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for Nuclear Decommissioning

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Annual Research Report 2019

IRID
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Greeting

The Mid-and-Long-Term Roadmap toward the Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS) of Tokyo Electric Power Company (TEPCO) Holdings, Inc. was revised by the government based on the updating of Technical Strategic Plan for 2019 issued by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) in December 2019.

The Mid-and-Long-Term Roadmap indicates that fuel debris shall be firstly retrieved in Unit 2 to optimize the entire decommissioning safely, assuredly and speedy, which includes avoiding interference with spent fuel removal. The Roadmap also suggests the fuel debris retrieval methods including the partial submersion and the side-access methods by using a robot arm that has been currently developed to grip and suck fuel debris. A trial retrieval will start in 2021, and then the scale of retrieval will gradually expand.

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

As a result, the development of investigation technology for inside the primary containment vessel (PCV) and detection technology for identifying the location of fuel debris by using cosmic rays has revealed the conditions of inside the reactor and PCV and besides, technical issues to be overcome are being clarified.

The Annual Research Report 2019 has been published to introduce the achievements of R&D projects (11 subsidized projects) undertaken by IRID in fiscal year 2019. I would appreciate if this report would help you to better understand the IRID's R&D results.

It has been nine years since the Fukushima Daiichi NPS accident occurred associated with the Great East Japan Earthquake. The situation has been largely improved compared to just after the accident; however, the decommissioning is about to enter a crucial phase. IRID is committed to advancing R&D for the steady and speedy nuclear decommissioning to fulfill our responsibilities.

Thank you for your continuous support and suggestion.

March 2020

Hideo Ishibashi

President of International Research Institute for Nuclear Decommissioning

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- R&D for Treatment and Disposal of Solid Radioactive Wastes

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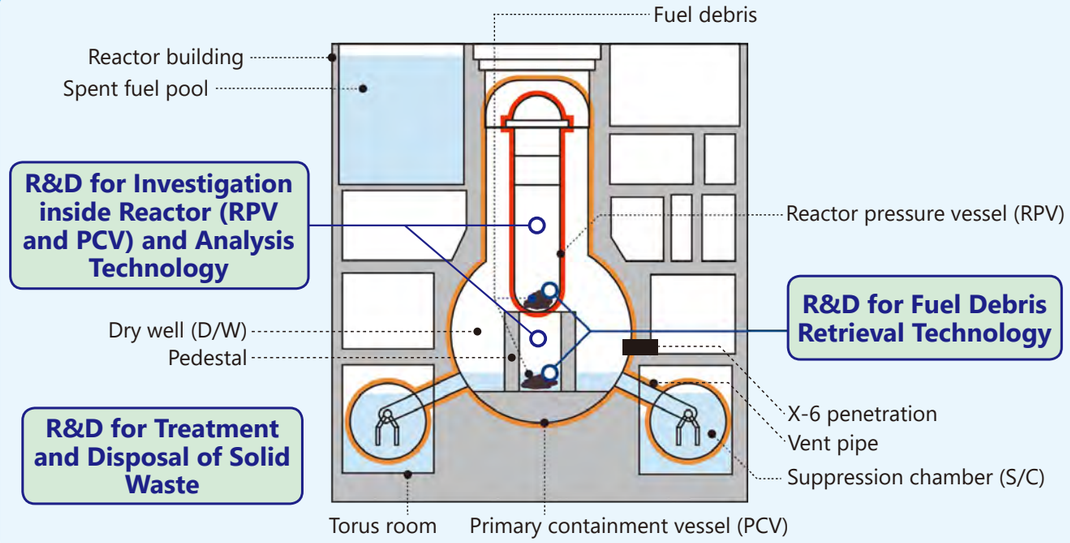
Overview of Reactor Building and IRID's R&D Projects



R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Detailed Investigation inside PCV (Onsite Demonstration of Technology for Detailed Investigation through X-6 Penetration)

Background

As a result of the investigation inside the primary containment vessel (PCV) conducted in Unit 2 of Fukushima Daiichi Nuclear Power Station, the result confirmed that the deposits accumulated at the bottom of the pedestal seemed to be fuel debris. Additionally, part of the fuel assemblies has fallen at the pedestal bottom, and the deposits around the fallen area were also assumed to be fuel debris.

Purpose

This project aims at validating investigation technologies using access and investigation device passing through X-6 penetration opening into the inside of the PCV which has a broader dimension than the previous investigation opening and also acquiring the detailed information on the situation of the pedestal bottom to clarify a fuel debris retrieval method at the site.

Major approach and results

1 Investigation and development plans

In consideration of images obtained from the previous investigation for inside PCV in Unit 2, the detailed procedures of the access and investigation device and the scope of the investigation were discussed. From the aspect of the feasibility of the investigation, the new manufacture of a shorter wand (the tip of the access and investigation device) was planned for response to risks that would interfere with internal structures of PCV.

2 Access and investigation device partly manufactured, overall assembly and verification test in factory

Part of the access and investigation device was made, and the entire components, including parts manufactured in the last fiscal year, were assembled (Fig.1: Assembly of access and investigation device). After the overall assembly, an arm of the access and investigation device was tuned (to adjust the motion of each joint). Then the functions of the access and investigation device were verified by test in the factory.

3 Onsite demonstrations of access and investigation device, and investigation technologies

(1) Mock-up test considering the site conditions

The test conditions and procedures of a mock-up test for the access and investigation device were discussed to specify the test requirements. Additionally, the manufacture of a test facility that will be required for a mock-up test was completed (Figure 2: Assembly of the mock-up test facility).

(2) Test of establishing the access route into PCV and operation training at the site

Connecting pipes with isolation valves (X-6 penetration connecting structure) that will connect with X-6 penetration by remote operation, and an isolation room was improved based on improvements suggested in tests of fiscal year 2018. Moreover, a combination test of the X-6 penetration connecting structure and the isolation room was conducted to confirm the feasibility of the technology, including the improvement of the device.

A deposit removal device for the X-6 penetration (a deposit removal device) was manufactured. A mock-up test for the device was conducted to confirm the feasibility of the technology, including the improvement of the device (Figure 3: Deposit removal device and mock-up test).

Additionally, a verification test for implementation and removal of devices were completed, which is related to establishing the access route, including the X-6 penetration connecting structure and the deposit removal device.

(3) Onsite demonstration

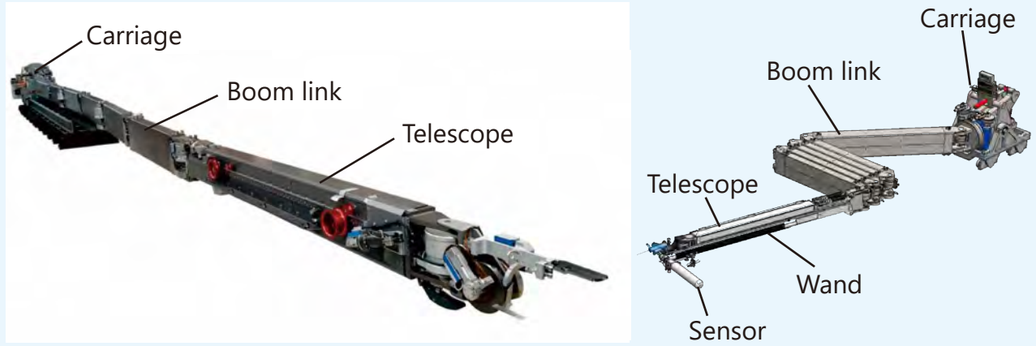
A neutron detecting system was manufactured, which can estimate a range and distribution of nuclear fuel substances during the onsite demonstration, and a verification test for the system was completed.

Towards the site demonstration, the layout of devices and equipment for the establishment of the access route was planned considering the environmental conditions at the site (radiation rates and spatial limitations, etc.).

Future development

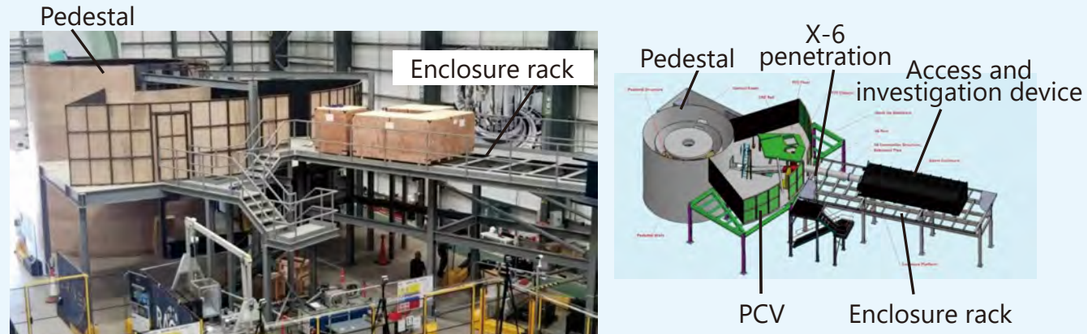
A mock-up test and operation training of the access and investigation device will be performed. Another operation training for equipment will be provided for establishing the access route.

After completing the operation training of each device, the device will be installed in on the PCV of Unit 2 and demonstrated at the site (for onsite investigation).



Concept of the arm structure for investigation

Fig.1: Assembly of access and investigation device



Concept of the mock-up test facility

Fig.2: Assembly of the mock-up test facility

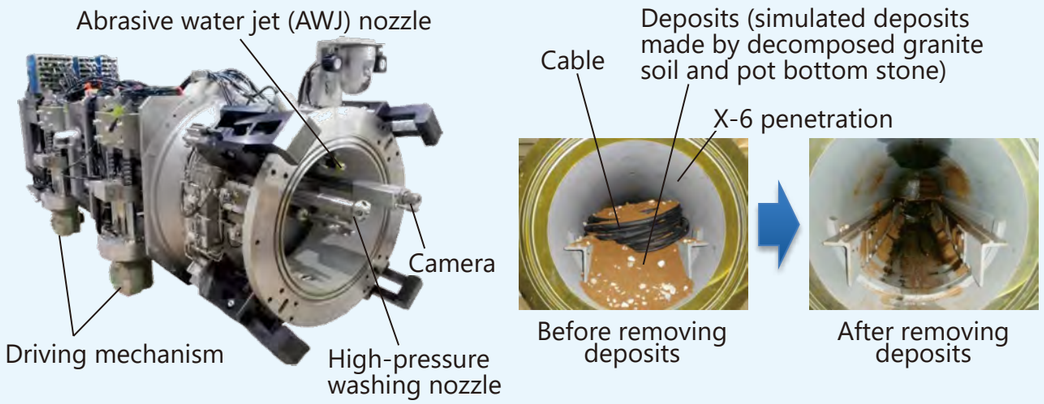


Fig.3: Deposit removal device and mock-up test

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Detailed Investigation inside PCV (Onsite Demonstration of Technology for Detailed Investigation Considering Deposit Measures)

Background

Fuel debris has existed under deposits accumulated inside and outside of the pedestal in Unit 1 of Fukushima Daiichi Nuclear Power Station. Therefore, the information on the deposits and inside the pedestal is necessary to retrieve fuel debris. Furthermore, it is also essential to enlarge access and investigation devices and improve appropriate investigation technologies to collect more accurate information.

Purpose

In Unit 1, it will be necessary to collect the deposits and remove fallen objects while retrieving fuel debris. For that reason, the purpose of the project is to understand the distribution of the deposits and fuel debris, the conditions of the reactor internals, and inside conditions of the primary containment vessel (PCV) by inserting a submersible type investigation device with measuring technology through a larger-dimension penetration.

Major approach and results

1 Development and investigation plans

A detailed plan for a mock-up test and operation training was discussed to accomplish a thorough investigation of inside PCV, in which six kinds of submersible type investigation devices will be used.

2 Onsite demonstration of access and investigation devices, and investigation technology

(1) Establishment of access routes in PCV

Isolation valves were connected with three points of the airlock outer door (*1), which will be a new boundary. After joining, hole opening operations of the outer door were performed while isolating from inside PCV (refer to Fig.1). A camera was inserted through those opening holes and confirmed the existence of deposits and accumulated water in the airlock (refer to Fig.2). As a result, it was confirmed that the deposits could be easily removed and were estimated to be peeled-off coating pieces due to low-level contamination, and there is no impact on future work. Assuming increasing water levels in the airlock during hole opening operations of the inner door by using an abrasive water jet (AWJ), a hole opening operation in the lower side of the inner door was performed after reviewing a plan of an opening operation to drain water in PCV. It was confirmed that dust generation in PCV increased without reason besides the contamination of the cutting parts. Therefore, the source of dust generated by a trial cutting for a short time was surveyed, and dust behaviors during cutting were confirmed. While expanding cutting ranges in stages to acquire dust data, one-hole opening operation in three parts of the inner door was performed. Moreover, a cleaning jig for PCV internals was developed for the future cutting operation, and cleaning and watering effects were confirmed by conducting a mock-up test to reflect the future cutting plan.

(2) Detailed investigation inside PCV

A full-scale mock-up test facility was manufactured, and then a mock-up test was conducted using six kinds of submersible type investigation devices. Those tests were conducted to confirm the feasibility of various measurements and work procedures. Such as the operability of the installation device in narrow spaces (refer to Fig.3), installing and collecting the investigation device in/out of the PCV basement floor, installation of a guide ring that can guide a cable during moving underwater on the basement floor, and a wide range of moving on the basement floor and entering inside the pedestal.

The surface conditions of a jet deflector (*2) that would affect the installation of a guide ring (refer to Fig.4) and decision criteria of applicability were considered. Responding to emergencies was also confirmed, assuming that a guide ring could not be installed and disconnected after the installation.

(*1) The airlock is a door to go in/out of PCV. The structure of the door is made by double doors (outer door and inner door) to maintain airtightness and to alternatively open/close.
(*2) A jet deflector is installed to protect vent pipes against the jet force in case of the rupture of the primary piping in PCV.

Future development

Onsite demonstration of establishing the access route will restart; Penetration of the inner door, cutting the interferences in PCV, and a guide pipe insertion will start to prepare for investigation using the submersible type investigation device.

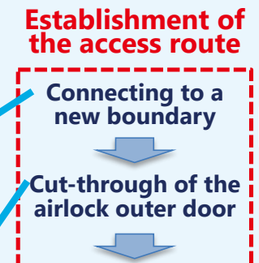


Fig.1: Established the access route

Fig.2: Deposits in the airlock room and accumulated water

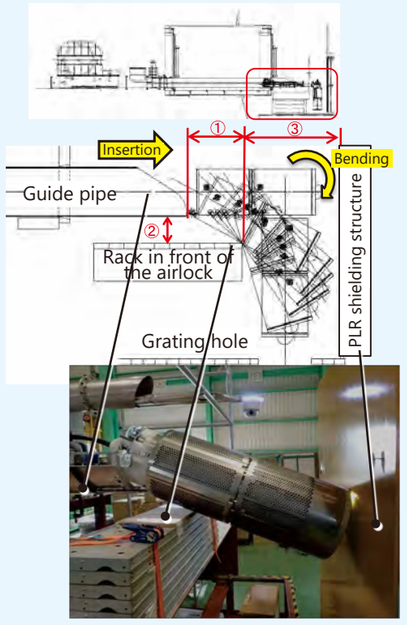


Fig.3: Bending action of installation device for submersible type investigation robot

Possibility of an actual implementation of the guide ring		Installation acceptable		Installation unacceptable
Assumed events that occur in the guide ring	Surface conditions (photos taken by a digital camera) / Measurement directions	Not-rusted steel sheet (anti-rust)	Rusting (no-bulge)	Rusting (bulging)
Falling	Adsorption force (vertical direction)	○ (More than 20Kgf)	○ (More than 20Kgf)	△ (12.8Kgf)
Sliding	Frictional force (horizontal direction)	○ (More than 20Kgf)	○ (More than 20Kgf)	× (6.8Kgf)
Rotation	Frictional force (rotational direction)	○ (8.3Kgf)	○ (8.9Kgf)	× (3.6Kgf)

Fig.4: Evaluation of installation possibility depending on the conditions of guide ring connecting parts

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Investigation inside RPV

Background

Prior information on the location, shapes, and conditions of the fuel debris inside reactor pressure vessel (RPV) and reactor internals are needed to retrieve. However, it is difficult to collect the data by directly accessing RPV because of the complicated internal structure and high radiation dose in the RPV.

Purpose

The information acquisition is required to clarify the uncertainty under current circumstances to proceed with further decommissioning including fuel debris retrieval safely and effectively. The project's purpose is to define the investigation target based on the organized information and develop applicable technology required for investigation by using a method for accessing from the top or side of RPV.

Major approach and results

1 Investigation and development plans

Organization of the process, and work steps that are currently planned before and after investigation inside RPV and the site work were reviewed. After that, necessary tasks and study items were clarified before starting top-access and side-access investigations such as work on the operation floor and the structure installation planning for fuel debris retrieval after removing fuel from the spent fuel pool.

2 Planning of implementation method

The safety design process for work steps during the investigation was established, and the safety requirements were studied. An exposure evaluation model was created to examine the safety requirements by using aerodynamic analysis for work steps that will cause risks to confinement of gas-phase parts. The environmental impacts on radioactive dust during processing the structures were evaluated to consider whether responding to radioactive dust is required or not. Safety functions in normal states are to confine radioactive materials in gas-phase by the primary containment vessel (PCV) that functions as a primary boundary. Assuming abnormal events and loss of the safety functions, plans were created to detect and respond to unusual circumstances, and implementation of the necessary system was considered.

Exposure assessment was performed by assuming the loss of boundary functions caused by earthquake considering the impact of external events. The evaluation confirmed that the functional requirements of investigation systems have no problem.

3 Study on supporting systems for investigation

Supporting systems for investigation will be necessary for gas management and nitrogen supply systems to maintain negative pressure in PCV, dust monitoring, criticality control systems, and water treatment systems from the aspect of the safety and investigation. The requirements of specifications were clarified after reviews of redundant gas management systems, installation of isolation valves for a toolbox and a guide pipe, dust monitoring for work cells and the reactor well, and detection and responding to abnormal events.

4 Development of access and investigation device

(1) Development of investigation device for the top access method (Figure 1)

Element tests were conducted to confirm the feasibility of device specifications reflected from proposed measures for issues identified in previous years (confirmation tests of opening small-diameter holes in PCV/RPV heads, removing heat-insulating materials for RPV, workability, and accessibility for processing reactor internals, accessibility of investigation device and evaluation test of image acquisition). These results were reflected in the specifications of the device.

(2) Development of investigation device for the side access method (Figure 2)

Element tests were conducted (cutting ability test using hybrid water jet tools, sealing test, analysis for collecting/draining treated water and connecting part strength test), and the systems were designed based on the results of these tests. Additionally, the previous phase's technical issues were discussed to compile the system specifications (ex. Weight limitation of the systems associated with the strength of the air-conditioning building rooftop where the installation of the system is planned).

Future development

The information such as progression of other work, preliminary site investigation, environmental information and plan for fuel debris retrieval, will be summarized to accelerate the detailed design of applicable systems for the site investigation and thereby, the investigation planning and the system specifications depending on the site conditions will be reflected and reviewed. To improve applicability of the top-access investigation method, a new opening operation for establishing the access route that would generate less secondary waste will be considered.

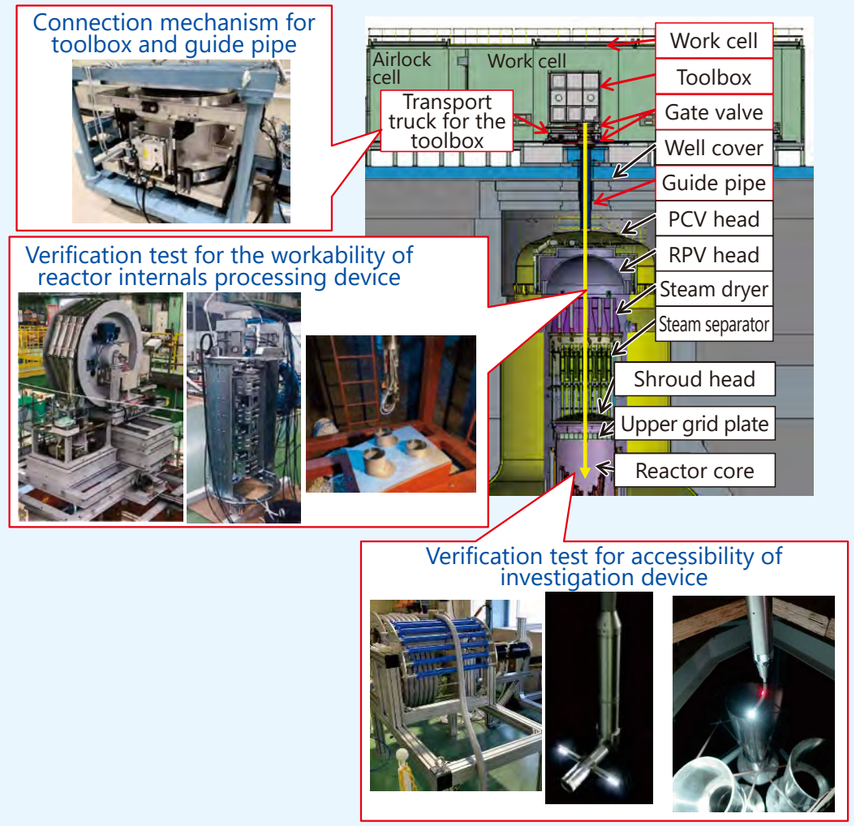


Fig.1: Overview of top-access investigation method

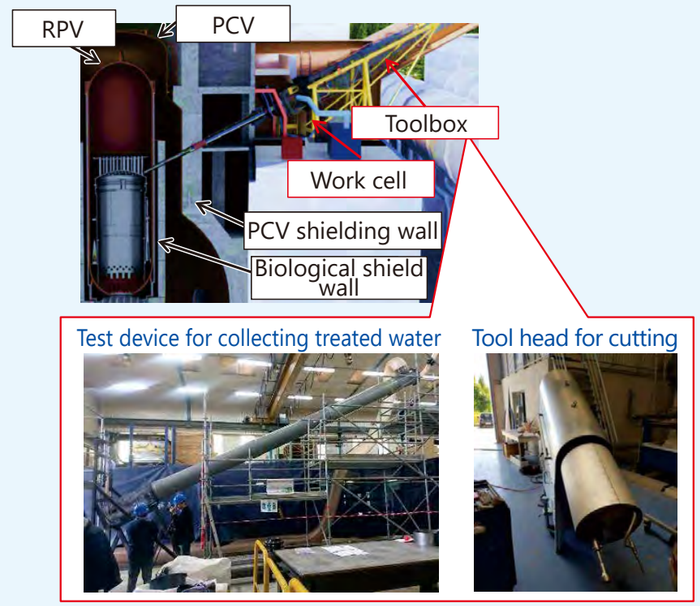


Fig.2: Overview of the side-access investigation method

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Increasing the Scale of Fuel Debris Retrieval in Stages

Background

Appropriate safety management and facility design for fuel debris retrieval are required. Therefore, it is essential to collect fuel debris samples from the lower part of the primary containment vessel (PCV) and inside the reactor pressure vessel (RPV) and to understand their components and mechanical properties. In addition, methods of transferring retrieved fuel debris into an analysis facility are under study.

Purpose

This project aims at planning a scenario of retrieving small amount of fuel debris based on results of detailed investigation of inside PCV, and development of access and investigation devices for the detailed research inside PCV, while studying design and prototype of a retrieval device, safety management and facility to transfer fuel debris, in order to acquire the information of fuel debris safely and promptly.

Major approach and results

1 Development plan of retrieval technology for increasing the scale of fuel debris in stages and retrieval plans

(1) Development plans and update of technologies for retrieving small amount of fuel debris

During a period until the starting combination test of the access and investigation devices for detailed investigation of inside PCV, test plans were developed for fuel debris collecting device manufactured in the last fiscal year that will be applied to the first implementing unit: Performance test, repeated operation test, and manipulator handling test.

(2) Development plans and update of technology for fuel debris retrieval devices and systems

An advanced remote operated manipulator that can manipulate fuel debris in the enclosure will be required. Therefore, developments of support tools and operational procedures were added to the development plan under the conditions of limited spaces and the range of a camera view. On the other hand, an access device for fuel debris retrieval will be manufactured after fiscal year (FY) 2020 to reflect the results of design verifications of the access and investigation device for detailed investigation of inside PCV.

(3) Plans and update of the entire scenario

A scenario of early removal was discussed to remove debris attached to the surface of the pedestal structures and pebble-like debris scattered at the pedestal bottom. Moreover, looking toward increasing the scale of fuel debris retrieval, a scenario of monitoring neutron flux during cutting debris in a cylindrical form was updated.

2 Development of retrieval devices and systems for increasing the scale of fuel debris in PCV

(1) Development of small-amount fuel debris retrieval device (Figure 1)

The collection capability of about 0.3g was confirmed by laying fine lead beads on the debris simulated concavo-convex plate. Additionally, the improvement plan was discussed to easily collect fuel debris by a manipulator.

(2) Development of fuel debris retrieval devices and systems (Figure 2)

The following devices and systems were developed based on the results of the conceptual study in the FY 2018.

① Access device for retrieving fuel debris (the arm and the enclosure, etc.)
The motor power was increased to improve payload (maximum load), and the link structure was reviewed. Additionally, sealing parts of the enclosure that are to protect leakage of radioactive materials were designed in duplicating to improve airtightness.

② Access route building device for fuel debris (X-6 penetration connection structure, etc.)
A double door mechanism was adopted for the connection structure with the enclosure, and airtightness and reliability of connection/ separation were confirmed at its element test.

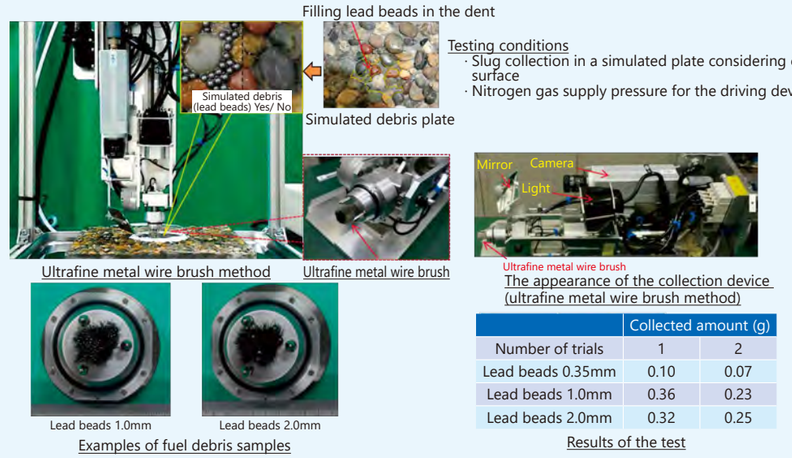
③ Fuel debris cutting and collection device
Two types of gripping device specialized in pebble-like and sand-like debris and the other two kinds of cutting and collection device to collect powder and cylinder core from debris block were manufactured experimentally, and collection performance was confirmed using simulated debris.

④ Neutron monitoring system (for monitoring criticality approach)
Two kinds of sic semiconductor type compact neutron monitors with high sensitivity were reviewed, and the equipment that can accomplish the target sensitivity for critical monitoring of 1cps/nv or higher was designed.

⑤ Remote operated transport track for fuel debris storage container
A five-ton airtight container with radiation shield was designed, and basic specifications were concretized. Additionally, running performance and connection functions of the container were understood by element tests, and a container transport system which has an ability of remote connection to the enclosure was developed.

Future development

- As a result of the basic design of retrieval devices and systems in this fiscal year that would lead to retrieval technologies for increasing the scale of fuel debris in stages , it is necessary to ensure the possibility and reliability of remote operation. Therefore, manufacturing design and improvement of a prototype will be promoted while conducting element tests.
- Additionally, in cooperation with the Project for Development of Technologies for Detailed Investigation inside PCV, this project will aim at ensuring fuel debris retrieval by using obtained knowledge and experience for retrieval devices and systems.



	Collected amount (g)	
Number of trials	1	2
Lead beads 0.35mm	0.10	0.07
Lead beads 1.0mm	0.36	0.23
Lead beads 2.0mm	0.32	0.25

Fig.1: Element test of small-amount fuel debris collection device (ultrafine metal wire brush method)

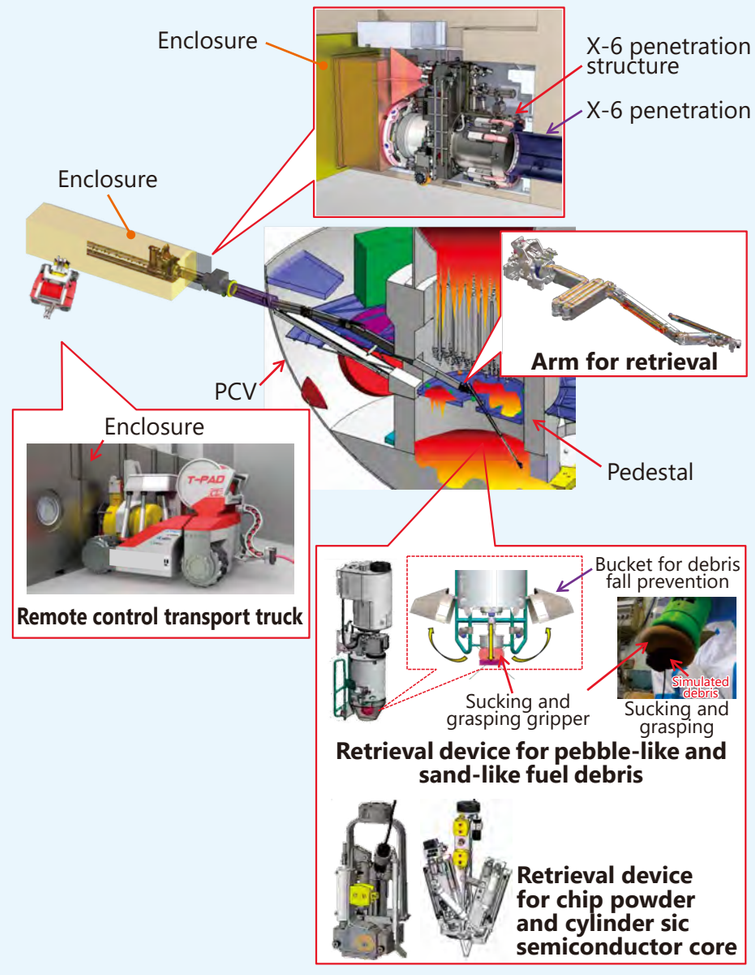


Fig.2: Concept of fuel debris retrieval devices and systems for PCV

R&D for Preparation of Fuel Debris Retrieval

Development of Analysis and Estimation Technologies for Fuel Debris Characterization

Background

The decommissioning of Fukushima Daiichi Nuclear Power Station (NPS) requires safety and steady implementation to retrieve, contain, transfer, and store fuel debris. Therefore, it is necessary to fully understand the fuel debris properties for decommissioning work. Additionally, the information acquisition of behaviors of radioactive particles that will generate during retrieving fuel debris is also needed.

Purpose

This project aims to estimate fuel debris properties based on the analysis results of deposit samples collected by investigation inside the primary containment vessel (PCV) and the conditions in the reactor at the time of Fukushima Daiichi NPS accident. Furthermore, the purpose of the project is to provide behaviors of radioactive particles during retrieving fuel debris by the test using uranium and plutonium for project teams related to the decommissioning and the operator.

Major approach and results

1 Development of technology required for analysis of fuel debris properties

Various samples were transferred and analyzed. These samples were included smear samples collected from a jig that removed deposits of X-2 penetration in Unit 1, and deposits collected by investigation inside the reactor in Fukushima Daiichi NPS (Fig.1). Additionally, the analysis of residue components generated by nitric acid dissolution of deposit samples before fiscal year (FY) 2018 was conducted. As for efficient analysis, discussion and case studies were made with the Nuclear Damage Compensation and Decommissioning Facilitation (NDF) and the decommissioning operator on analysis sequence for samples to be collected during duel debris retrieval in future. Then, information on specific analysis items and preparation flows were organized.

A Japan-expert meeting and a decommissioning-operator task force with Japan Atomic Energy Agency (JAEA) were organized and proceeded with the upgrading of fuel debris property list and risk study of fuel debris retrieval based on analysis results of deposit samples and knowledge obtained from previous accidents cases.

According to characteristics of accident progression for each area of unit 1-3, the process of fuel debris generation was studied to establish a hypothesis about fuel debris and other damaged structures in each area, and properties of the compositions and other deposits. After that, the outline of an advanced fuel debris property list was summarized.

In the above Japan-expert meeting, analysis items of samples that will be obtained during fuel debris retrieval and knowledge gathered from international projects were reviewed.

2 Development of estimation technology for particle behaviors of fuel debris

A large-scale test apparatus where uranium can be used was installed to investigate behaviors of radioactive particles that would generate associated with processing fuel debris in cooperation with France, assuming cutting methods including mechanical and laser heat. In this test apparatus, sample products produced by a large-scale Molten Core Concrete Interaction (MCCI) test in France in 2017 were utilized. Additionally, simulated fuel debris that contains uranium adding simulated fission products (FP) were produced to newly obtain a wide range of data on fuel debris with various compositions.

To confirm similarities and differences of behaviors between plutonium and uranium for generation behaviors of radioactive particles, a preliminary test by using plutonium was conducted in a small-scale test apparatus where it was arranged for light-concentrating heating test and mechanical cutting test by using simulated fuel debris containing plutonium and uranium (Fig.2).

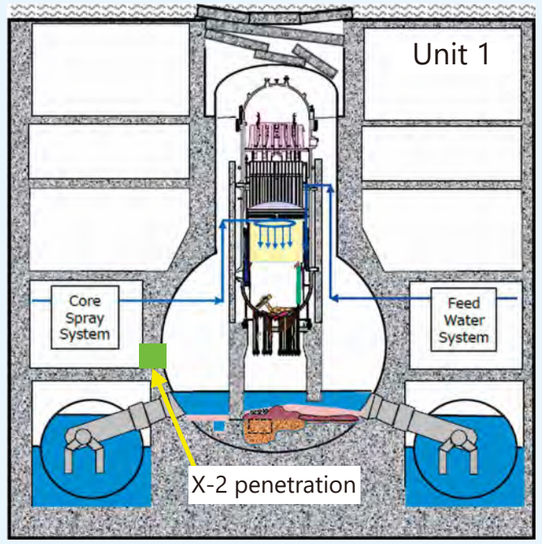
Moreover, airborne radioactive particle cases in Japan's nuclear facilities were investigated, and behaviors of particles generated by dismantling nuclear facilities were reviewed.

On the other hand, the transfer rates of generated radioactive particles that transfer from the liquid phase to the gas phase were measured by a test using simulated materials.

Future development

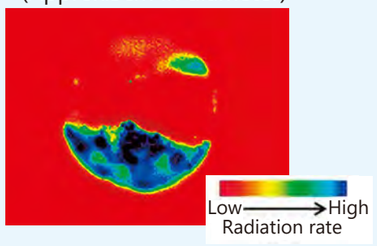
Following activities in FY 2019, analysis of the deposit samples will be performed, and besides, the process of fuel debris generation and retrieval risks for each unit will be continuously studied. In addition to this knowledge, estimation of fuel debris properties will be improved to utilize for practical decommissioning while exchanging opinions with decommissioning operators.

Data on generation behaviors of radioactive particles will be obtained and estimated by using simulated fuel debris and test apparatus developed in FY 2019. Furthermore, migration behaviors of radioactive particles will be continuously tested using simulated materials and estimated migration behaviors in the air-liquid interface and liquid phase, as well as migration behaviors of particles in the liquid phase by using computational fluid dynamics simulation models.



Sampling points (X-2 penetration of Unit 1)

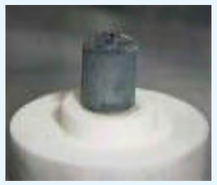
Appearance of sample
(A smeared sample on the jig for removing deposits from X-2 penetration of Unit 1)
(Approx.5cm in diameter)



Result of measurement using an imaging plate

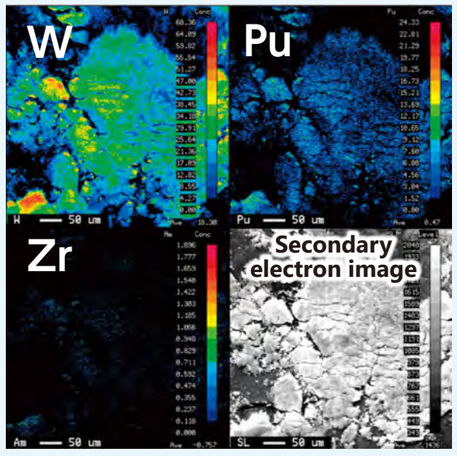
Fig.1: Example of samples including transported deposits (Sampling points, the appearance of sample and results of measurement using an imaging plate)

Deposits of jig were rubbed with a smear filter paper to collect samples. The analysis results using the imaging plate measurement show that sediments on the smear filter paper were contaminated with high radioactivity.



Produced sample of (Pu, Zr) O_{2-x}

Solidification of fumes generated when condensing heats for (Pu, Zr.) O_{2-x} samples (white-colored deposits indicated by a red sphere)
A photo was taken of a mirror image as a photographing place is located on the opposite side of the operation screen in a globe box.



Results of surface analysis by using EPMA* of fume solidification (partly)
*EPMA: Electron Probe Micro Analyzer

Fig.2: Analysis results of solidification of O_{2-x} in fumes by condensing heats (Pu, Zr)

Dioxide-solid solution of plutonium and zirconium was adjusted to generate fumes by condensing heats. After collecting the deposits on the surface of a bell jar, an element mapping was carried out using EPMA (Tungsten is an element mixed with materials in a crucible fume when adjusting samples). Plutonium was detected more than zirconium, and therefore plutonium was found out to form fumes quickly.

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Construction of Water Circulation Systems in PCV

Background

For improvement of the environment to ensure the safety and risk reductions during fuel debris retrieval work towards the decommissioning of Fukushima Daiichi Nuclear Power Station, it is necessary to install the water intake structure for the primary containment vessel (PCV) water circulation system after reflecting the results of the study by the project of Advancement of Retrieval Method and System of Fuel Debris and Internal Structures.

Purpose

In the water circulation system, technical issues for water intake are confinement functions of gas/liquid phases, long-term integrity and remote operability under the high-radiation environment on site during installation and operation. This project aims at developing applicable technologies for accessing and connecting inside PCV to take water by the water circulation system.

Major approach and results

1 Review of technical specifications for the advancement of the water circulation system in PCV, and operation and development plans

(1) Study of the water circulation system and technologies by using the dry well (D/W)

- In order to study technologies for the establishment of the access route to take water from the D/W and the suppression chamber (S/C), the results of the various investigation conducted until now were organized for the site situation inside/outside of PCV (environmental radiation rates of 1st floor of the reactor building, estimation results of the reactor internals, deposits accumulated in PCV and water levels in PCV of each unit including a current water level, the levels during construction and operation of the water circulation system).
- Technical specifications for establishment of the access route in PCV (standard specifications with the D/W and the S/C) and design specifications for the D/W water intake were reviewed based on the results of the study on the water circulation system developed by the project of Advancement of Retrieval Method and System (Fig.1). Considering the site environments in each unit, a candidate penetration that will be a D/W water intake port was clarified.
- Existing technologies for the establishment of the access route to inside/outside of PCV were examined. As a result, existing access methods for PCV that the other project used during the site verification test were applicable. Therefore, issues for the route establishment to water intake points (pump pits, etc.) in PCV (Fig.2) were clarified: ① A suspension method of lowering pumps (piping) to the basement floor by a remote operation and ② A method for remote operated connection and replacement of piping (hose).

(2) Study of the water circulation system and technology by using the suppression chamber (S/C)

- Design specifications for the S/C water intake were reviewed based on the results of the current study in (1). Additionally, the S/C water intake position was clarified, taking into consideration of the site environment in each unit.
- The functional requirements of the S/C water intake were developed based on the study's result by the project of Advancement of Method and System. To satisfy those requirements, the S/C water intake structure, discussions were held about a work plan of the construction and a maintenance plan.
- According to the construction and maintenance plans for the S/C water intake, existing technologies were examined to identify issues of applicable devices during construction and maintenance, which should be developed for this project.

2 Development and verification of fundamental technologies for accessing and connecting PCV internals

(1) Development and verification of fundamental technologies required for accessing and connecting the D/W internals

- By discussing a solution to issues identified in the above 1 (1), a test plan was developed to verify the feasibility of the solution.
- According to the test plan, element tests were performed for the development of remote-operated piping (hose) in D/W (Fig.3) and hose loading, installation into the bottom of D/W (Fig.4) and collection of waste piping (hose) from the bottom of D/W. The test results provided a suggestion of the feasibility. At the same time, engineering tasks were identified, which should be solved in the future engineering stages, and the study of the measures started.

(2) Development and verification of fundamental technologies required for accessing and connecting the S/C internals

- Development items of this project were clarified in the above 1 (2); The establishment of S/C water intake (Fig.5), test planning of an applicable device during maintenance, and test productions of major devices (a positioning device (Fig.6), automatic welding device for extension pipes on the S/C (Fig.7), a welding bead dressing device and a tentative sealing device for air leakage test).
- Element tests of each device and unit function tests of the prototype were conducted, and the results of those tests confirmed that the devices had prescribed functions (Fig.8). Moreover, issues that should be solved in the future engineering stages were identified as a response to the problems.
- The results of the tests reflected into the full-scale test procedures for the establishment of S/C water intake developed by the other project, Development of Technology for Water Circulation System in PCV (a full-scale test).

Future development

The engineering study of this project continues after reviewing identified issues and results of verification tests including element tests or unit function tests of suspending a pump (piping) by remote-operation required for the establishment of the D/W water intake, a pipe connection method, a pipe replacement method during maintenance, and connection and maintenance methods of extension pipes by remote-operation required for the establishment of the S/C water intake.

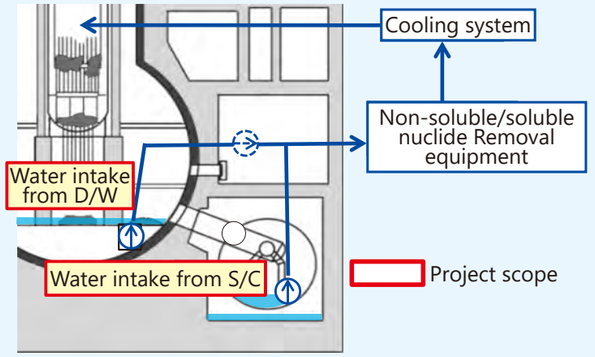


Fig.1: Water circulation system during fuel debris retrieval

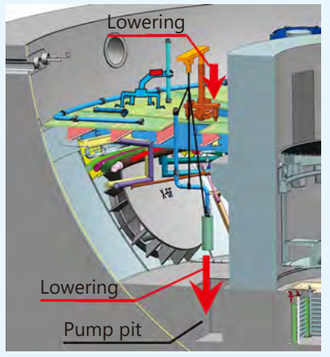


Fig.2: Image of establishing D/W water intake line

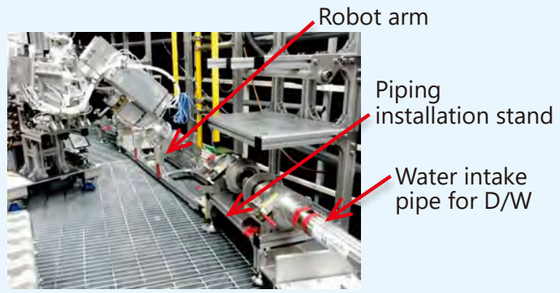


Fig.3: Connection of water intake pipe for D/W

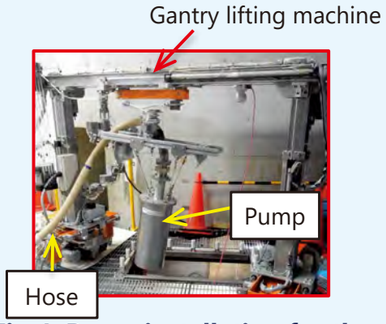


Fig.4: Pump installation for the D/W basement floor

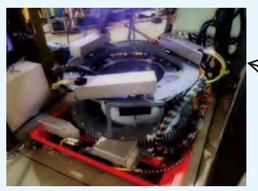


Fig.6: Positioning device for extension pipe

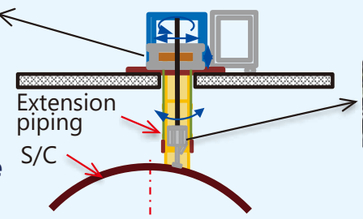


Fig.5: S/C water intake structure (extension pipe)

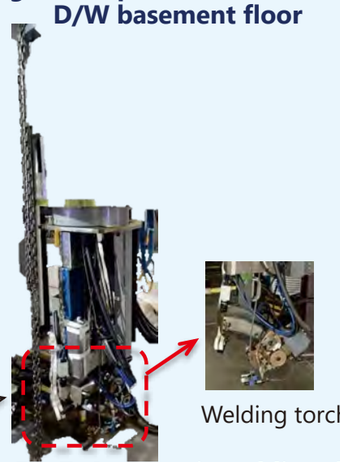


Fig.7: Automatic welding device for extension pipe on S/C

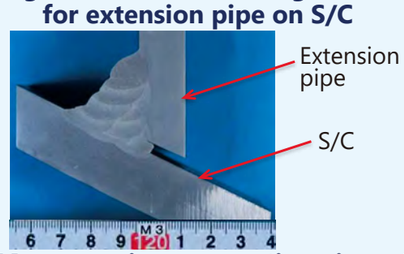


Fig.8: Macroscopic cross-section view of welding joint (three layers eight passes)

R&D for Preparation of Fuel Debris Retrieval

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

Background

To improve the environment of Fukushima Daiichi Nuclear Power Station for ensuring the safety and risk reductions during fuel debris retrieval work, development of element technology that is to establish the water intake structure for water circulation in primary containment vessel (PCV) by remote operation has been promoted under the project of Development of Technology for Water Circulation System (Water Circulation Project). Based on the results of these element tests, a verification test in actual-scale was conducted.

Purpose

This project aims to conduct a verification test in actual-scale for establishing the water intake structure in a suppression chamber (S/C) developed by the Water Circulation Project. Furthermore, the actual-scale test is to confirm the effectiveness of a liquid-phase boundary, which was constructed by placing repairing materials on the inner circumference side of the torus room in combination with the reinforcement of the S/C support column and the S/C structure.

Major approach and results

A full-scale verification test of technologies for accessing and connecting PCV (verification of the water circulation system and technology using the S/C)

(1) Confirmation of remote operation workability in full-scale test and issue identification

- A large-scale test facility of the S/C vent pipe that was manufactured under the project of Development of Repair Technology for Water Leakage in PCV was used for a verification test. A test plan was developed to verify the feasibility of remote operation procedures (positioning of the extension pipe-extension pipe-welding joint of S/C) by using a prototype of the extension pipe-S/C welding joint device (Fig. 1) designed as element technology of the S/C water intake structure under the Water Circulation System project.
- According to the test plan, a full-scale test was conducted by a remote operation (Fig. 2, 3, and 4). The test results confirmed the feasibility of establishing the S/C water intake structure by a remote operation. Furthermore, engineering issues that should be solved in the future engineering stage were identified to respond to the issues.

(2) Ensuring of confinement functions toward actual construction, the study of exposure reduction measures for workers and issue identification

- Conceptual studies of the boundary formation and procedures for maintenance of tentative containers that will be used for the establishment of S/C water intake were performed to ensure the confinement functions of radioactive materials (gas) in S/C for construction work at the site. Additionally, work procedures that would contribute to radiation exposure to workers were analyzed based on the measurement results of work hours during a full-scale test. Approaches to the reduction of exposure and issues were identified.

(3) Integrity confirmation after welding work

- The connecting parts were welded according to the test plan described in (1). Non-destructive/destructive tests confirmed the quality of the welding parts.

(4) Validation of the water circulation system boundary

- In order to control water leaked from the drywell to inner periphery of the S/C in torus room of Unit 1, a full-scale test facility was used to confirm the validity of liquid-phase boundary that was established by placing repair mortars, where is located in the Naraha Center for Remote Control Technology Development, the Japan Atomic Energy Agency (JAEA). The full-scale test facility was placed mortars at the bottom of the S/C structures and a torus room, which was manufactured under the project of Full-scale Test of Repair Technology for Leakage Sections in PCV (Fig.7 and 8). In addition, prior to this test, a basic test of the repair material was conducted. It was confirmed that the space inside the S/C of the torus room can be used as a boundary for contaminated water and powdery fuel debris (Fig.5 and 6). On the other hand, the full-scale facility was dismantled at the final stage of the test, and then the condition of capturing simulated powdery debris was investigated (Fig.9).

Future development

- It is expected that engineering study for establishment of the S/C water intake structure will be promoted toward practical use based on the results obtained from the verification test of remote operation (positioning of extension pipes – welding work for extension pipes and the S/C connection part) and identified issues for establishment of the S/C water intake by using a prototype developed by the Water Circulation Project.
- The liquid-phase boundary will be established by placing repair materials adding to mortars in between the S/C structure and the bottom of the torus room. It is expected that the results of the boundary validity test, using the full-scale test facility, and basic tests of repair materials obtained from this project will be effectively utilized when considering future engineering and the workability.

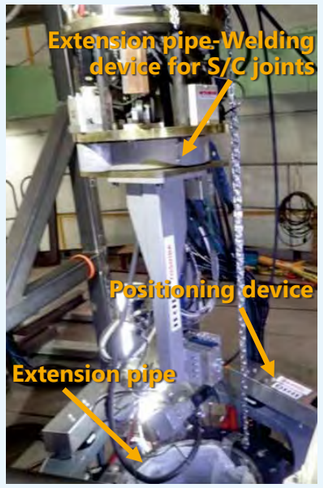


Fig. 1: Injection into extension pipe-welding device for S/C joints

Fig.2: Remote operation for extension pipe-welding device for S/C joints

Fig.3: Remote operation for positioning device

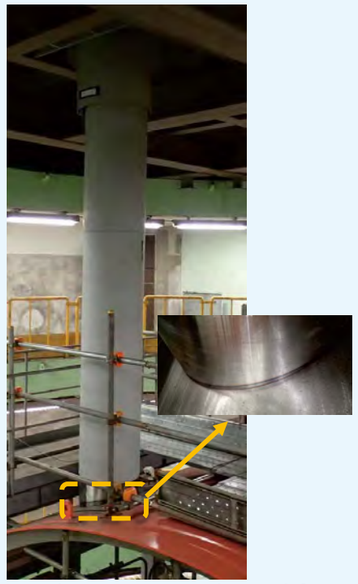


Fig.4: Connection with extension pipe and S/C

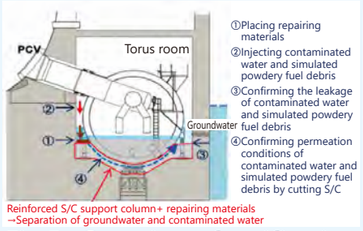
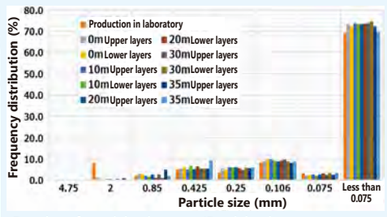


Fig.5: Overview of verification test for boundary efficacy

Inner periphery side (Stagnant water is contaminated with simulated powdery fuel debris and colorant)

Outer periphery side (Stagnant water is clear)

Fig.6: Conditions of inner/outer periphery sides after injecting simulated powdery fuel debris



Results of particle size test (Particle size components are equivalent regardless of flow distance)

Fig.7: 35-meter flow test for repairing materials

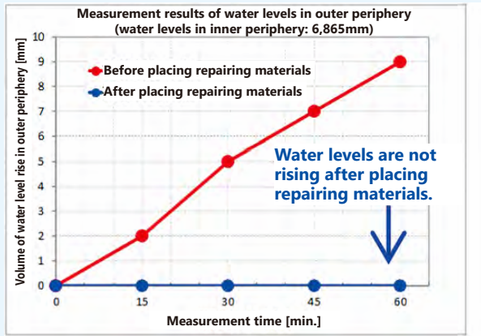


Fig.8: Water levels before and after placing repairing materials

Fig.9: Wire saw cutting surface of full-scale test facility

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures (1) (Development of Fuel Debris Retrieval Method)

Background

Fuel debris in the reactor pressure vessel (RPV) and the primary containment vessel (PCV) of Fukushima Daiichi Nuclear Power Station has currently been secured cooling conditions. However, the reactor building, RPV and PCV were damaged by the accident, and the plant condition is in unsettled state. A goal of the project is to retrieve fuel debris while maintaining a stable condition without spreading radioactive materials.

Purpose

This project aims to develop technology for establishing an access route based on the site information, which will be needed to retrieve fuel debris existing in RPV and PCV. Specifically, technology for removing interferences can shorten the process of fuel debris retrieval. Therefore, the feasibility of technology is confirmed, assuming actual conditions. Various technologies are developed other than technology for removing the interference, the supporting system for the remote-operated device and preventing technology from spreading radioactive contamination and technology required for the establishment of the access route, considering shielding structure against exposure reduction in the reactor building (R/B).

Major approach and results

1 Development of technology for removing interferences

(1) Top-access and transportation methods for removing large-scale structures

- Damaged conditions of the reactor structures were estimated in consideration with investigation results in PCV and results from various analysis.
- A method of removing large-scale structures can shorten the process of fuel debris retrieval. A concept of the technology, such as a retrieval method passing through spent fuel pool (SFP) and removing the bottom of the reactor with fuel debris, was reviewed (Fig.1).

(2) Side-access method for removing interferences inside/outside of the pedestal

- The interference objects have existed on the access route for fuel debris retrieval. The interferences outside the pedestal were identified to clarify the difficulties of removal work.
- The interference removal device for PCV has an issue of cable hose handling. A handling device device driving utility is installed outside of the pedestal was developed and confirmed the feasibility by an element test (Fig.2).
- To remove the interferences in the pedestal, a removal method using existing structures including a control rod drive (CRD) platform is under study.

2 Development of various technologies other than removal technology for interferences

(1) Development of remote operation support method in environments with the low visibility and narrow spaces

- When remotely operating a manipulator, a mechanism that an operator can concentrate on handling manipulator was established by automatic interference avoidance actions. The device was confirmed the feasibility by simulator verification (Fig.3).

(2) Prevention method for spreading of contamination into the suppression chamber (S/C)

- To prevent the spreading of contamination into S/C due to fuel debris, a prevention method was created to confine fuel debris by a weir built around the pedestal opening and a jet deflector. A folded form of the weir can be developed in the basement of the pedestal outside and made by injecting dry mortar. Element tests were conducted to confirm the feasibility of the method (Fig.4).

(3) Establishment of the access route for cell installation and conceptual study of reducing the impact on the R/B

- To reduce the weight load on the R/B floor, a weight reduction of the cell in the R/B has a possibility by optimized shielding thickness required cell surroundings and the cell height reduction that was revised considering the access rail structure (Fig.5).

(4) A method of transporting the unit can from the R/B

- The safety and functional requirements for the transport system were examined to identify necessary element technology for the transport system of fuel debris. The conceptual design of the technology was performed mainly for hydrogen treatment and remote operated opening mechanism.
- The work procedure plan and process evaluation for the transport system operation were conducted and the study results on equipment layout in the reactor building are being reflected (Fig.6).

Future development

- Technology for removing interferences has been developed for the top-access/side-access methods. An element test for the technology will be performed based on the results of the conceptual study conducted in this fiscal year.
- Various technologies have been developed other than technology for removing interferences: A remote-operation support method, a prevention method of spreading contamination in the S/C, a conceptual study of the access route and the unit can transport method. Element tests for each technology will be conducted to confirm the feasibility of the methods after examining the results of the conceptual study undertaken in this fiscal year.

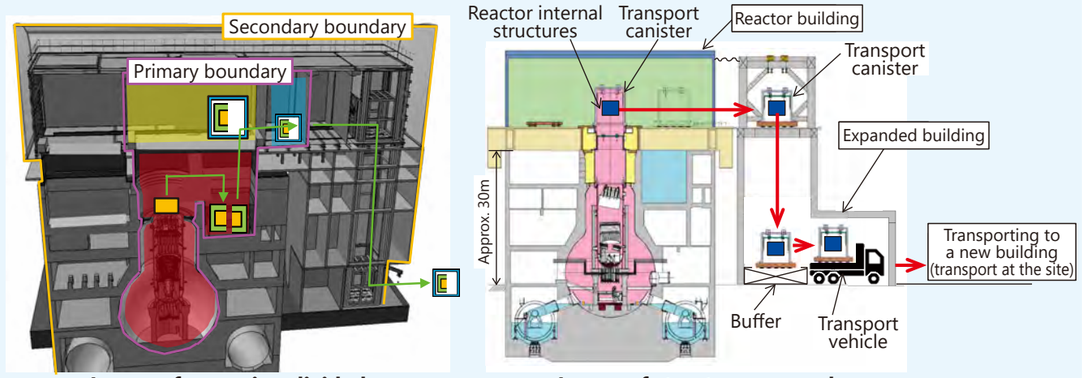
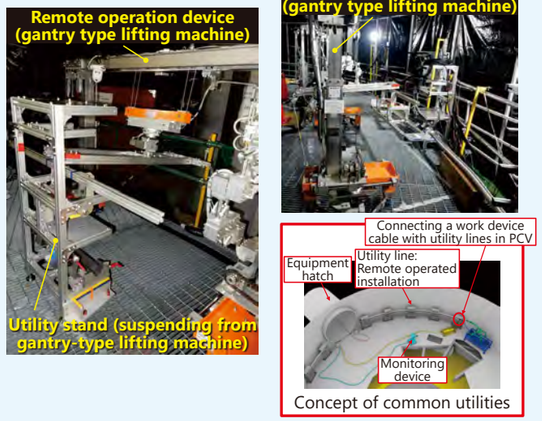


Image of removing divided structures through the SFP

Image of structure removal under the integrated status

Fig.1: Concept of removing large-scale structures



Concept of common utilities

Fig.2: Element test for installing utilities at the outer periphery of the pedestal

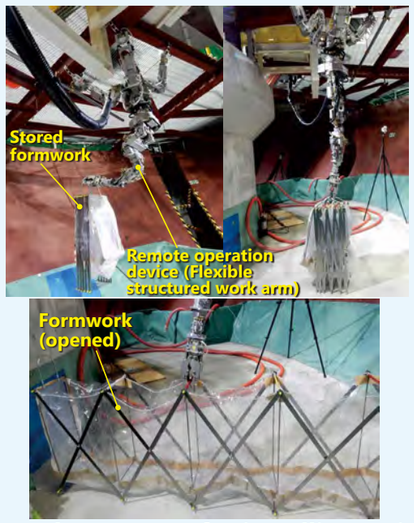


Fig.4: Element test for installing weir to prevent spreading contamination to S/C

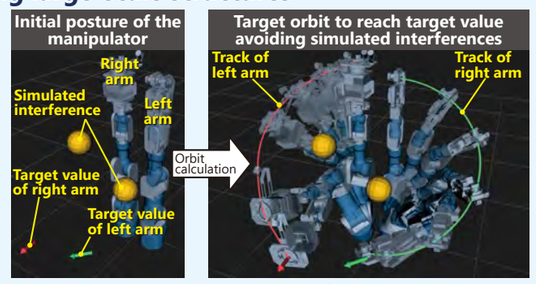


Fig.3: Simulator validity for interference avoidance of manipulator

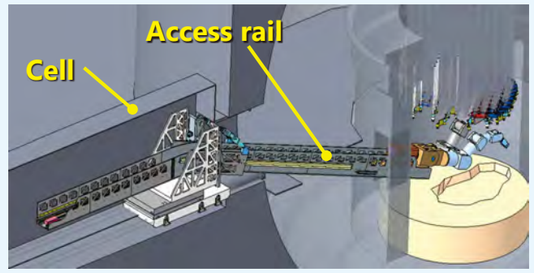
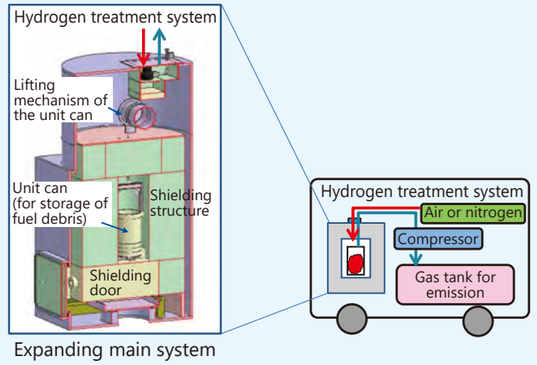


Fig.5: A revised plan of the access method to decrease the cell height



Expanding main system

Fig.6: Concept of the transport system

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures (2) (Development of Technology for Processing Fuel Debris)

Background

Fuel debris in the reactor pressure vessel (RPV) and the primary containment vessel (PCV) of Fukushima Daiichi Nuclear Power Station has been currently secured the cooling conditions. However, the reactor building, RPV and PCV were damaged by the accident, and the plant condition is in unsettled state. The project aims to retrieve fuel debris while maintaining a stable condition without spreading radioactive materials.

Purpose

The purpose of this project is to study methods for collecting and storing fuel debris depending on the conditions and to develop the systems. Additionally, the project aims to select appropriate adsorbent to remove soluble nuclides and develop treatment technologies for wastewater generated from filtration and backwashing filter to remove insoluble nuclides. Furthermore, the necessary technology for sorting fuel debris and radioactive materials is surveyed.

Major approach and results

1 Technological development of fuel debris collection and storage systems

(1) Development of suction collecting system for particulate fuel debris

- A suction collection system was studied to collect particulate fuel debris effectively. As a result of a benchmark survey of existing technology for the system, the suction pump method and ejector method were selected.
- Considering transport and maintenance of fuel debris, a loading plan of the suction collection system on the robot arm was developed, and a conceptual diagram of separator replacement was created (Fig.1).

(2) Development of technology for transferring fuel debris and wastes

- Based on the results of the existing analysis, fuel debris was classified according to estimates of the distribution and conditions of fuel debris.
- Classified fuel debris was organized depending on the availability of processing, processing methods, and collecting methods. A conceptual study of grinding stone cutter and hydraulic cutter was performed, adding to previous processing methods (Fig.2).

2 Technological development of treatment for fuel debris and deposit

(1) Removal technology for soluble nuclides in circulating cooling water

①Conceptual system design of soluble nuclide removal facility

- A benchmark survey on existing technology was conducted to remove soluble alpha nuclides in circulating water of the liquid phase system during fuel debris retrieval. As a result, technology for adsorption removal has been developed.
- Test methods for selecting adsorbents were determined by conducting literature research on adsorbents, estimation of dissolved form and solubility for selected adsorbents, and preliminary confirmation test of adsorption performance (Fig.3).

②Conceptual design of boric acid conditioning facility

- Assuming issues such as depositions for the use of sodium pentaborane to prevent criticality during fuel debris retrieval work, a literature survey and element tests were conducted to discuss the measures (Fig.4).

(2) Treatment technology for deposits collected from inside PCV

①Characterization of collected wastewater

- To remove non-soluble particles in circulating water of the liquid phase system during fuel debris retrieval, properties of collected wastewater were estimated and organized through a literature survey and device testing. The results suggest that it is essential to separate and remove particles contained in the wastewater by size and stages.
- A filter separation device was selected as a method of separating and removing particles. The test plan was developed to confirm the applicability of the technology (Fig.5).

②Development of technologies for separating and storing solid materials in wastewater

- Technology for sedimentation separation has been developed to remove micro-particles contained in wastewater collected from PCV.
- Technology for sedimentation separation using aggregating agents was selected according to the results of the survey on existing technology. A test method was considered to confirm the applicability of technology (Fig.6).

3 Survey on sorting technology for fuel debris and radioactive wastes

- The technology required for sorting fuel debris and radioactive materials was surveyed. The feasibility of a sorting scenario was evaluated based on the evaluation results of technical applicability (Fig.7).

Future development

- A project plan is to perform element tests for the fuel debris collection and storage systems: the suction collecting system for particulate fuel debris and the methods of processing and collecting fuel debris depending on the conditions of fuel debris. The feasibility of the system will be confirmed.
- To develop technology for the treatment of fuel debris and deposits, a candidate adsorbent for removing soluble alpha nuclides will be selected to study a conceptual system and identify issues.
- Additionally, the applicability of candidate technologies for the removal of insoluble nuclides, including filter separation and precipitation separation, will be verified.

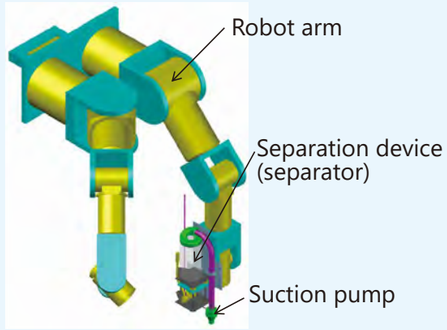


Fig.1: Image of conceptual study of particulate debris suction collecting system

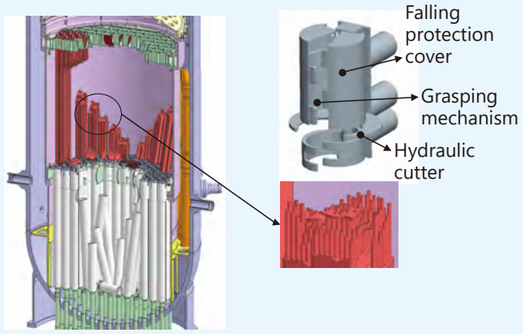
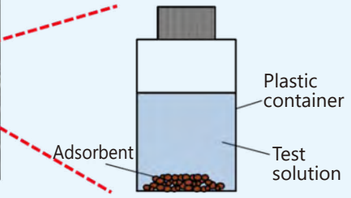


Fig.2: Fuel debris collection and storage system

Appearance of shaker

Inside of shaker
Shaking through all night



Canister for adsorbent test

✓ Test conditions set by estimation results of target nuclides such as the dissolved forms and solubility, and preliminary test results.
✓ Measurement of the adsorbed amount by measuring the concentration of adsorbed substances in a canister before/after starting a test.

Fig.3: Overview of performance validation test for adsorbent to remove soluble alpha nuclides

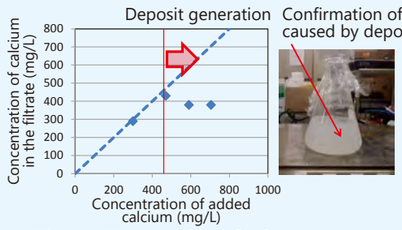


Fig.4: Example of element test for depositions in case of using sodium pentaborane

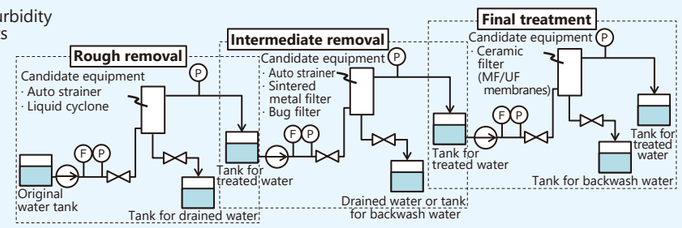
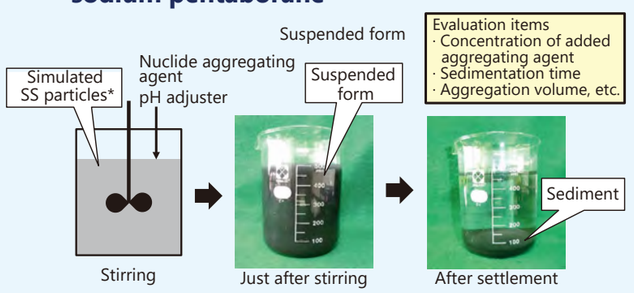
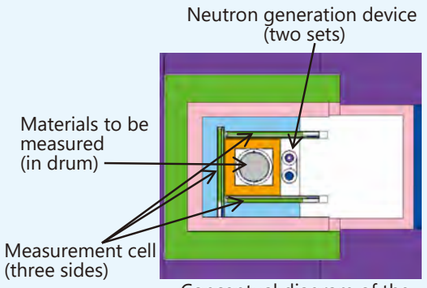


Fig.5: Conceptual diagram of particle removal facility and system



* Spontaneous sedimentation requires long-term sedimentation time because assuming SS particles including minor particles.

Fig.6: Overview of preliminary test for sedimentation separation by using aggregating agents



Conceptual diagram of the neutron measurement device

Fig.7: Example of investigation results of sorting technology

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures (3) (Development of Technology for Ensuring Safety during Retrieving Fuel Debris)

Background

Fuel debris in the reactor pressure vessel (RPV) and the 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 accident, and the plant condition is unstable. The purpose of the project is to retrieve fuel debris from the unsettled state while maintaining a stable condition without spreading radioactive materials.

Purpose

The project aims to develop element technologies for the confinement of radioactive materials, prevention of criticality, and monitoring for approaching criticality, which is essential to ensure the safety of the public and workers during retrieving fuel debris.

Major approach and results

1 Development of element technology for confinement functions

(1) Technology for prediction of dust behaviors in PCV

- Dust behaviors in Fukushima Daiichi NPS were evaluated using the general thermal fluid analysis code, GOTHIC. The analysis code shows that gravitational sedimentation is dominant, and besides, accurate predictions are possible.
- A new R/B model was developed to analyze irregular leakage from PCV. The analysis revealed characteristics of leakage flows and the tendency of dust depositions (Fig.1).
- Decay heat of fuel debris and effects of heat input while cutting fuel debris were evaluated, and thereby the evaluation proved the relations with temperature gradient due to heat input and a position of damaged opening based on temperature gradient and chimney effects.

(2) Technology for ensuring confinement functions in connection parts

- The flow of connection with an access tunnel and PCV was organized. Additionally, specifications of basic requirements for the welding connection of PCV are being clarified.

2 Development of element technology for prevention and monitoring of criticality

(1) Technological development of criticality monitoring method

- Careful retrieval work for fuel debris is required to prevent criticality caused by fuel debris retrieval while monitoring the criticality approach. Therefore, a subcriticality measurement method has been developed based on neutron measurements. Now, to confirm the feasibility of the method in the inhomogeneous distribution of fuel debris, subcriticality test for various subcritical cores (Fig.2) at the Kyoto University Criticality Assembly (KUCA) were conducted, and the neutron signals data was acquired. The degrees of subcriticality will be evaluated using the data to confirm the feasibility of the method.
- To measure neutrons nearby fuel debris, it is necessary to confirm the applicability of a neutron detector to the field from the point of view, such as the resolution of neutron measurement, gamma ray-resistant performance, weights, and sizes. Therefore, specifications required for the neutron detector were clarified, and then a candidate neutron detector was selected.
- Work procedures for monitoring the criticality approach according to the fuel debris retrieval methods, including the top-access and side-access methods (Fig.3) were organized in a combination of subcriticality and neutron counting rates measurement methods.

(2) Development of technology for criticality prevention

- A neutron absorber that is not soluble in water has been developed to prevent criticality. To study a device and the operating method for injecting non-soluble absorber into near fuel debris, an injecting test device with a hopper and pump for viscous type (water glass, Gd_2O_3 granulated powder) and granulation type (Gd_2O_3 particles) non-soluble absorber was manufactured. It was confirmed that the test device can inject the absorbers by element testing at water equivalent depths of 5m in a recompression chamber (Fig.4).
- Element tests were conducted to confirm the effects of processing viscous type non-soluble neutron absorber with fuel debris. The test results confirmed that there were no effects on processing fuel debris (the range and speed of processing fuel debris).
- Using a rust inhibitor is considered to prevent corrosion of the structures. Therefore, an irradiation test was conducted to study corrosion affected by radiation environments in case of using non-soluble adsorbent at the National Institutes for Quantum and Radiological Science and Technology (QST), Takasaki Advanced Radiation Research Institute. The results of the test confirmed that there was no effect on corrosion.

Future development

- Element test for development of criticality monitoring technology will continue to evaluate the applicability to Fukushima Daiichi NPS. The control procedures will be continuously discussed, assuming practical application.
- The achievements obtained from dust behavior prediction and criticality prevention technology are planned to be utilized for engineering made by the operator.

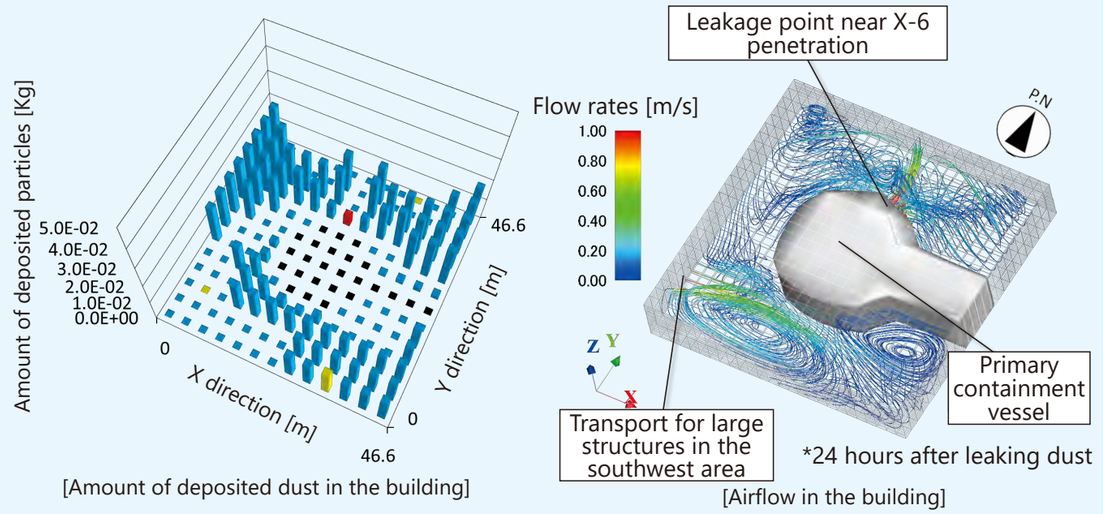


Fig.1: Airflow analysis and dust prediction for inside the reactor building with GOTHIC code (Ex. Assuming leakage from near X-6 penetration on 1st floor of reactor building in Unit 3)

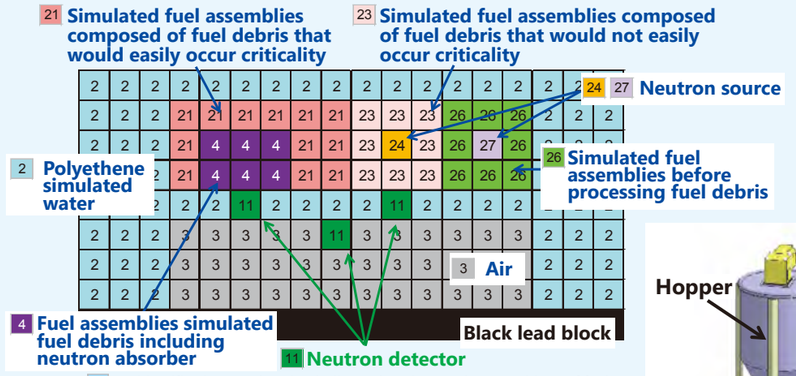


Fig.2: Example of fuel assembly configuration for sub-criticality measurement test at KUCA

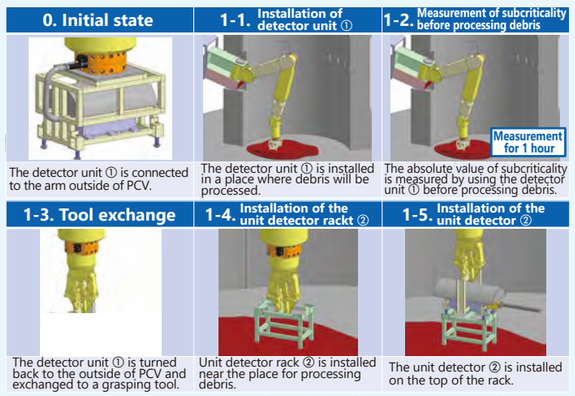
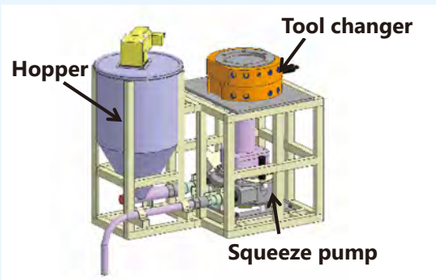
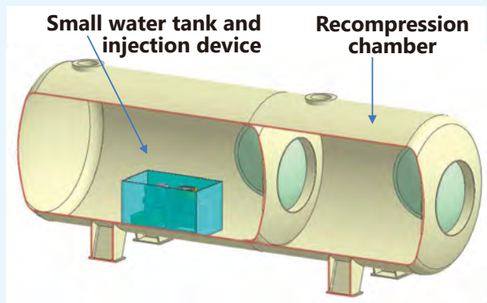


Fig.3: Example of criticality approach monitoring procedures for using the side-access method



(a) Absorber injection device



(b) Underwater injection test device

Fig.4: Absorber injection device for viscous materials and underwater injection test

R&D for Preparation of Fuel Debris Retrieval

Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures (Development of Technology for Fuel Debris Dust Collection System)

Background

Fuel debris exists inside the primary containment vessel (PCV). When retrieving fuel debris, various particle-sized dust including powdery dust would generate from adjacent fuel debris cutting area. From the aspect of reducing radiation exposure, system development is required to control dust created from the cutting area.

Purpose

A conceptual study of the dust collection and dispersion-preventing control systems are performed considering the site applicability of remotely operated maintenance at adjacent fuel debris processing point. The purpose of the project is to evaluate dust migration rates in gas-liquid phases, dust collecting efficiency, and reduction efficiency of decontamination capability that will be required for the ventilation system of PCV.

Major approach and results

A conceptual study on dust collection and dispersion-preventing/scattering-prevention systems that are combined with various processing tools were performed considering improvement of efficient fuel debris retrieval in PCV and maintenance of retrieving device. The cutting methods for fuel debris retrieval including a mechanical cutting method are used to evaluate the effects of collecting and preventing scatter dust in the test. A rotary automatic cutting (disk saw) was selected as a cutting method for fuel debris retrieval, which is not needed for abrasive that will generate a large amount of waste, and applicable to cutting of ceramics and metallic materials. A preliminary test was conducted to measure the dust generation amount, the direction of scattering dust and data of speed, and the summarized issues.

1 Development of dust collection and dispersion-prevention systems

Assuming that fuel debris exists in PCV in the form of various types (block-like, pebble-like and particulate debris, etc.), dust may generate during processing fuel debris. The dust collection and dispersion-prevention systems will be installed the debris processing device equipped with a robot arm for fuel debris retrieval to reduce airborne dust adjacent to the processing point. The conceptual study on the dust collecting and scatter preventing system was performed.

As a result of broad investigations in the existing dust collection system, the dust collection system was designed to install a fence around the processing site. Additionally, water is sucked from inside the fence to drain water containing dust by using a water ejector and the system is designed to spray mist for capturing dust leaked into the surroundings. The conceptual design of the system that is combined with various processing tools including a rotary mechanical cutting tool (disk saw), hydraulic cutter tool, a chisel tool and a laser gouging tool was performed (Fig.1).

2 Development of remote maintenance technology for dust collection and dispersion-prevention systems

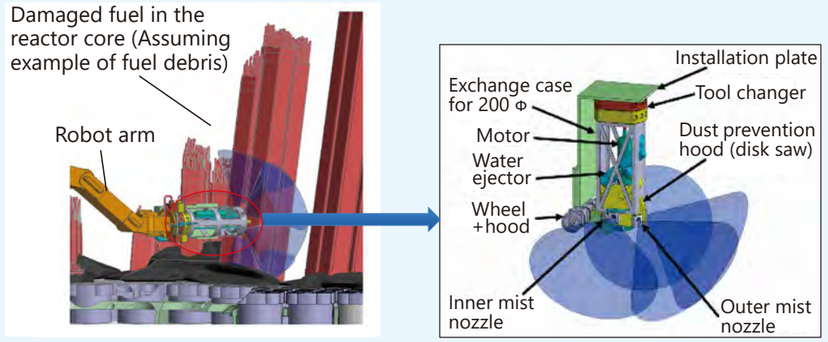
Some of the dust collection and dispersion-preventing systems will be regarded as wastes; Devices installed in PCV will be contaminated, and filters and waste liquid tanks will be classified as waste. To reduce the frequency of maintenance such as replacement of consumable devices and removal of waste materials, the concepts of the dust collection and dispersion-preventing systems that are not required for filters and waste liquid tanks were studied from the aspect of minimizing maintenance. A remote-operated replacement method for consumable materials including processing tools in PCV or the primary boundary cell was discussed (Fig.2).

3 Evaluation test of dust collection and dispersion-prevention systems

By reviewing the dust evaluation tests during the process of fuel debris that was conducted in Japan and overseas, the test procedures that can derive the evaluation results were considered. A preliminary analysis was conducted to understand the conditions of dust generated near the processing site by using a disk saw, which contributes to the design of dust collection and dispersion-preventio systems, and dust evaluation test for the future (Fig.3). Moreover, a manufacturing method of simulated fuel debris was discussed, and simulated Molten Core Concrete Interaction (MCCI) products were created to simulate fuel debris that exists at the bottom of PCV.

Future development

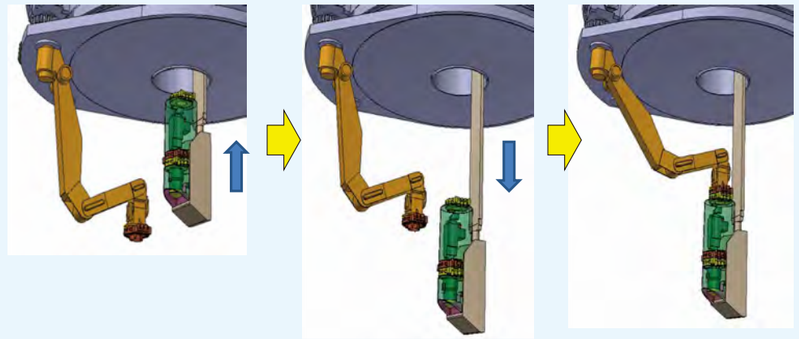
- A dust evaluation test will be completed by using a disk saw with the system for dust collecting and dispersion-prevention and simulated fuel debris.
- The dust evaluation test will be conducted to calculate the spreading dust rates for the loss of weight after processing fuel debris that can be calculated by weight assessment of airborne dust, dust floating in water and fallen dust. The PCV Aerodynamic analysis will be performed based on the calculation results to evaluate the amount of dust that would reach ventilation apparatus of the environmental control system.
- At the time of fuel debris retrieval and maintenance of retrieval device, the applicability of the systems for dust collecting and dispersion-prevention will be evaluated based on the results of the conceptual design of the systems.



Example of the application for damaged fuel in the reactor core

Example of the application for disk saw tool

Fig.1: Application example of disk saw tool for dust collection and dispersion-prevention systems

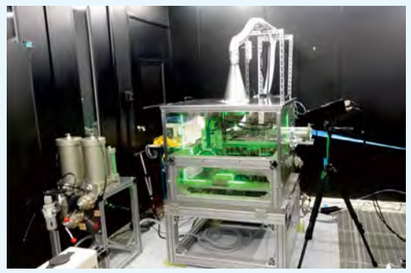


Removal/transport of spent tool

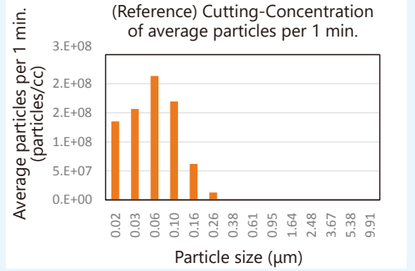
Installation of exchange tool

Loading of exchange tool

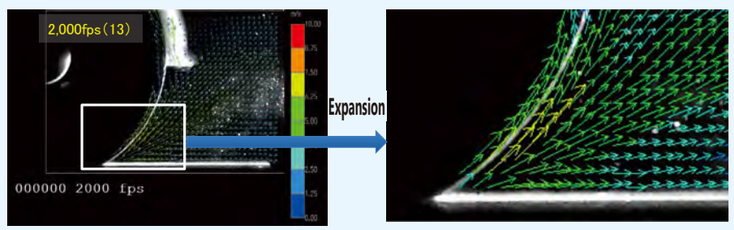
Fig.2: Concept of replacement for maintenance tool



Dust evaluation test device



Distribution of airborne dust particle sizes



Observation of dust dispersion during cutting by disk saw

Fig.3: Overview of dust evaluation test for disk saw

R&D for Preparation of Fuel Debris Retrieval

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

Background

According to the Mid-and-Long-Term Roadmap toward the Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS) of Tokyo Electric Power Company (TEPCO) Holdings Co. Inc., the fuel debris retrieved from the Fukushima Daiichi NPS is planned to be stored until such time as effective treatment and disposal methods have been estimated after carrying out from the reactor building. Therefore, it is necessary to establish the system of containing, transferring, and storing fuel debris.

Purpose

The purpose of the project is to develop fuel debris canister (referred as the canister) for containing, transferring and storing fuel debris safely and effectively as well as the canister handling device, on the basis of the experience of the Three Mile Island Nuclear Power Station Unit 2 (TMI-2) in the United States and proven technologies for transport and storage of spent fuel. In fiscal year (FY) 2019, the major development of the project is planning of full-scale verification test of the canister for preparation of the prototype and the study on prediction methods of hydrogen generation to propose ideas of the transfer conditions and the drying conditions of fuel debris. For the preparation of the verification test of the full-scale canister in FY 2020, basic concepts of hydrogen gas management during transportation and fuel debris drying systems were proposed.

Major approach and results

1 Investigation and research plan of containing, transfer and storage of fuel debris

The latest information on Fukushima Daiichi NPS was obtained while upgrading process flows and work steps from retrieving to storing fuel debris and knowledge on the physical properties of fuel debris, which were tentatively established at the end of FY 2018. A research plan was reflected in analysis and tests for investigation (drying technology and measurement technology for hydrogen concentration in general industries) required for the following item from 2 through 4.

2 Development of containment technology

Various studies to verify the structural integrity of the canister were conducted. For example, a design policy of the sealing structure and the vent mechanism was determined for specifications and structure plans of the canister tentatively established in FY 2018. The canister (prototype) for full-scale structural verification test that is planned in FY 2020 was designed (Fig.1) and preparation of test production of the canister (prototype) started. Additionally, verification items for the full-scale structural test and test planning were developed (Fig.2).

3 Development of transfer technology

Various studies and tests for planning of hydrogen gas management during transporting fuel debris were conducted. For example, based on survey results from the previous research and interviews with specialists, discussion items and activities were studied, which would be required for a proposal of the transfer conditions, evaluation methods for predicting hydrogen generation were studied, and the hydrogen generation test was planned. Furthermore, catalyst performance test was conducted to confirm the effectiveness of catalysts for hydrogen suppression (Fig.3, 4, and 5).

4 Development of drying technology and systems

Various drying systems for reduction of water content were studied and tested from the aspect of reducing hydrogen generation during fuel debris transportation and dry storage. For example, an element test for the operating conditions of drying apparatus was conducted, and measurement technology for hydrogen concentration was surveyed to confirm the completion of drying treatment after required technology specifications were examined.

5 Development of related technologies

Technology for sorting fuel debris and radioactive wastes will be developed under the Development of Retrieval Technology Project for Further Increasing the Scale of Fuel Debris. The conditions and benefits for technological development that would be effective for the improvement of containing, transfer, and storage were provided.

Future development

A full-scale verification test of the canister will be performed and evaluated to develop containment technology. The transfer conditions will be proposed after the study of hydrogen measurement methods during transportation and hydrogen management, while drying technology and systems will be developed based on a survey on drying treatment technology and evaluation technology for pre-storage treatment.

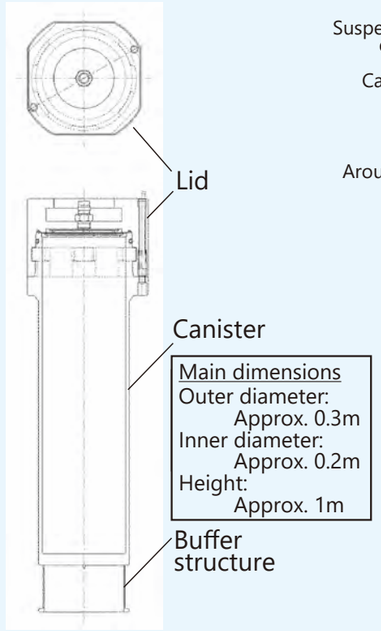


Fig.1: Canister structure plan (canister for testing)

· The canister for the verification test of the full-scale structure was designed to verify the structural integrity.

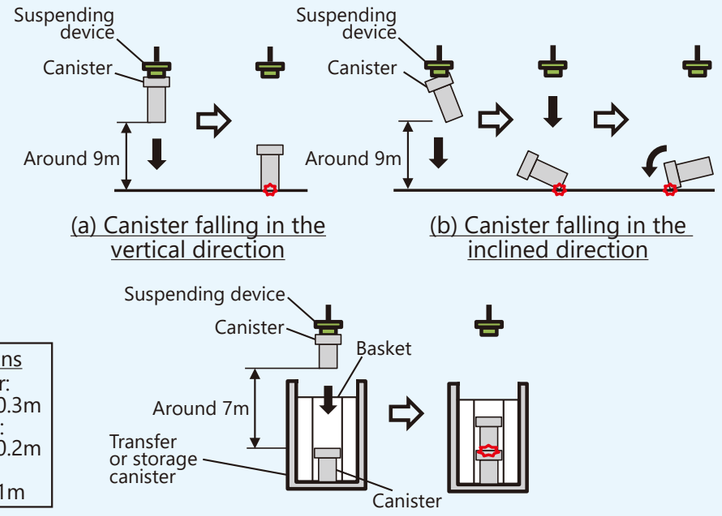


Fig.2: Image diagram of event evaluations

· To verify the structure of the canister, a full-scale structure verification test that simulates evaluation events to be considered to give significant effects of the structure strength evaluation was planned.

Fig.3: Catalyst (photo)

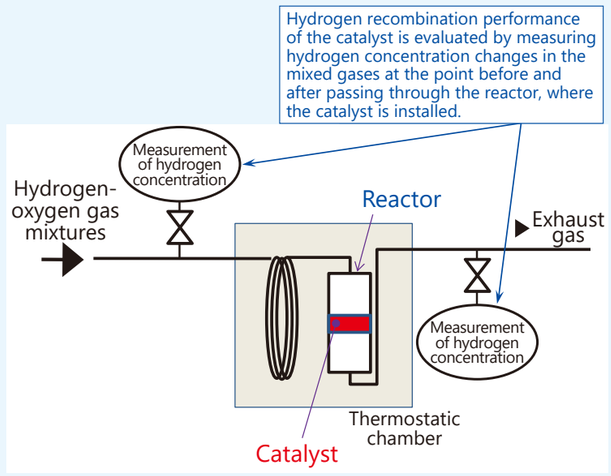


Fig.4: Conceptual diagram of catalyst performance verification test

Fig.5: Reactor (photo)

· Validation test of catalyst was conducted to confirm the effectiveness of catalysts for hydrogen generation measures.

R&D for treatment and disposal of solid radioactive wastes

R&D for Treatment and Disposal of Solid Radioactive Wastes

Background

In Fukushima Daiichi Nuclear Power Station, a massive amount of wastes, such as rubbles and fallen trees that have already been stored, will generate as fuel debris retrieval work progresses. In these situations, it is necessary to develop the methods of storage, treatment and disposal to implement the project while the waste characterization proceeds.

Purpose

The purpose of the project is to study and evaluate the storage and management methods, and to develop the safety evaluation method considering the properties of wastes generated by the accident. Besides, obtained results are utilized for the waste characterization and development of technology for safe treatment and disposal of the solid wastes generated by the accident.

Major approach and results

1 Storage management

(1) Evaluation of storage and management methods

The progress of other projects concerning fuel debris retrieval was reflected for the waste generated by fuel debris retrieval and the waste information was updated. On the other hand, concepts of the container, filtered vents, and drying and measurement apparatus, which were identified issues in the previous discussions, were studied for practical implementation, and the process flows were updated.

(2) Technological development of contamination evaluation for sorting solid wastes

An alpha camera prototype was improved, and element tests were continuously conducted. Based on the results of the element tests, the measurement system's specifications were determined, assuming the site environments and measurement methods. A preliminary test for systematizing pan-tilt mechanism and data synthesis was conducted to design the measurement system (Fig.1).

2 Concepts of treatment and disposal, and development of safety evaluation methods

(1) Establishment of selecting advance treatment methods

Concerning technology for solidifying secondary waste generated from water treatment at low temperatures, a simplified evaluation method of the solidification conditions was considered. Then, the solidification test of carbonate slurry was conducted to investigate the properties including condensation and transformation. A selection method has been developed to select appropriate technology among various technologies (Fig.2) while collecting data of facility characteristics including high-temperature treatment.

(2) Proposal of disposal methods and development of safety evaluation methods

A disposal method is considered based on the properties of waste types, and the development of the safety evaluation that applies to the disposal method has been studied (Fig.3). Firstly, clarifications of disposals (trench, pit, and mid-depth) were evaluated for 27 kinds of categorized accident wastes in case of disposing original waste, while organizing and evaluating waste information and properties required for study on disposal methods. Then, several proposals for waste disposal methods were selected based on the results of the study so far until now (disposal cases in Japan and overseas, waste information and properties, and disposal classification of original wastes), and the safety evaluation method (scenario, model, and parameter) was considered.

3 Efficient characterization

Waste analysis continued to collect data while developing the estimation method for radioactivity containing wastes by using the data. Incorporating a probabilistic approach, a new method that suggests certainty of estimate values was established (Fig.4). Analysis methods were discussed to rationalize nuclide analyses that are difficult to analyze, such as a mass measurement method that can be used instead of radioactivity (ICP-MS/MS method) and automatic chemical separation operation. Furthermore, since it is difficult to approach a cesium adsorption tower due to high dose rate, therefore a sampling device for adsorbents in the adsorption tower was prepared for test (Fig.5).

4 Integration of research results

In addition to the results of research on waste (characterization) and treatment (preliminary treatment, treatment, and reprocessing), requirements from the results of the treatment research were reflected in the waste stream to select treatment methods from the aspect of properties, treatment and disposal of wastes.

Future development

The characterization of the wastes will be continuously studied for waste sampling, practical analysis, and improvement of the inventory evaluation method. Additionally, the sorting and storage methods will be also considered for the preparation of high-level radioactive waste genaration. Furthermore, advanced treatment technology will be continuously selected for a stable treatment of the secondary wastes generated by water treatment, and various disposal methods will be considered assuming specific waste materials.

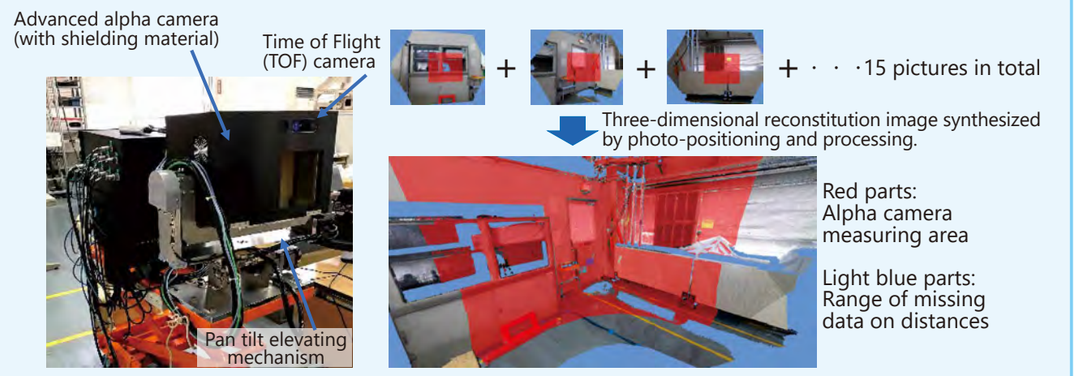


Fig.1: Example of the preliminary test device for alpha contamination measurement system

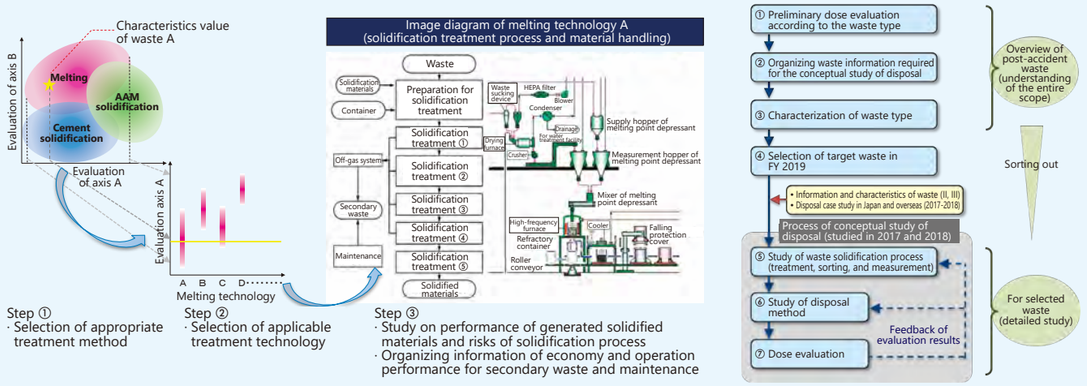


Fig.2: A method of extracting potential technology among various solidification treatment technologies (image of the study flow)

Fig.3: Approaches to development of disposal and safety evaluation methods

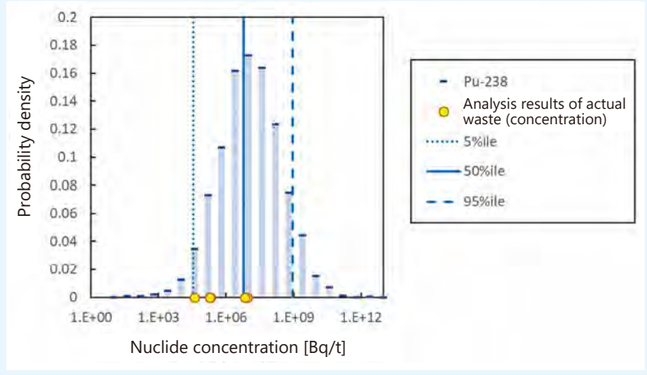


Fig.4: Statistics method to estimate the amount of radioactivity (Example of nuclide concentration distribution of carbonate slurry)

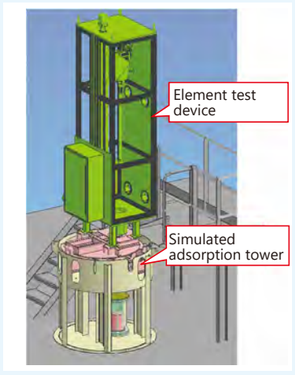


Fig.5: Image of element test of adsorption tower sampling device

List of Major Results of Research and Development in FY2019

No.	Presented by	Date	Details
1	KURNS Progress Report 2018 (Annual Report, Kyoto University Institute for Integrated Radiation and Nuclear Science)	Apr. 4, 2019	Measurement of Fundamental Characteristics of the Nuclear Reactor at KUCA (III)
2	Lecture at International Research Center for Nuclear Material Science, Institute for Materials Research, Tohoku University	Apr. 11, 2019	Development of Fuel Debris Retrieval Technology Conducted by IRID
3	The 65th Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment	Apr. 25, 2019	Analytical Results of Waste Sample (Rubbles in the Reactor Building, Unit 1 through 3)
4	The 27th International Conference on Nuclear Engineering (ICONE27)	May 20 – 23, 2019	○ Approach to the Stabilization of Fukushima(Panel Display) ○ Development of a Remotely Controlled Device for Investigation inside Primary Containment Vessel at Fukushima Daiichi Unit 2 ○ Hitachi's Activities for Technological Development Necessary in the Japan Nuclear Industry
5	International Topical Workshop on Fukushima Decommissioning Research (FDR2019)	May 24 – 26, 2019	○ Robot Technology for Decommissioning of Fukushima Daiichi Nuclear Power Stations (Keynote) ○ Characterization of Sludge Generated from Decontamination Device in Fukushima Daiichi NPS ○ Investigation of the Spearing Contamination on the Operation Floor of Unit 2 Based on the Radiochemical Analysis Data ○ Study on the Radioactive Contamination in the Reactor Building Unit #4 of Fukushima Daiichi NPS
6	The 66th Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment	May 31, 2019	Analysis of Sample Collected from PCV inside, Fukushima Daiichi NPS
7	Magazine “Metals”, July 2019, AGNE Gijutsu Center	June, 2019	Robot demonstration test, Naraha Center for Remote Control Technology Development
8	Symposium on Waste Disposal and Decontamination Technology for the Restoration of Fukushima (Sponsored by Nano-process Research Institute, Nano & Life Innovation Research Organization, Waseda University)	June 4, 2019	Current Status of Technology Development Related to Fuel Debris, Fukushima Daiichi NPS
9	The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO): Science and Technology conference (SnT 2019)	June 24 – 28, 2019	Radioactive Gas Metrology at NPL and the Development of Short-lived Gas Standards (Poster Presentation)
10	Research Results Presentation, Fukushima Technology Center	June 25, 2019	Status of Decommissioning Technology for at Fukushima Daiichi Developed by International Research Institute for Nuclear Decommissioning (IRID)
11	The 67th Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment	June 27, 2019	Analytical Results of Waste Sample (Np-237 and I-129 of Accumulated Water/ Stagnant Water, Containing the Sludge of Unit 1 – 4)
12	TOSHIBA REVIEW SCIENCE AND TECHNOLOGY HIGHLIGHTS 2019	July, 2019	Image Capture Using Remotely Operated Robot Inside PCV of Fukushima Daiichi Nuclear Power Station Unit 2
13	The 36th Regular Study Group, Water Chemistry Sectional Meeting, Atomic Energy Society of Japan	July, 2019	Overview of R&D toward Decommissioning of Fukushima Daiichi NPS, International Research Institute for Nuclear Decommissioning (IRID)
14	The 36th Regular Study Group, Water Chemistry Sectional Meeting, Atomic Energy Society of Japan	Jul. 9, 2019	Hydrogen Generation Test Using Spent Fuel
15	Special Lecture at “System Engineering”, National University Corporation Tsukuba University of Technology, NTUT	Jul. 11, 2019	Technological Transition of Robots Working in Nuclear Power Stations: Robots for Regular Inspection Purpose during Normal Operation and Decommissioning Purpose.
16	Third TITECH-CRIEPI-JAEA Joint Workshop-R&D Updates on Fuel Debris and FP Behavior during Severe Accidents	Jul. 15, 2019	Investigation of In-reactor Cesium Chemical Behavior in TEPCO’s Fukushima Daiichi Nuclear Power Station Accident-Leaching Behavior of Zn, Si and other Elements From Inorganic Zn-Rich Paint-(Poster Presentation)
17	Posted on the Website of Nuclear Regulatory Commission as Meeting Handouts for the Nuclear Backend Countermeasure Monitoring Team, Japan Atomic Energy Agency, Nuclear Regulatory Commission	Jul. 18, 2019 (Discussion session)	Study toward Acceleration of Waste Treatment
18	The Japan Society of Maintenology: The 16th Academic Conference	Jul. 25 – 26, 2019	○ Remote Transport Method Using Low Floor Type Truck in High Dose Environments ○ Fukushima Decommissioning Robot by Hitachi Group
19	The 12th Radiation Measurement Forum, Fukushima (Hosted by the 186th Committee Meeting, Japan Society for the Promotion of Science)	Jul. 30, 2019	○ Investigation inside Primary Containment Vessels, Unit 2 and 3, Fukushima Daiichi NPS ○ Development of Compact Dosimeter Using Near-infrared Fluorescence and Dose Rate Distribution Measurement in Primary Containment Vessels
20	IRID Symposium 2019	Aug. 1, 2019	○ Status of R&D Conducted by IRID (lectures) ○ Introduction of Technology Developments (Panel Display)
21	25th International Conference on Structural Mechanics in Reactor Technology (SMiRT25)	Aug. 4 – 9, 2019	Development of Fuel Debris Canister
22	The 4th International Forum of the Fukushima Daiichi Decommissioning (Technology Poster Session)	Aug. 5, 2019	○ Prediction of the Dose Rate of Various Fuel Debris to be Sampled from Fukushima Daiichi Nuclear Power Station ○ Introduction of Research and Development Regarding Treatment Technology for TEPCO's Fukushima Daiichi NPS Accident Waste ○ Uranium-Containing Particles Found in the Fukushima Daiichi Primary Containment Vessel Interior ○ Development of Analytical Methods for 1F-Samples –Analysis of .93Zr by ICP-QQQ-MS and Automated Sample Preparation Instruments– ○ The Radiochemical Analysis of the Genuine Samples at Fukushima Daiichi NPS site
23	13th Vietnam Conference on Nuclear Science and Technology (VINANST-13)	Aug. 8, 2019	Development of Analytical Methods for Measurement of Radioactive Elements
24	The 17th Summer Seminar, Materials Subcommittee, Atomic Energy Society of Japan	Aug. 10, 2019	Development of Robotic Technology and Status of its Application to Site for Decommissioning Work of Fukushima Daiichi Nuclear Power Station
25	Open Forum, Academic lecture 2019, The 37th Robotics Seminar, Japan Robotics Society (RSJ2019)	Sept. 3, 2019	Expectations for Remote Work to Develop Debris Retrieval Technology
26	56th Annual Meeting on Hot Laboratories and Remote Handling (HOTLAB 2019)	Sept. 8 – 12, 2019	○ Current situation of OECD/NEA Preparatory Study on Analysis of Fuel Debris (PreADES) Project ○ Collection of Information on International Hot Analysis Capabilities for the OECD/NEA Preparatory Study on Analysis of Fuel Debris(PreADES) Project
27	Severe Accident Phenomenology-2019 Short Course	Sept. 9 – 14, 2019	Fukushima-Daiichi (1F) Accident, Current Status
28	Research Briefing Session, Subsidy Project by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), The Center of World Intelligence Project for Nuclear Science and Technology (S&T) and Human Resource Development “Research and Human Resource Development for Fuel Debris Analysis and Decommissioning Technology at Fukushima Daiichi NPS” (Tsuruga Decommissioning Seminar)	Sept. 10, 2019	Status of Decommissioning Technology Development for Fukushima Daiichi conducted by International Research Institute for Nuclear Decommissioning (IRID)
29	2019 Fall Meeting, Atomic Energy Society of Japan	Sept. 11 – 13, 2019	○ Development of Dose Rate Prediction Method for Various Sampling Fuel Debris ○ Development of Criticality Control Technology for Fuel Debris (50) Subcriticality Measurement of Two-Divided Core Simulating Large-Sized Fuel Debris ○ Development of Criticality Control Technology for Fuel Debris (51) Effect of Non-Soluble Neutron Absorber Spray that is Used for Crushing Debris by Using Chisel. ○ Development of Canister for Fuel Debris (14) Verification Test of the Canister Head Structure ○ Development of Canister for Fuel Debris (15) Alpha Ray Impact Study by Hydrogen Generation Test Using Spent Fuel (Part 2) ○ Development of Inventory Evaluation Method for Fukushima Daiichi Accident Wastes (15) Study on Introduction of Bayesian Statistical Method for Analytical Estimation ○ Study on Nuclide Migration by Collected Sample Analysis Data in Fukushima Daiichi NPS (5) Estimation Method Related to the Origin of Contaminants in the Reactor ○ Study on Nuclide Migration by Collected Sample Analysis Data in Fukushima Daiichi NPS (6) Estimation of the Origin of Radionuclides for Contaminants in the Reactors of Unit 1 and 2. ○ Study on Nuclide Migration by Collected Sample Analysis Data in Fukushima Daiichi NPS (7) Actinoid Nuclides in Contaminated Water ○ Study on Long-term Storage Measures of Waste Zeolite (13) Water Behaviors in Full-Scale Drying Test ○ Study on Long-Term Storage Measures of Waste Zeolite (14) Chloride Ion Behaviors in Full-Scale Drying Test ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (1) Study on Processing Issues ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (2) Study Approach for Waste Solidification Processing Technology ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (3) Overview of Characterization Assessment Study Related to Low-Temperature Solidification Materials ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (4) Evaluation of Dissolution Behaviors of Low-Temperature Processing Materials ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (5) Irradiation Test of Low-Temperature Treatment Materials ○ R&D Related to Advanced Treatment of Wastes Generated from Contaminated Water Treatment for Decommissioning of Fukushima Daiichi (6) Analysis on Nuclides Inventory in Waste and Simulation Analysis of Waste Temperature ○ Analysis of Sample Collected from Inside PCV in Fukushima Daiichi NPS (1) Analysis for Fuel Debris Characterization ○ Analysis of Sample Collected from Inside PCV in Fukushima Daiichi NPS (3) Analysis of Nuclides Collected from Inside PCV
30	11th International Conference on Nuclear Criticality Safety (ICNC2019)	Sept. 15 – 20, 2019	○ The High-Speed Statistical Criticality Evaluation Method Based on the Multidimensional Interpolation for On-Demand Criticality Evaluation ○ Sub-criticality Monitoring System for the Retrieval of Fuel Debris in Fukushima Daiichi Nuclear Power Plants
31	17th International Conference on the Chemistry and Migration Behavior of Actinides and Fission Products in the Geosphere (Migration 2019)	Sept. 17, 2019	ESTIMATION OF FUEL DEBRIS PROPERTIES BY EXPERIMENTAL APPROACH FOR FUKUSHIMA DAIICHI NPS

No.	Presented by	Date	Details
32	Light Water Reactor Safety Seminar, Tohoku University (Decommissioning of Nucler Reactor)	Sept. 18 – 21, 2019	○ Current Status and Issues of R&D for Decommissioning of Fukushima Daiichi ○ Development of Robotic Technology Associated with Decommissioning and State of Site Application ○ Characterization and Treatment of Fuel Debris
33	The Nuclear Almanac, 2020	Oct. 2019	Development of Remote Survey Technology at International Research Institute for Nuclear Decommissioning (IRID) toward Decommissioning of Fukushima Daiichi Nuclear Power Station
34	Geotechnical Society Magazine, Oct. 2019 issue; Decommissioned Ground Engineering Featured	Oct. 2019	R&D Current status of IRID at Decommissioning of Fukushima Daiichi Nuclear Power Station
35	The 9th INMM-ESARDA-INMM JAPAN Joint Workshop	Oct. 7, 2019	Overview of IRID R&D for Fuel Debris Retrieval Technologies at Fukushima Daiichi
36	Investigation Committee, Institute of Electrical Engineers "Radiation Measurement Technology Investigation Committee Related to Fukushima Daiichi NPS Decommissioning"	Oct. 18, 2019	Surface Alpha Contamination Imaging at Fukushima Daiichi
37	The 2nd Decommissioning Ground Engineering Committee, Geotechnical Society	Oct. 28, 2019	Status of 1F Decommissioning Technology Development at International Research Institute for Nuclear Decommissioning (IRID)
38	2019 International Joint -Workshop Post-Fukushima Challenges on Severe Accident Mitigation and Research Collaboration (SAMRC-2019).	Nov. 6 – 8, 2019	○ Current Situation of OECD/NEA, Preparatory Study on Analysis of Fuel Debris (PreADES) Project ○ Current Status of JAEA R&D Effort and International Cooperation toward Decommissioning of Fukushima Daiichi NPP
39	NACE East ASIA & Pacific Area Conference 2020	Nov. 11, 2019	Assessment of Corrosion Risks by Neutron-Absorbers Used for Criticality Prevention During the Fuel Debris Removal in the Fukushima Daiichi NPPs
40	The 18th Lead Annual Meeting	Nov. 20, 2019	Status of Decommissioning Technology for at Fukushima Daiichi Developed by International Research Institute for Nuclear Decommissioning (IRID)
41	Robot & Aerospace Festival Fukushima, 2019	Nov. 22 – 23, 2019	Panel Exhibition of IRID's R&D Status and Display of Submersible Robot
42	The 2nd Investigation Committee Related to the Sophistication of Skill Retention Technology Involved in the Aging of Nuclear Structure, Kansai Round-Table Conference	Nov. 29, 2019	Development of Robot Technology Associated with Decommissioning Work and Status of Site Application
43	Hitachi Review 2020	Dec. 2019	Remote Measurement Telemetry Technology to Survey Molten Fuel Directly under the Reactor
44	No. 11, 2019; Atox Technical Report	Dec. 1, 2019	Pilot Study on Slurry Stabilization Treatment Facility
45	Dec. 2019 Issue, OHM (Ohmsha Magazine)	Dec. 5, 2019	Decontamination Robot Technology in Nuclear Power Station
46	Award Lecture, Facility Sharing Award, QST Takasaki Science Festa 2019 (National Institutes for Quantum and Radiological Science and Technology, National Research and Development Agency)	Dec. 11, 2019	Radiation Resistance Evaluation of Non-Soluble Neutron Absorber for Fuel Debris Criticality Control
47	Nuclear Fuel Cycle and Environment, Vol. 26, No. 2 (December issue) (Journal of Nuclear Fuel Cycle and Environment, Atomic Energy Society of Japan)	Dec. 13, 2019	Current Status of Waste Analysis, Fukushima Daiichi Nuclear Power Station
48	International Robot Exhibition 2019	Dec. 18 – 21, 2019	Robot Arm Technology Under Extreme Environments by Mitsubishi Heavy Industries
49	Journal of Nuclear Materials Volume 528	Jan. 2020	Material Characterization of the VULCANO Corium Concrete Interaction Test with the Concrete Representative of Fukushima Daiichi Nuclear Plants
50	The 1st and 2nd Decommissioning Human Resource Development Training (Nuclear Human Resource Development Center, JAEA)	Dec. 11 – 13, 2019 Feb 5 – 7, 2020	○ Status of Decommissioning R&D (Decommissioning and Contaminated Water Management Project) ○ Remote Control Technology: Technology for Robot Operational Under High Dose Rate ○ Criticality Control Technology During Fuel Debris Retrieval
51	Journal of the Atomic Energy Society of Japan Vol. 62, No. 2 (2020)	Feb. 2020	Serialization Course of the 5th: Basic Course for Subcriticality, Development of Criticality Approach Monitoring Method for Fuel Debris in Fukushima Daiichi

List of Joint/Contract Research in FY2019

No.	Project name	Category	Subject	Partner	Period
1	Development of Technology for Fuel Debris Analysis/ Characterization	Contract Research	Research on Radioactive Fine Particle Migration Behavior at Liquid Phase and Gas-Liquid Interface	The University of Tokyo	Jul. 1, 2019 – Jan. 31, 2020
2		Contract Research	Research on Case Example of the Radioactive Fine Particle Scattering in Japan and International Nuclear Facilities	Radioactive Waste Management and Nuclear Facility Decommissioning Technology Center	Jul. 1, 2019 – Jan. 31, 2020
3	Development of Retrieval Technology for Further Increasing the Scale of Fuel Debris and Internal Structures	Contract Research	Validity Evaluation of Remote Operation Support Tool in Poor Visibility and Narrow Environment	Kobe University	Jul. 1, 2019 – Feb. 15, 2021
4		Contract Research	Verification Test of Detection System for Criticality Approach Applied to Inhomogeneous System Including Fuel Debris	Kyoto University	Nov. 8, 2019 – Mar. 13, 2020
5	R&D for Treatment and Disposal of Solid Radioactive Wastes	Contract Research	Study on Long-Term Behavior Evaluation on Cement-Based Material	Taiheiyo Consultant Company, Limited	Apr. 1, 2019 – Feb. 28, 2020
6		Contract Research	Acquisition and Arrangement of Data Used to Review the Evaluation Approach	Central Research Institute of Electric Power Industry, General Incorporated Foundation	Apr. 1, 2019 – Feb. 28, 2020
7		Contract Research	Review on the Long-Term Behavior Evaluation of Alkali Activated Solidification Material (AAM)	Hokkaido University	Apr. 1, 2019 – Feb. 28, 2020
8		Contract Research	Research on Simple and Quick Analytical Method for the Treatment and Disposal of Solid Waste from Fukushima Daiichi NPS	Japan Chemical Analysis Center, Public Interest Incorporated Foundation	Jul. 1, 2019 – Jan. 31, 2020
9		Contract Research	Research on the Reliability Improvement for Statistical Inventory Estimation Method	Central Research Institute of Electric Power Industry, General Incorporated Foundation	Jun. 1, 2019 – Jan. 31, 2020
10		Contract Research	Analysis and Evaluation of Highly Contaminated Materials Involved in Fukushima Daiichi NPS Accident	Nippon Nuclear Fuel Development Company, Limited	Jun. 1, 2019 – Feb. 28, 2020
11		Contract Research	Implementing Arrangement Between Japan Atomic Energy Agency and National Nuclear Laboratory Limited for Co-operation in the Development of Statistically Underpinned Sampling and Analysis Plans for Fukushima Daiichi Wastes.	The National Nuclear Laboratory (NNL) in the U.K.	Aug. 28, 2019 – Feb. 14, 2020

List of Major Research Facilities and Equipment

Over 1 Million Yen

No.	Project name	Equipment name
1	Full-scale Test of Repair and Water Stoppage Technology for Leakage Points inside the Primary Containment Vessel	Heating and Water Supply Facilities
2		Muddy Water Treatment Facility
3	Development of Technology for Construction of Water Circulation System in PCV	Positioning Device
4		3D Handy Scanner (Measuring Equipment Installed in the Gap Measuring Device)
5		S/C Joint Welding Equipment
6		Weld Bead Processing Equipment
7		Temporary Sealing Equipment
8		Element Test Facility Related to implementation of D/W Water Intake Pipe in PCV
9	Development of Technology for Construction of Water Circulation System in PCV (Full-scale test)	Installation Cart
10		Transport Cart
11	Development of Technology for Investigation inside Primary Containment Vessel	Investigation Device
12		Scattering Prevention Facility for B1 Investigation Device
13		Ancillary Facility for B1 Investigation Device
14		Simulated Object for Mockup Test, B1 Investigation Device
15		Shielding Block Removing Device
16		Fuel Debris Shape Measuring Device
17		Fuel Debris Shape Measuring Device, Device for Element Test
18		A2 Investigation Device (Including Chamber and Guide Pipe)
19		Device for Cutting to Open a Hole of X-6 Penetration: 1 set
20		Advanced Confirmation Device for inside Penetration: 1 set
21		Sediment Removing Device: 1 set (Chamber included)
22		Ancillary Equipment for A2 Investigation Device: 1 set
23		Advanced Confirmation Device for inside Pedestal: 1 set
24		Simulated Mockup Apparatus of PCV Internal Structures: 1 set
25		Investigation Element Test Device: 1 set
26		Hatch Opening Device: Associated Machine, 1 set

No.	Project name	Equipment name
27	Development of Technology for Investigation inside Primary Containment Vessel	B2 Investigation Device
28		Scattering Prevention System for B2 Investigation Device
29		Ancillary System for B2 Investigation Device
30		B2 Investigation Device; Simulated Test Device for Mockup Test
31		Prototype of the Submersible Type Device: 1 set
32		Remote Operated Device to Cut a Hole for X-6 Penetration: 1 set
33	Development of Technology for Investigation inside Reactor Pressure Vessel	Single Cable Drum
34		Gamma-Theta Positioning Mechanism
35		Short Telescoping Pipe for Sliding Ability Test
36		Long Telescopic Pipe
37		Camera Remote Control Software
38		Reactor Internal Structure Processing Device
39	Fuel Debris Characterization	Large Capacity Thermogravimetric Scales/ Simultaneous Thermal Analyzer
40		Crystal Piezoelectric Type 4-Component Cutting Dynamometer
41		Elemental Analyzing System for SEM
42		Hydraulic Type Automatic Embedded Equipment
43		Inverted Metal Microscope
44		Carbon Coater
45		Vacuum Replacement Arc Melting Furnace
46		Fuel Debris Compression Test Device
47		Fuel Debris Sonic Speed Measurement Device
48		Metallographic Image Analyzer
49		Dynamic Micro Hardness Tester
50		Simultaneous Thermal Analyzing System
51		Gas Piping Valve Heater
52		Sample Cutting Machine
53		Sample Polishing Machine
54		Core Sampling Collection Unit
55		Laser Diffraction Type Grain Size Distribution Measuring Device
56		Dry Automatic Density Meter
57		Heating Furnace for Thermal Analyzer
58	Development of Technologies for Fuel Debris Characterization and Analysis	Alpha Particle Aerosol Basic Experimental Device
59		Particle Measuring Instrument
60	Development of Analysis/ Estimation Technology for Fuel Debris Characterization	UNIV Workstation
61		High Dispersion Type Powder Generator
62		COMSOL Multiphysics
63	Project of Development of Fundamental Technology for Retrieving Fuel Debris/ Internal Structures	Full Scale Test Device
64		Full Scale Test Facility
65		1/4 Scale Test Device
66		1/4 Scale Test Facility
67		1/4 Scale Model Test
68		1/4 Scale Reactive Force Retaining Mechanism Combination Test Sample
69		Test Sample of Water Shielding in PRV Upper Part
70		Flexible Structure Arm: 1 Set
71		Flexible Structure Arm Control Device
72		Facility for Mockup in PCV
73		Facility for Equipment Hatch Transport Test
74		1/1 Scale Hydraulic Type Reactive Force Retaining Mechanism
75		1/1 Scale Electric Reactive Force Retaining Mechanism
76		Laser Gouging Power Measurement Unit
77		Laser Gouging Head
78		Equipment for Element Test of Access Device
79		Robot Arm
80		Access Rail
81		PCV Welding Device
82	Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures	Hydraulic Cutter (For Element Test of Fuel Debris Processing)
83		Absorber Injection Device (Viscous Material) (For Development of Criticality Prevention Technology)
84		Absorber Injection Device (Powdery Material) (For Development of Criticality Prevention Technology)
85		Tool Changer (For Development of Criticality Prevention Technology)

No.	Project name	Equipment name
86	Development of Technology for Increasing the Scale of Fuel Debris Retrieval in Stages	Trial Retrieval and Recovery Device for the Initial Unit
87		Element Test Device for Remote Transport Cart
88		Retrieval and Recovery Device
89		Element Test Device for X-6 Penetration Connection Structural Double Door
90		Test Device for Cutting Powder Scattering Rate
91	R&D for Treatment and Disposal of Solid Wastes	Chamber for Alpha Nuclide Analysis
92		Digital Spectrometer
93		Efficiency Calculation Program for Gamma-Ray Measurement
94		Aerosol Migration Observation Instrument
95		Well-Type Ge Detector
96		Core Data Collection Unit
97		Test Equipment for Zeolite Sample Collection
98		Prototype of Small-size Core Sample Collection Device
99		Portable X-Ray Fluorescence Analyzer
100		Alpha Camera
101		Optical Test Equipment
102		Image Data Synthesizing Software
103		Cart with Lifting and Pan-Tilt Function
104		KURION, SARRY Simulated Adsorption Tower
105		Solidified Sample Crusher
106		Thermostatis Tank for Dissolution Test
107		Solidified Body Curing Cabinet
108		Solidified Substance Residue Decomposer
109		Dry Humidity Control Device
110		Solidified Material Condensing Test Apparatus
111	R&D for Treatment and Disposal of Solid Wastes (R&D for Advanced Processing and Analytical Methods)	Evaluation System Software
112		Material Cross-Section Processing Machine
113		Solidified Material Condensing Test Apparatus
114		Alpha-Ray Remote Measuring Device-1 (Equipment Including Packaging Detector, Camera, and Temperature Adjustment Mechanism in Housing: 1 Set)
115		Alpha-Ray Remote Measuring Device-2 (Combination of Detector and Circuit: Used for the Comparison to Above Alpha-Ray Remote Measuring Device-2 for Backup)
116		Dust Testing Device
117	Test and Research to Aim the Stable Operation of Advanced Liquid Processing System and Slurry Stabilizing Facility	Full Scale Filter Press
118		Tank Storage Tent for Slurry Preparation Tank Facility
119		Slurry Preparation Tank Facility
120		Addition of Full-Scale Filter Press, Dehydrator Pump and Cleaning Discharge Pipe
121		Filter Cloth Replacement Stand, Full-Scale Filter Press Test Apparatus
122		Crushing/ Transfer Device