ray Fluorescence Spectrometers
77	R&D for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods)	Evaluation System Software
78		Material Cross-Section Processing Machine
79		Solidified Material Setting Testing Machine
80		Alpha-ray Telemeter-1; (Equipment set packaging detector, camera and temperature adjustment mechanism in a housing: 1 set)
81		Alpha-ray Telemeter-2; (Combination of detector and circuit: Used for the comparison to above Alpha-ray Telemeter-1, for backup)
82		Dust Testing Device
83	Test and Research for the Stable Operation of Advanced Liquid Processing System and Slurry Stabilizing Facility	Full Scale Filter Press
84		Tank Storage Tent for Slurry Preparation Tank Facility
85		Slurry Preparation Tank Facility
86		Addition of Full-Scale Filter Press, Dehydrator Pump and Cleaning Discharge Pipe
87		Filter Cloth Replacement Platform for Full-Scale Filter Press Testing Device
88		Crushing and Transfer Device

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