(Provisional translation)

Mid-and-long-Term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO

December 21, 2011

Nuclear Emergency Response Headquarters

Government and TEPCO's Mid-to-Long Term Countermeasure Meeting

Contents

1. Introduction

After the accident at TEPCO Fukushima Daiichi nuclear power station, TEPCO and the government prepared the "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station", and pursued planned action on that basis towards an early resolution to the accident. The first objective of the above roadmap, the "steady downward trend in radiation levels" was achieved in July 2011, and the objective of Step 2, "Release of radioactive materials is under control and radiation doses are being significantly held down" has recently been achieved. Through these efforts, the reactors have reached a state of cold shutdown, and it is now possible to maintain an adequately low level of radioactive exposure at the site boundaries, even in the event of unexpected situations. Therefore, in addition to the reactors of TEPCO Fukushima Daiichi nuclear power station to reaching a stable state, the impact of radiation beyond the plant site has been adequately reduced.

After the end of Step 2, there will be a transition from efforts up to that point, aimed at plant stabilization, to efforts to reliably maintain that stable state. In parallel, it is vitally important that the removal of fuel from the spent fuel pools of units 1–4, removal of fuel debris[1] from the reactor pressure vessels and primary containment vessels (PCVs) of units 1–3, and other measures towards decommissioning, should continue over the mid-and-long term, so that evacuated residents will be able to return to their homes as soon as possible and the people of the region, and of the country as a whole, will be able to live without fear.

For this kind of mid-and-long term efforts, the Expert Group for Mid-and-long Term Action at TEPCO Fukushima Daiichi Nuclear Power Station (referred to below as the "Japan Atomic Energy Commission Expert Group"), which was established by the Japan Atomic Energy Commission in August, is examining technical challenges and research and development points. It has concluded that "The target is that it will take no more than ten years before removal of fuel debris starts. We estimate that the completion of decommissioning will take at least 30 years".

On November 9, Mr. Edano, the Minister of the Economy, Trade and Industry, and Mr. Hosono, the Minister for the Restoration from and Prevention of Nuclear Accident, issued an order (referred to below as "the joint ministerial order") on the writing of a mid-and-long term roadmap for decommissioning and other objectives (referred to below as "this roadmap") to TEPCO, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency.

Furthermore, with the completion of Step 2, the Government-TEPCO Integrated Response Office was abolished and the Government and TEPCO's Mid-to-Long Term Countermeasure Meeting was established under the Nuclear Emergency Response Headquarters to manage the preparation and progress of this roadmap.

This roadmap was written by the above three parties, in response to the joint ministerial order, and decided by the Council.

This roadmap defines the period from the completion of Step 2 to the start of fuel removal from the spent fuel pools (target is within two years), as Phase 1. In addition to work preparing to start removing fuel from the spent fuel pools, this phase will include

---

[1] Material in which fuel and its cladding tubes etc. have melted and resolidified.

research and development necessary for the removal of fuel debris, the start of site investigations using the results of that R&D, and other tasks in a period of intensive preparation for decommissioning to begin in earnest.

Beyond Phase 1, this roadmap defines the period targeted to start ten years after the completion of Step 2 and continuing to the start of fuel debris removal, as Phase 2, and the subsequent period to the end of decommissioning as Phase 3.

The implementation of this roadmap is a long-term task that faces many technically difficult challenges that have never been experienced before, so it is important to bring together the collective wisdom of the nation as the government and TEPCO work in close partnership.

2. Basic Policy towards Addressing the Mid-and-long Term Issues

[Policy 1] Systematically tackle the issues while placing top priority on the safety of local citizens and workers.

[Policy 2] Move forward while maintaining transparent communications with local and national citizens to gain their understanding and respect.

[Policy 3] Continually update this roadmap in consideration of the on-site situation and the latest R&D results etc.

[Policy 4] Harmonize the individual efforts of TEPCO, ANRE, and NISA to achieve our goal.

◆ Based on the above policy, TEPCO, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency, will take appropriate action on the basis of the following policies, aware of the importance of realizing this roadmap.

1. With the shared awareness that many of the tasks involved are unprecedented and of great technical difficulty, they will collaborate with relevant industries and research agencies to implement the necessary research and development, and to apply it to the site.
2. TEPCO will set detailed Holding points at each juncture as these results are obtained, and take on-site conditions into consideration in appraising the feasibility and suitability of the technologies to be applied, as it works steadily through action in the mid-and-long term and builds an organization to that end.
3. The Agency for Natural Resources and Energy will take a leading role in budgetary provisions and project management for the above research and development, and provide appropriate guidance and supervision to the work of TEPCO.
4. The Nuclear and Industrial Safety Agency will prepare necessary regulatory systems for work in the mid-and-long term, and confirm that safety is assured in work by TEPCO.
5. TEPCO, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency will maintain transparency by periodically reviewing this plan and publishing the status of work in the mid-and-long term.

3. Approach to Ensuring Safety

3-1. Basic Policies on Ensuring Mid-and-long Term Safety

(1) Facilities Operation Plan Based on the Concept of Ensuring the Mid-Term Safety

To ensure the safety of Fukushima Daiichi nuclear power station after the accident, Step 1 and Step 2 provided cooling to the damaged reactor cores through injection and circulation of water, provided circulating cooling to the spent fuel pools, processed and prevented the leakage of water contaminated with high-level radioactivity, injected nitrogen gas into the PCVs to prevent hydrogen explosions, and restored power supplies lost in the accident, among other actions. Furthermore, key equipment was installed with redundancy and diversity to ensure availability of necessary functions in the event of an accident. With the completion of Step 2, the cooling of the reactors is maintained in a stable state, and the amount of public exposure to additional emissions from PCVs has been greatly suppressed.

To ensure the safety of the public and workers in the period extending from the completion of Step 2 to the start of specific work towards decommissioning, the Nuclear and Industrial Safety Agency published “SAFETY DIRECTIVE Ensuring the Mid-Term Safety” on October 3rd, and TEPCO responded by publishing its “Facilities Operation Plan Based on the SAFETY DIRECTIVE Ensuring the Mid-Term Safety”.

The Nuclear and Industrial Safety Agency confirmed that this facilities operation plan provided suitable measures for the following:

- It must be possible to appropriately remove decay heat from the reactor pressure vessels and PCVs.
- Hydrogen explosions in the PCVs must be prevented.
- Decay heat must be appropriately removed from the spent fuel pools and transported to a location for ultimate release.
- It must be possible to prevent criticality in the reactor pressure vessels and PCVs.

These measures together, devised appropriately, make it possible to rapidly restore cooling function from backup functions in the event that an accident causes a loss of cooling function, and even if extremely severe conditions are envisaged for such an accident, it is confirmed that radioactive exposure levels at the site boundaries would be adequately low.

Over the coming three years, TEPCO is to ensurely implement this facilities operation plan, reporting regularly to the Nuclear and Industrial Safety Agency. NISA will check and assess the safety of TEPCO’s efforts, based on those reports and its own independent investigations. Based on the results of those assessments, it can revise individual items in “SAFETY DIRECTIVE Ensuring the Mid-Term Safety” at any time, as the need arises, and make an overall review at least once per year, to ensure the safety of the power station.

(2) Main basic goals for ensuring the safety of mid-and-long term actions

In the mid-and-long term, removal of fuel from the spent fuel pools, removal of fuel debris from reactor cores, and other tasks will be performed to move fuel from the accident-affected pools in the reactor buildings and fuel from the reactor cores to common pools and storage containers, which are in more stable condition. Safety measures must be devised for this fuel removal work, to prevent accidents such as dropped fuel in the removal process causing new emissions of radioactive substances.

TEPCO will continue to consider specific working methods for these tasks on the basis of basic targets indicated by the Nuclear and Industrial Safety Agency. At each stage, it will assess the safety of equipment and procedures (including earthquake resistance) and the radioactive impact on the surrounding environment, and will receive assessment and confirmation from the Nuclear and Industrial Safety Agency before implementation.

<Main basic goals for ensuring the safety of mid-and-long term actions>

1. It must be possible to identify emission sources of radioactive substances, devise appropriate anti-emission measures, and perform monitoring.
2. It must be possible to appropriately remove decay heat from the reactor pressure vessels, PCVs and spent fuel pools.
3. It must be possible to prevent criticality in the reactor pressure vessels, PCVs and spent fuel pools.
4. It must be possible to appropriately detect, manage and process flammable gases.
5. The effective dose caused by the reactor facilities must be reduced as far as is rationally attainable.
6. Even in the event of any temporary loss of safety-related function, the amount of exposure due to additional emissions of radioactive substances at the site boundaries must have no adverse effect on safety.
7. Worker radiation exposure must comply with the law.

3-2. Policies for Ensuring Safety

(1) Equipment safety

In the same way as Step 2, Phase 1 will maintain and strengthen [1] functions for the suppression and management of radioactive substance emissions, [2] cooling functions in the reactors and spent fuel pools, [3] criticality prevention functions, and [4] hydrogen explosion prevention functions. Specifically, in addition to improvement of accumulated water processing facilities and addition of continuous monitoring functions against recriticality, the operational status of the equipment will be checked continuously, and necessary measures will be devised, to further improve reliability. The plan to start removing fuel from the spent fuel pool and further stabilize the plant is in parallel with that work.

In Phase 2 and beyond, the equipment necessary to maintain plant stability in the long term will continue to receive work to enhance its reliability, including appropriate maintenance and management. The removal of fuel debris and other operations will transition the plant into a state that can be maintained stably without depending on the above equipment, to be followed by final decommissioning.

(2) Working safety

General working safety, radiation management and health management for workers will continue and expand the work that was under way up to Step 2, including preliminary safety assessment, dose reduction measures, medical treatment organization development, and other measures.

For radiation management, monitoring of the working environment will be expanded, dosage management will be implemented thoroughly, dosage due to decontamination etc. will be reduced. Robots and other remote operation technologies will be applied as appropriate in high-radiation environments. These and other measures will cut amounts of exposure to workers to below exposure limits.

(3) Reduction and management of radiation levels at site boundaries

The reactors are now being cooled stably, emissions of radioactive substances from PCVs have been suppressed, and as a result, annual radiation exposure at site boundaries is assessed at a maximum of 0.1 mSv/year. Furthermore, the target to be achieved within FY2012 is to cut effective dose at the site boundaries to below 1 mSv/year. This is to be achieved by reducing the impact of additional emissions from the power station as a whole, and of radiation from rubble etc. and secondary waste from water processing (used cesium adsorption towers, sludge, etc., collectively referred to below as “secondary waste from water processing”), which are generated after the accident and stored on site.

In addition to the above, decontamination within the site will be implemented systematically to further reduce radiation at the site boundaries.

For gaseous waste, efforts to further reduce environmental emissions will continue, together with emission monitoring. For liquid waste, the following necessary deliberations will be made in future and used to devise countermeasures, and discharges of contaminated water to the ocean will not be made lightly.

[1] Radical countermeasures against inflow of groundwater to reactor buildings, which raises water levels

[2] Measures to raise the decontamination capacity of the water purification facilities and ensure their stable operation, including substitute facilities to use in case of failure

[3] Further installation of land-based facilities for contaminated water management

Discharges to the sea must not be performed without the approval of the relevant ministries.

To confirm that there is no abnormal situation, airborne radiation dosage rates and radioactivity of environmental samples will be monitored continuously, near the boundaries of the perimeter monitoring areas and in nearby areas.

(4) Other safety matters

Appropriate measures will be implemented, under the relevant laws and the guidance of the national government and related agencies, concerning physical protection of nuclear material, and nuclear material safeguards.

4. Phase Divisions and Timed Targets in the Mid-and-long Term Roadmap

Appendix 1-1 presents the main schedule of this Mid-and-long-term Roadmap for Decommissioning Reactors 1–4 of Fukushima Daiichi Nuclear Power Station. This roadmap was prepared jointly between TEPCO, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency, based on December 7 report from the Japan Atomic Energy Commission Expert Group and the joint ministerial order issued on November 9, and drawing on currently-available knowledge, such as the case of stabilizing the US TMI-2 accident[2]. The three parties performed the roles stated in Chapter 2, and are working steadily on the implementation tasks stated in this roadmap.

The processes and tasks in this roadmap are subject to revision due to future on-site circumstances, research and development results and other inputs, and will be revised accordingly through an ongoing process of verification.

4-1. Approach to Categorization in the Mid-and-long Term

This roadmap employs the following definitions for Phase 1–3.

- Phase 1: From the completion of Step 2 to the start of fuel removal from the spent fuel pool (target is within two years)
  - In addition to work preparing to start removing fuel from the spent fuel pool, this phase will include research and development necessary for the removal of fuel debris, the start of site investigations, and other tasks in a period of intensive preparation for decommissioning.
- Phase 2: From the end of Phase 1 to the start of fuel debris removal (target is within ten years)
  - Within this phase, we will step up many research and development tasks towards the removal of fuel debris, and tasks such as reinforcement of PCV.
  - This phase will be further divided into three steps: early, mid, and late, as a guideline for judging progress within the phase.
- Phase 3: From the end of Phase 2 to the end of decommissioning (target is 30–40 years)
  - This is the phase for implementation of tasks from fuel debris removal to the end of decommissioning.

4-2. Timed Targets and Holding points in the Mid-and-long Term Roadmap

For the immediate period of approximately three years (to the end of FY2014), including Phase 1, we have set the progression for each year, with timed targets wherever possible. In FY2015 and beyond, the timing and content of measures are subject to major change in response to on-site circumstances, research and development results, and other inputs. Therefore, rough timed targets have been set as far as possible. The tasks within each Phase also face many technical issues, and will have to proceed in a phased process, based on on-site circumstances, research and development results, safety requirements, and other circumstances. Therefore, at the key points for judgment on progression to subsequent processes, there will be

[2] Unit 2 of Three Mile Island nuclear power station at US.

further deliberation and judgment, including additional research and development and revision of process and task content. These are set as Holding points (HP).

The main timed targets and holding points (HP) in this roadmap are as follows:

(1) Reactor cooling / accumulated water[3] processing

- Methods to improve the reliability of the existing water processing facilities will be considered, with implementation of the main measures by FY2012, and ongoing improvements thereafter.
- Multi-nuclide removal facilities will be installed within 2012 that will be able to remove radioactive substances other than Cesium, which are difficult to remove with the existing facilities.
- Scale down of circulation loop will be implemented in stages, by improving the reliability of the existing water processing facilities, and by measures in Phase 2 (mid), such as stopping inter-building water leakage and repairing lower part of the PCV.
- Accumulated water processing of water in the turbine building and reactor buildings will be completed in Phase 2 (late).

<Holding points concerning accumulated water processing>

Methods for working to reduce accumulated water could change according to the success or failure of stopping inter-building water leakage and repairing lower part of the PCV, so the following related holding point is set:

(HP1-1): Completion of stopping inter-building water leakage between reactor and turbine buildings and repairing lower part of the PCV [Phase 2 (mid)]

(2) Plans to Mitigate Sea Water Contamination

- Should underground water be contaminated, in order to prevent underground water flowing into the ocean, installing water shielding walls by mid FY2014
- A silt fence will be installed on the side of units 5 and 6, and the seabed areas in front of units 1–4, and of units 5 and 6, will be covered with solidifying seabed soil, to prevent diffusion of seabed soil. In addition, circulating seawater purification facilities will continue to operate in the area in front of the intake canal for units 1–4, with the target of reducing radioactive substance concentrations in seawater in the port below the limit outside of the environment surveillance area, as stipulated by government notification, within FY2012.

(3) Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries

- Plans to reduce the effective radiation dose at the site boundaries to below 1 mSv/year within FY2012 as a target date, due to additional emissions from the whole site and radioactive waste stored on the site after the accident (secondary waste materials via water processing and debris etc.).

[3] Contaminated water accumulated in the turbine buildings and reactor buildings of units 1–4

- Based on the form of secondary waste due to water processing that is now in progress, and the estimated lifespan of storage containers, a facility renewal plan for storage containers etc. will be adopted by the end of FY2014.
- Facilities will be updated as necessary, in Phase 2 (late) and beyond.

(4) Plan to Remove Fuels from Spent Fuel Pools

- Plan to start fuel removal from Unit 4 within 2 years after completing Step 2 (within 2013).
- Plan to start fuel removal from Unit 3 approximately 3 years after completing Step 2 (end of 2014).
- As for Unit 1, plan to develop a specific fuel removal plan based on knowledge and experiences at Units 3 & 4 and investigations of rubble, and finish fuel removal in the Phase 2 (mid).
- As for Unit 2, plan to develop a specific fuel removal plan based on the situation after the inside-building decontamination etc. and investigations of the installed facilities, and finish fuel removal in the Phase 2 (mid).
- Plan to complete fuel removal from all Units during Phase 2 (late).
- Plan to determine reprocessing and storing methods for removed fuels during Phase 2 (late).

<Holding points concerning removed fuel>

The following holding points are set for the handling of removed fuel, because it will be necessary to base such handling on assessment of the soundness of long-term storage and research and development results for reprocessing.

(HP2-1): Determination of methods for reprocessing and storing spent fuel [Phase 2 (late)]

(5) Fuel Debris Removal Plan

- Plan to start fuel debris removal in the first unit within 10 years after completion of Step 2.
- Research and development concerning construction methods, equipment development and other topics will be implemented for realization of the plan. Implementation of this plan will include thorough demonstration of the suitability of technologies produced by this research for use on the site (referred to below as “field test”).
- The products of the development of remote decontamination technology, to be completed by the end of FY2013, will be applied on site, as appropriate. Other than decontamination within the reactor buildings, this technology will be used to develop technology for identification of PCV leakage point (by around mid-FY2014, including field test). That will be used for decontamination within reactor buildings by the end of FY2014, to gain access to building interiors, and begin surveying PCV leakage point, and making PCV internal investigations of reactor containment from outside.

<Holding points concerning fuel debris removal work etc.>

The following holding points are set on the basis of the on-site situation, research and development results (including field test), and the situation of safety requirements, etc. Holding points are also set concerning the handling of the removed fuel debris.

(HP3-1): Determining methods for repairing PCV, determining water stop methods [Phase 2 (early)]
(Target research and development timing)
End of field test of PCV repairing technology (inter-building, lower parts of PCV)
: Around the end of FY2015

(HP3-2): Completion of flooding of lower parts of PCV, determining PCV internal investigation methods [Phase 2 (mid)]
(Target research and development timing)
End of field test of PCV internal investigation technology: Around the end of FY2016

(HP3-3): Determining methods to repair upper parts of PCV [Phase 2 (mid)]
(Target research and development timing)
End of field test of PCV upper part repairing technology: Around the end of FY2017

(HP3-4): Completion of flooding of upper parts of PCV, determining RPV internal investigation methods [Phase 2 (late)]
(Target research and development timing)
End of field test of reactor pressure vessel internal investigation technology: Around mid-FY2019

(HP3-5): Determining fuel debris removal method and completion of preparation of fuel debris containers, etc.
[Phase 2 (late)]
(Target research and development end timing)
End of field test of fuel debris removal technology: Around the end of FY2021
End of development of fuel debris containers: Around the end of FY2019
Establishment of a fuel debris weighing and management policy: Around the end of FY2020

(HP3-6): Determining processing / disposal methods of fuel debris. [Phase 3]

(6) Reactor Facilities Demolition Plan

- Plan to complete the reactor facility demolition in Units 1 to 4 within 30 to 40 years after the completion of Step 2.
  (Reference) Demolition of one reactor unit is expected to take over 20 years, judging by the time taken for fuel debris removal at TMI-2 (over four years) and the standard demolition process for regular reactor facilities (around 15 years).
- The plan for establish a basic database of on-site contamination status etc., which will be required for consideration of demolition and decontamination engineering methods, is to be written within FY2012.

- A basic database for use in demolition of reactor facilities will be built between Phase 1 and Phase 2 (mid).
- Research and development of remote demolition (disposal standards etc. for demolition waste) for remote demolition of reactor facilities, based on the above database, will be implemented between Phase 2 (mid) and Phase 3.

<Holding point for demolition of reactor facilities>

(HP4-1): Determining demolition and decontamination engineering methods. Developing disposal standards for dismantled waste. [Phase 3]
-> Begin the design and manufacture of devices and equipment necessary for demolition and disposal.

(HP4-2): Outlook for disposal of demolition waste. Complete research & development and make plans. [Phase 3]
-> Begin demolition.

(7) Radioactive Waste Processing and Disposal Plan

- The form of waste generated after this accident differs from that generated normally in nuclear power stations (nuclide composition, salt content, etc.), so a plan for research and development related to its processing and disposal will be written within FY2012.
- The form of waste materials will be identified and their quantities assessed by the end of FY2014.
- The disposal concept will be devised in Phase 2 on the basis of the results.

<Holding points for radioactive waste processing and disposal>

The aim is to carry these wastes to disposal sites at the end of Phase 3 together with waste generated in the demolition works, subject to the setting of the following holding points. Consideration of this area will continue, reflecting research results.

(HP5-1): Confirm the suitability of existing disposal concepts for the forms of waste [Phase 2 (mid)]

(HP5-2): Confirm the outlook for safety in the processing and disposal of waste [Phase 2 (late)]

(HP5-3): Confirm solid waste specifications and manufacturing methods [Phase 3]

(HP5-4): Installation of solid waste manufacturing equipment and the outlook for processing [Phase 3]

5. Specific Plans for Mid-and-long Term Action

5-1. Efforts for Maintaining Plant in an Ongoing Stable State

(1) Plan for reactor cooling

1. Ongoing monitoring of reactor cold shutdown states

The reactors have already reached a state of cold shutdown in Step 2. In the period until the end of fuel debris removal in Phase 1 and beyond, cooling by water injection will continue as the reactor interior is reliably cooled. The stable maintenance of the state of cold shutdown will be monitored continuously, using parameters such as temperature and pressure. To complement the above monitoring, optical fiber instruments will be inserted into the PCVs, first in Unit 2, to permit at least partial observation of the interior, for direct confirmation of water level, temperature, and other circumstances. Implementation for units 1 and 3 will be judged on the basis of results from Unit 2 and the findings of on-site investigations.

2. Improving the reliability of circulating water injection cooling equipment

The equipment for coolant water injection to the reactors current draws water from the turbine building and stores water that has been processed by accumulated water processing equipment in the processed water buffer tank. The stored water is used as the source for injection to units 1–3, via three normal reactor injection pumps on the hill and water injection lines.

As a backup for this equipment, two systems of tanks and water injection lines have been ensured as water sources, for diversity and redundancy. Furthermore, the condensate storage tank (CST) and the processed water buffer tank for Unit 3 are used as the water source for a normal water injection line fed by a water injection pump in the turbine building. These are to be added at the start of 2012, and will achieve highly reliable water injection.

In Phase 1, some of the pipes and other elements that make up the line will be strengthened and made more earthquake resistant, as a measure to further improve reliability, based on the operating status etc. of the line.

3. Decreasing circulation loop

In Phase 2, the water intake source will be systematically changed from the current turbine buildings to the basement levels of the reactor buildings and the PCVs. This change will be implemented to ensure consistency with the plan to block inter-building leakage between the reactor buildings and the turbine buildings and reinforce leaking points in the PCVs, which will use the results of future research and development.

After reinforcement of the leaking points in the PCVs is complete, the interiors of the PCVs will be filled with water, and consideration will be given to decreasing the circulation loop of coolant circulation and cleaning, to use only water held inside the PCVs. That would make cooling more stable.

(2) Plan for accumulated water processing

1. Improvement of the reliability of accumulated water processing facilities

Processing facilities for contaminated water (accumulated water) that has accumulated in turbine buildings will have their designs improved, based on various problems which occurred early in their operation, and redundancy will be added, to enhance their reliability. Leakage detectors within the embankment will be installed by the end of Step 2, in response to the water leakage from the evaporative concentration apparatus that happened on December 4th.

In Phase 1, reliability improvement etc. for the existing facilities will be considered, and the plan is to implement the main countermeasures in FY2012, to maintain stable operation. In combination, countermeasures will be implemented to reduce risks of leakage from pipes etc., focusing on shortening the circulation lines from the current length of approximately 4km. Furthermore, multi-nuclide removal equipment, able to greatly reduce concentrations of radioactive substances in processed water[4], will be installed within 2012. The equipment will be managed so as to keep radioactive substance concentrations in processed water well below density limits by the announcement for out of supervised areas.

In Phase 2 (mid), the further reduction of circulation lines will be considered in response to the state of closure of leaks between reactor and turbine buildings, and of leaks from the PCV, which will be implemented on the basis of future research and development.

Storage facilities for waste etc. necessitated by water processing will be dealt with as necessary, such as by expanding existing storage facilities.

2. Rapid processing of accumulated water

Sub-drainage[5] has yet to be raised from within the pits (wells) built around the turbine buildings etc., in which low-level contamination has been confirmed. Therefore, groundwater is constantly flowing into the turbine buildings etc.

In Phase 1, sub-drainage will be purified and confirmed free of contamination, and the level of accumulated water in the turbine buildings etc. will be managed so that it does not rise above the sub-drainage level, which will be gradually reduced. In this way, measures will be implemented on the basis of the state of sub-drainage purification etc., to suppress the volume of groundwater inflow and reduce the volume of accumulated water in the turbine buildings.

In Phase 2 (mid), once leakage between the reactor buildings and turbine buildings, and leaks from PCVs, have been blocked, there will no longer be any increase of accumulated water due to leakage of reactor coolant water. Therefore, accumulated water processing will continue to be implemented steadily, with the aim of completing processing accumulated water below ground in the turbine buildings and reactor buildings by Phase 2 (late).

For the processing of accumulated water, the following necessary deliberations will be made and used to devise countermeasures, and discharges of contaminated water to the ocean will not be made lightly.

- Radical countermeasures against inflow of groundwater to reactor buildings, which raises water levels
- Measures to raise the decontamination capacity of the water processing facilities and ensure their stable operation, including substitute facilities to use in case of failure
- Further installation of land-based facilities for contaminated water management

Discharges to the sea must not be performed without the approval of the relevant ministries.

[4] Water from which cesium has been removed by the current water purification facilities.
[5] Groundwater that has flowed into pits (wells) built around buildings.

(HP1-1) Completion of stopping inter-building water leakage between reactor and turbine buildings and repairing lower part of the PCVs

- Based on the ability to adequately suppress inflow of groundwater into buildings by blocking inter-building leakage between reactor buildings and turbine buildings and reinforcing the lower parts of PCVs, and by managing the level of sub-drainage, the volume of accumulated water below ground level in the turbine buildings and reactor buildings will be systematically processed and reduced.

5-2. Plan to Reduce Radioactive Dosage in the Power Station as a Whole, and to Mitigate Sea Water Contamination

(1) Plans to Mitigate Sea Water Contamination

1. Reduction of the risk of expanded sea water contamination when contaminated water leaks

   Until now, a portion of the accumulated water in the buildings has passed through pits etc. to flow into the sea, so a variety of countermeasures have been devised, including blocking pits etc., installation of silt fences[6] in the port, and installation of circulating seawater purification facilities. The level of accumulated water inside buildings is managed to suppress its outflow into the ground, and that management will continue.

   In addition to these measures, work began in October to install water shielding walls on the front of the existing breakwaters in front of Units 1–4, to prevent the dispersion of sea water contamination in the event of contaminated water into groundwater. It is planned for completion by mid-FY2014.

2. Reduction of radioactive substance concentrations in sea water in the port (below announced density)

   The silt fence on the side of Units 5 and 6 will be installed by the end of FY2011, and seabed soil in the area in front of the intake canals for Units 1–4, and for Units 5 and 6, will be covered with solidifying soil by mid-FY2012. These measures will prevent diffusion of seabed soil. In addition, circulating seawater purification facilities will continue to operate in the area in front of the intake canal for Units 1–4, with the target of rapidly reducing radioactive substance concentrations in sea water in the port below the density limit by the announcement for out of supervised areas. Mud raised by dredging the port to a depth sufficient for the passage of large vessels will be accumulated within the port, and prevented from dispersing by covering it with solidifying soil, or other measures.

   Also, in addition to the maintenance and management of constructed facilities etc., the quality of groundwater and sea water will be monitored constantly until decommissioning is complete.

(2) Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries

1. Solid waste management

[6] This is an underwater fence consisting of curtains hung in the water, to retain dispersing silt.

The earthquake, tsunami and hydrogen explosions generated rubble etc. within the power station site. The rubble that has been recovered mainly consists of concrete and metal and varies widely from low to high radioactive dose rates. The accident restoration work also generates felled trees, secondary waste from water processing, used protective clothing, etc.

The rubble etc. is sorted, as far as possible, by dose rate and material, and that which risks airborne dispersion of radioactive substances will be protected by dispersion countermeasures (placement in containers, sheet covering, etc.) for temporary storage. Secondary waste from water processing will be stored in temporary storage facilities, based on consideration of radiation shielding.

Used protective clothing etc. will be packed in bags or containers and stored temporarily in a predetermined location. Felled trees will be stored temporarily in a predetermined location, and treated against fire.

As rubble etc. will require a long period of temporary storage before it is moved to disposal sites in Phase 3, a management plan will be written for ensuring and appropriately managing areas corresponding to the volumes and radioactive levels of waste generated in future. The plan will be implemented systematically, and reviewed as necessary. Within that plan, countermeasures will be implemented using shielding etc. according to the radioactive impact of the rubble etc. on the site boundaries. Consideration will also be given to reducing the volume of rubble, and reusing it.

Storage areas will also be ensured according to the quantities of secondary waste from water processing generated in future, and measures such as further shielding will be implemented, according to the radioactive impact of the waste on the site boundaries, to reduce that impact. Also, based on the form of secondary waste from water processing that is now in progress, and the estimated lifespan of storage containers, a facility renewal plan for storage containers etc. will be adopted by the end of FY2014.

In Phase 2 (late), measures implemented up to that time will continue, and storage containers and other equipment for secondary waste from water processing will be renewed as necessary.

2. Gaseous waste management

By now, with the cooling of the reactor, the annual radiation exposure at site boundaries due to emission of radioactive substances from PCVs is assessed at a maximum of 0.1 mSv/year, and new emissions have been suppressed.

In Phase 1, the PCV gas control system now installed and in operation on Units 1 and 2 will be installed as soon as possible on Unit 3, in order to suppress the emission of gaseous waste. Radiation monitors on that equipment, and on the reactor building covers and filter outlets will provide continuous monitoring.

When the level of accumulated water containing radioactive substances in the underground parts of turbine buildings for Units 1–4, waste processing buildings and centralized waste treatment buildings falls, drying could lead to the airborne re-dispersion of radioactive substances, so underground openings are blocked. Such emissions will continue to be monitored in each building, as far as is appropriate and possible, in Phase 1 and beyond.

Airborne concentrations of radioactive substances will be monitored in areas near the site, to confirm that they are below airborne concentration density limits by the announcement for out of supervised areas. As all supervised areas are currently set as areas requiring the same level of management as controlled areas, airborne concentrations of radioactive substances will be monitored in perimeter monitoring areas as well, to confirm that they are below airborne concentration limits by the announcement.

3. Liquid waste management

Accumulated water and other liquid wastes will be stored, or treated (purified) in water purification facilities to reduce their levels of radioactive substances. Processed water generated by purification processes will be stored in tanks, and will be appropriately managed, such as by reuse after desalination.

Contaminated water will be handled as stated in 3-2 (3).

4. Reduction of dosage at site boundaries (attainment of dosage <1 mSv/year at site boundaries due sources such as new emissions of radioactive substances etc. from the power station as a whole)

The aim is to reduce the effective radiation dose at the site boundaries to below 1 mSv/year within FY2012, including effective dose due to additional emissions of radioactive substances from the power station as a whole, and radioactive waste produced after the accident and stored on the site (secondary waste from water processing, rubble, etc.), through appropriate implementation of the above measures.

5. Continuous implementation of environmental monitoring

To confirm that there is no abnormal situation, airborne radiation dose rates and radioactivity of environmental samples are monitored near the boundaries of the supervised areas and in nearby areas. Monitoring in the environment, both on land and at sea, will continue in Phase 1 and beyond. Current monitoring covers, to the extent possible, the environmental impact of radioactive substances released at the time of the accident, and watches for further abnormal emissions. In future, environmental monitoring will be performed in line with environmental radiation monitoring policies that are based on measurement targets and measured parameters etc. that were used before the accident.

(3) Plan for Decontamination within the site

Decontamination within the site will eventually cover the entire site, but in order to reduce exposure doses to the general public and to workers, and to facilitate work for smoother accident response in future, the site will be grouped into four areas, and specific decontamination plans will be devised and gradually implemented for those areas.

<Area categories within the site>

- Executive areas: Areas that are intended to be made into non-controlled areas (Main anti-earthquake buildings, etc.).

- Working areas: Areas in which many workers are engaged in restoration work.
- Access areas: Main roads on the site for access to working areas.
- Other areas: Forests and other areas not included in the above.

The decontamination plan will set orders of priority, based on area categories, for areas to receive decontamination, and decontamination will be implemented sequentially. The plan will be revised, checking effects on dose rate reduction and improving decontamination methods. Executive areas will be assigned the highest priority, to make them into non-controlled areas as soon as possible. Decontamination of working areas and access areas will start from areas of higher dose rates.

In Phase 2 and beyond, decontamination within the site will proceed with linkage to the state of reduction in the dosage environment as radioactive sources outside the site are eliminated. Ultimately, decontamination will cover the entire on-site area.

Work will begin promptly in checking whether rubble that was scattered by the hydrogen explosions has accumulated within the power station premises, and will end within FY2014 at the latest.

5-3. Plan for Fuel Removal from the Spent Fuel Pool

(1) Current situation

The impact of the tsunami caused the spent fuel pools of Units 1–4 to temporarily lose cooling function, but the injection of coolant water using concrete-pumping vehicles maintained cooling of fuel in the spent fuel pools. Fuel is now stably cooled by circulating cooling systems. Cooling function must be maintained until fuel removal is complete, so the maintenance management of the equipment will carry on, with equipment replacement as necessary, to maintain and improve reliability. The results of analysis of radioactive substance concentrations in the spent fuel pool water indicate that most of the fuel is in sound condition.

Sea water was injected into the spent fuel pools of Units 2–4 as an initial emergency measure, leading to corrosion of the lining[7] of those spent fuel pools, and of equipment within the pools. Therefore, the water quality is now being improved using a desalting facility installed in Unit 4. The plan is to improve water quality in Units 2 and 3 in future, in the same way as in Unit 4. In Unit 3, rubble from the hydrogen explosion that dropped into the pool raised the pH of the pool water, so water quality was improved by the injection of a neutralizing agent (boric acid). Water quality will be monitored continuously in future, and countermeasures and improvements will be applied as necessary.

(2) Summary of Fuel Removal Work (see appendix 2)

The plan for the removal of fuel from the spent fuel pools is to remove rubble that was dropped onto the refueling deck by the hydrogen explosions, install covers (or containers) to improve the working environment that includes the fuel handling

---

[7] The lining applied to the inner walls of the spent fuel pools.

equipment, and then transfer fuel to the common pool inside the power station, for a more stable storage situation.

Appendix 2 shows the steps involved in fuel removal from the spent fuel pool. By now, the first step of this process, which is the removal of rubble from the upper part of the reactor building, and preparations for subsequent steps, including covers for fuel removal, fuel handling equipment, and on-site transportation containers, are being considered and designed for Units 3 and 4.

[1] Removal of rubble from upper parts of reactor buildings

The upper parts of the reactor buildings for Units 1, 3 and 4 were damaged and rubble was scattered over the refueling deck and into the spent fuel pools. As a result, fuel removal must be preceded by the use of heavy equipment and fuel handling equipment to clear rubble from the fuel handling floor and the spent fuel pools. A plan will be devised for rubble removal, including removal of the cover installed on Unit 1, and implementation will follow the plan.

[2] Cover (or container) installation and installation or restoration of fuel handling equipment

The upper parts of the reactor buildings for Units 1, 3, and 4 are damaged, so covers (or containers) will be installed to cover the fuel replacement areas, to maintain a working environment for fuel removal by blocking wind and rain. New fuel handling equipment will be installed inside for the fuel removal work.

The soundness of the fuel handling equipment in Unit 2 has not yet been checked, because of the high dosage within the reactor building. In future, the equipment will be inspected and repaired once decontamination etc. makes it possible to approach the fuel handling equipment.

[3] Design and manufacture of on-site transportation containers and storage drums

The movement of undamaged fuel from the spent fuel pools to the common pool will employ existing or newly constructed on-site transportation containers.

If fuel is confirmed to be damaged, it will be placed in newly designed and manufactured storage drums, then placed in on-site transportation containers for movement, so that it can be handled with the same level of safety as moving undamaged fuel.

[4] Ensure/ remodel space within the common pool

To ensure an area to receive and store the fuel removed from the spent fuel pools, the undamaged spent fuel currently stored in the common pool will be stored in dry casks and moved out of the common pool. New dry cask temporary storage equipment will be installed within the power station site as the destination for these dry casks. The dry cask temporary storage equipment will be a modular type with flexible storage capacity. For the time being, it will house the existing dry casks now stored in the cask repository, in addition to dry casks received from the common pool.

Also, as the fuel removed from the spent fuel pools may be damaged by, or encrusted with salt, the necessity of washing it will be considered, and equipment will be remodeled and added, such as by installing a dedicated storage location.

[5] Fuel removal from the spent fuel pools

A crane will be used to lower on-site transportation containers into the spent fuel pools in the reactor buildings, and fuel handling machinery will be used to move fuel from spent fuel racks into the on-site transportation containers. The crane will then lower on-site transportation containers to ground level, where a trailer will be used to move them from the reactor building to the common pool on the power station site.

The soundness of the fuel will be checked before it is placed in the on-site transportation containers, and any fuel that is confirmed to be damaged will be placed in the above-mentioned storage drums for transportation.

[6] Storage and management of removed fuel

In the common pool, pool cooling and purification systems will improve and maintain the purity and transparency of the water. Water in the transportation containers will be changed to avoid bringing water from the spent fuel pool, which was injected with sea water, into the common pool.

(3) Plan for Fuel Removal from the Spent Fuel Pool (schedule)

Removal of fuel from the spent fuel pool differs between units in aspects such as fallen rubble, damage to buildings, equipment and fuel etc., and dosage levels, so periods required for preparation and movement will also differ. Therefore, the plan will consider the state and characteristics of each unit, specific plans for later units will reflect knowledge and experience gained in earlier ones. Other than receiving the removed fuel, the common pool will be used in parallel for the inspection of existing dry casks, placement of fuel into dry casks and relocation, preparations for receiving removed fuel, and other diverse operations. Therefore, the plan will consider ensuring safety, reducing confusion between tasks, and faster working.

The plan for fuel removal from Units 1–4 will be considered and formulated to optimize the fuel removal process as a whole, with the focus on ensuring safety and removing fuel as early as possible. It will include cask manufacture, port restoration, and dry cask temporary storage equipment.

The aim is to complete removal of rubble from the upper parts of the reactor buildings ([1] above) for Unit 4 in mid-2012. The state of fallen rubble in Unit 3 has not been adequately checked, so it is expected to be completed around the end of FY2012. After rubble has been removed, installation of fuel removal covers and fuel handling equipment ([2] above), and the design and manufacture of on-site transportation containers etc. ([3] above), will be implemented in parallel. Units where dosage is high in working areas will have fuel handling equipment and on-site transportation containers capable of remote operation. In preparation for receipt of removed fuel into the common pool, the equipment will be inspected and restored, and dry cask temporary storage equipment will be installed, by around the end of 2012. Over around one year after that, fuel will be gradually moved from the common pool to the dry cask temporary storage equipment, to clear the space necessary for receiving the removed fuel ([4] above).

The newly installed fuel handling equipment etc. will be used to remove rubble from inside the pools, the fuel will be investigated, and preparations will be made in the reactor buildings and the common pool. Once these are complete, fuel removal will begin ([5] above). The targets for the timing of the start of fuel removal will be within two years from the completion of Step 2 for Unit 4, which is scheduled to begin removal first, followed by Unit 3 within three years of the completion of Step 2. Knowledge and experience will be gathered from Units 3 and 4 concerning removal of rubble, the operability and faults of remote operation equipment, and investigation. The rubble will also be investigated, and then a specific plan for Unit 1 will be studied and formulated. For Unit 2, decontamination of the building interiors and use of shielding will be based on the establishment of remote decontamination technologies. Once it is possible to approach the fuel handling equipment, the equipment will be investigated, and then a specific plan for inspection, repair and fuel removal in Unit 2 will be studied and formulated. Fuel removal from Units 1 and 2 depends on conditions on the site, and other factors, but the aim is to start within Phase 2 (mid).

It is assumed, based on the envisaged future working environment, that removal of undamaged fuel in Unit 4 will employ the same equipment, working organization and procedures as in normal operation, taking around two years on that basis. If a normal environment can be produced in Unit 2, it would take around 1.5 years. If dosage is high in Units 1 and 3, fuel removal by remote operation would use newly-installed fuel handling equipment and transportation containers, necessitating detailed consideration in future, but the target is to take 2–3 years per unit. The working environment, the state of the fuel, and other factors will be checked in future, and working organizations, procedures and times etc. will be considered in order to formulate specific plans. The aim is to complete removal of fuel from Units 1–4 by Phase 2 (late).

The issues listed below, which could impact the process, must be solved in order to realize fuel removal according to plan. The work will be implemented through collaboration and liaison between all those involved, with the highest priority on ensuring safety.

- Rubble removal

  Many aspects of rubble scattering and dosage levels etc. have yet to be confirmed, and it is possible that the work could be prolonged, or require additional tasks.

- Installation of covers for fuel removal

  There are still many uncertain factors, such as the condition of building damage, dosage levels, and the condition of underground structures that obstruct foundation construction, and it is possible that the work could be prolonged, or require additional tasks.

- Common pool restoration and removal of fuel from the common pool

  Equipment is being checked for the restoration of the common pool, and it is possible that unanticipated faults could occur or be discovered, necessitating repairs.

- Step by step handling up to the start of usage

  Equipment related to fuel removal will be approved through a process with the steps of [design-> manufacture-> installation-> start of operation], and the process will be created with the approval periods in mind.

- Confirmation of fuel soundness

  Effective confirmation methods and procedures etc. will be devised with working efficiency in mind.

- Removal of fuel from the pools

  If the proportion of damaged fuel is higher than anticipated, or the degree of damage is more severe, it is possible that the work could be prolonged, or require additional tasks.

  There is no experience of remote operation, and particularly of handling faults, inspection and repair, and the handling of physical distortion etc. of fuel through remote operation. The aim will be to improve equipment reliability and safety and make the work faster, and equipment and working procedures will be improved to reflect knowledge and experience gained on the earlier units.

(4) Research and development into the handling of fuel after removal

Fuel removed from the spent fuel pools will be stored in the common pool for the time being. At the same time, assessment of the long-term soundness of fuel, taking the effects of sea water into account, related countermeasures, and research and development on reprocessing. will be implemented. (See the separate “Research and Development Plan” for details).

(HP2-1): Determination of methods for reprocessing and storing spent fuel

- Future processing and storage methods for spent fuel removed from the spent fuel pools will be decided on the basis of assessment of its long-term soundness and the results of research and development into its reprocessing.

5-4. Fuel debris removal plan

(1) Present status

When the earthquake occurred, there were a total of 1,496 containers of fuel loaded into the reactor core at Units 1–3 (in operation at the time). The reactor cores at all Units are damaged. Consequently, the fuel inside the reactor became fuel debris, and it is surmised that a portion of that debris is flowing out from reactor pressure vessels and into PCVs.

The coolant that is still being injected into the reactor cores is flowing into the adjoining turbine and other buildings via the lower basement levels of the reactor buildings from the bottom of the PCVs, and coolant is currently leaking into both the reactor pressure vessels and PCVs.

At the current time, neither the status of the fuel debris nor the exact outflow locations are known.

(2) Overview of the fuel debris removal plan

Work that will be required before beginning fuel debris removal presents a number of technological challenges considering as this work will need to be carried out in high dosage conditions inside reactor buildings. Thus, deciding definitively on a specific course of action is difficult at the present time. It is believed that removing the fuel debris while underwater (as was done at TMI-2) due to the excellent radiation shielding afforded will be the most reliable method.

At TMI-2, filling the reactor pressure vessel was accomplished without difficulty. As is mentioned above, however, at Units 1–3 the coolant added to the reactors in their current state is currently leaking out of the PCVs. Thus, creating the necessary boundaries for water filling will be an important step in removing fuel debris.

Consideration was thus given to the workflow that would be required to allow the underwater removal of fuel debris. The resulting plan that we formulated is comprised of the below work steps (1) through (10) and 6 holding points. We also included at each work step the technological challenges and necessary research and development—for which will seek assistance with from the national government, nuclear plant manufacturers and research institutes—necessary to resolve them. Having received the agreement of the Japan Atomic Energy Commission Expert Group concerning the validity of this research and development, the necessary research and development is to begin this fiscal year.

<Work steps involved in fuel debris removal>

Attachment 3 shows the work steps involved in fuel debris removal. Details of work steps (1) through (10) are provided below. Multiple holding points have been created for each process based on the idea that future site conditions and the results of research and development will require review of the content provided below. Developmental achievements will be assessed at each step and applied to the next step wherever possible.

1. Decontamination of the inside of the reactor building

Past inspections have identified rubble scattered about and the existence of areas of high dosage (several hundred to 1,000 mSv/h) inside reactor buildings. Decontamination work will thus be prioritized for the necessary areas inside buildings.

Decontamination work will be performed by workers in areas of relatively low dosage and remote removal will be used for high-dosage areas.

Thorough measures (shielding, work hour management, etc.) will therefore be taken to reduce exposure while workers perform their duties, and remote contamination inspection devices and other useful decontamination technologies (or the development of remote decontamination devices using such technologies) will be used—or serve as a basis for developing remote contamination devices—as dosage conditions require.

2. Inspections of leakages inside PCVs

Performing the underwater fuel debris removal will require repairing leaks in PCVs and filling them up with water. Before this, inspections will be conducted to identify PCV leakages.

Because leakages may be located in highly radioactive environments, under water and in narrow parts, technologies for remotely accessing these areas and detecting leakages will be developed and applied.

3. Reactor building water stop, and PCV lower parts repair

Leakages identified through the inspections described in 2 will be repaired, leakages between the reactor buildings and turbine buildings stopped, and boundaries set up for partial filling up of the lower parts of PCVs.

Because leakages may be located in highly radioactive environments, under water and in narrow parts, technologies for remotely accessing these areas, as well as technologies and methods for performing repairs, will be developed and applied.

Also, it will be necessary before stopping any leakages from reactor buildings to switch intake sources for circulating water cooling from under turbine buildings to under reactor buildings or the lower parts of PCVs, which will require downsizing circulating injection loops.

To prepare for filling up PCVs, evaluating structural strength and seismic resistance and performing the necessary reinforcements will also be required.

4. Partially filling up the PCVs

The lower parts of the PCVs will be filled up by continuously injecting them with water after making repairs to and stopping leakages in the PCVs, as per 3.

When doing this, because the cooling water flow rate around the fuel debris will change, due consideration will also need to be given to critical detection and prevention measures.

5. Inspections and samplings of the insides of the PCVs

After partially filling up the PCVs as per 4, workers will remotely access the insides of PCVs and by performing thorough inspections and samplings, ascertain fuel debris distributions and characteristics.

Because the insides of PCVs are highly radioactive and we presume the contaminated water inside is murky, remote inspection technologies and jigs will developed and used.

6. Repairs to the upper parts of PCVs

After performing inspections as per 5, workers will repair the upper parts of PCVs in an effort to raise water levels inside these PCVs.

Repair equipment utilizing remote repair technologies will also be developed here.

7. Filling up PCVs and reactor pressure vessels

After repairing the upper parts of PCVs as per 6., workers will fill up reactor pressure vessels and PCVs with consideration for critical detection and prevention measures.

After the above water filling procedures are completed, thorough safety checks for radioactive substance emissions and radioactive environments will be performed. Workers will then open the upper lids on PCVs and reactor pressure vessels and remove the steam separators and moisture separators, which are structures on the upper part of reactor pressure vessels.

Before starting the process of opening the upper lids, workers will install reactor building containers (or modify the covers) to create confined spaces. Because these reactor building container (or modified cover) structures will need to conform to fuel debris removal methods and equipment, further consideration will be made while assessing research and development progress.

8. Reactor core inspections and sampling

After completing the PCV and reactor pressure vessel opening procedures as per 7. above, workers will set up work cars for working on the upper parts of these vessels and ascertain the distributions and characteristics of fuel debris by performing inspections and samplings of the insides of reactor pressure vessels.

Because the insides of PCVs are highly radioactive and we presume the contaminated water inside is murky, remote inspection technologies and jigs will need to be developed and used.

9. Fuel debris removal technology preparation, and removal work

Workers will perform fuel debris removal with regard for critical detection and prevention measures using work carts, as per 8. After storing the removed fuel debris in special canisters, workers will transport them to a specified location.

As the removal work will likely entail a variety of processes including crashing, holding, vacuuming, etc. the fuel debris, methods, equipment, and jigs for performing this work remotely will be developed and used.

10. Safe storage, processing, and disposal of removed fuel debris

Because seawater was pumped into the core for a short time at Units 1–3, it is assumed that the fuel debris will be highly saline. Thus, in addition to the normal requirement specifications concerning cooling functions, sealing functions, etc., fuel debris will be stored in storage canisters developed to resist corrosion caused by salt. The canisters will then be removed and, for the time being, safely stored in suitable storage facilities.

(3) Research and development to facilitate the above

We will work with the support of and collaboration with the national government, industry, and research institutes in conducting the research and development mentioned in 1 through 10 above. These research and development efforts will be conducted as per the schedule in Chapter 4, and we will try to move schedules forward as much as possible. Along with research and development, we will also be making preparations for work using any machinery developed, as the case may be. (See Supplementary Document 1: “Research and Development Plan" for more details)

- Shared platform technology development

  Given the high-dosage environments present inside reactor buildings, it will be necessary to develop and use robots and other remote-control technologies to perform various kinds of work such as decontamination, inspections, and repair work to remove fuel debris from inside these buildings.

  As these remote-control technologies will need to be usable with in a number of different work processes performed inside reactor buildings, we will clarify what is required for each process and identify the kind of shared platform (shared elemental technologies, basic technologies, etc.) that will be needed and then developing them with an eye to modularizing and standardizing them.

- Consideration of alternative policy

  The development of methods for repairing PCVs will be a necessary step in the process of removing fuel debris, and we suppose there will be major technological difficulties involved. We therefore suppose difficulties will be encountered in the development of repair technologies based on the results of inspections of PCV leakages, and will be moving forward with the development of repair methods as we look at alternative methods along the way.

- Maintaining the structural integrity of reactor pressure vessels and PCVs

  Maintaining the structural integrity of reactor pressure vessels and PCVs will be extremely vital to performing the proper removal of fuel debris. Currently, to prevent the corrosion of reactor pressure vessels and PCVs, we are conducting water quality management measures including the inhibition of chloride ion concentrations and deaeration (dissolved oxygen reduction via nitrogen bubbling) of the treated water being pumped in. We will also gather data from various assessments and examine anticorrosion measures aimed at ensuring the long-term integrity of the reactor pressure vessels and PCVs.

(4) Fuel debris removal schedule

Looking at TMI-2 as a point of reference, the Japan Atomic Energy Commission

Expert Group has established the goal of beginning fuel debris removal within 10 years. Based on the fact that both ministers have instructed this same goal to be met, we will be conducting the necessary research and development to begin fuel debris removal for the first Unit within 10 years (beginning with the completion of step 2).

We surmise that all removal procedures for all Units will be completed in 20 to 25 years' time (10 to 15 years for removal). This is due to the fact that fuel debris distribution here is much broader in comparison to TMI-2, as evidenced by such phenomena as fuel debris having fallen into even PCVs.

To achieve this goal, we will be working in collaboration with the national government, industry, and research institutes in research and development, the results of which we will apply and use to complete plant work. However, based on the fact that site conditions are unknown and that there are many uncertainties concerning the development of repair technologies for leakages, we will be making revisions to the removal plan to ensure it is always optimal. As far as work processes, we have established several holding points and, in addition to applying the necessary development results achieved up to that point, we will be taking into consideration related site work conditions, the status of preparations regarding work processes and safety equipment aimed at the next step, progress made with regulatory procedures, etc.

Concerning the decontamination of reactor buildings, we will begin with areas of relatively light contamination as determined by current technologies and, by effectively combining remote contamination removal technologies that are developed along the way, remove contamination in stages from highly contaminated areas. Through these efforts, we will enable the areas around PCVs (the lower parts in particular) to be accessed by the end of FY2014.

We are also aiming for a full scale start to internal inspections performed from outside PCVs and inspections of leakages in PCVs by the end of FY2014 depending on the results of the above decontamination and onsite conditions.

(HP3-1): Determining methods for repairing lower parts of PCV, determining water stop methods

- Through inspections of PCV leakages, we will identify leaks and conditions present in the lower parts of PCVs and building basement levels and verify that the development of the methods and equipment required to repair these parts has been completed. At the same time, we will verify the extent to which these technologies can be used, and that circulating coolant can be removed from these areas, etc. before determining when to begin repair work (water cutoff) in these areas.
- At this time, we will also decide the Unit order for the repair of these parts based on the locations of leakages, which will allow us to conduct primary evaluations of Unit order for the removal of fuel debris.

(HP3-2): Completion of flooding of lower parts of PCV, determining PCV internal investigation methods

- In determining when to begin internal inspections of PCVs, we will first verify that both the repair of any leakages present in the lower parts of the PCVs and the filling of these vessels have been completed, and that internal inspection methods and the development of any necessary equipment has been completed.

(HP3-3): Determining methods to repair upper parts of PCV

- Once the areas requiring repair in these parts are identified as and we verify that the development of the necessary methods and equipment has been completed, we will determine when to begin repair work on the upper parts of the PCVs.
- Depending on research and development progress and on site conditions and number of personnel required, it may be possible to perform these repairs in tandem with repairs to the bottom parts of PCVs.

(HP3-4): Completion of flooding of upper parts of PCV, determining RPV internal investigation methods

- In determining when to begin the opening of the top lids on RPVs and reactor inspections, we will first verify that water has been pumped in up to the upper parts of PCVs (including the reactor pressure vessels), that reactor building containers have been created or covers modified to create confined spaces, and that the development of methods and equipment for inspecting reactors has been completed.

(HP3-5) Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.

(Target : to accomplish within 10 years from the completion of step 2)

- In determining when to begin fuel debris removal, we will first look at the results of internal inspections of PCVs and reactor pressure vessels to verify that the development of fuel debris removal methods and equipment, as well as storage containers (storage canisters) needed for removal, has been completed and that there are places to store the removed fuel debris.

(HP3-6) Determining processing / disposal methods of fuel debris

- We will act in conformity with any related research and development and national policy in devising methods for the future processing and disposal of removed fuel debris.

(*) We will continuously refer to the below holding points and make revisions as necessary concerning Unit priority for fuel debris removal established in HP3-1.

5-5. Plan for Disassembly of Reactor Facilities and Processing and Disposal of Radioactive Waste

(1) Plan for disassembly of reactor facilities

1. Outline

With regard to the disassembly of Units 1–4, following the removal of fuel from the spent fuel pools and fuel debris from the reactor cores, it will be necessary to proceed on the basis of a plan for the disassembly of the reactor facilities that takes into consideration factors including the projected type and quantity of radioactive waste, the impact on the environment (including the general public), the risk of exposure for workers, the work methods and procedures applied, and the prospects for disposal of the waste.

Given this, in line with the status of progress in decontamination of buildings, the surveying of reactor pressure vessels and PCVs, the removal of fuel debris and other work, from this point onwards we will collect the necessary data for the formulation of a decommissioning plan, encompassing factors including the state of radioactive contamination of buildings and equipment (including evaluation of the degree of migration of radioactive substances due to the buildup of high-level contaminated water in reactor buildings, turbine buildings, main process buildings, etc.) and the amount of fuel debris remaining in the reactor pressure vessels and PCVs, in addition to conducting the research and development necessary for the development of technologies including remote disassembly technologies and technologies for the decontamination and reduction in volume of concrete and metal.

Based on the standard procedural schedule examined in accordance with the system of allowances for disassembly of nuclear facilities, a period of approximately 15 years is projected for disassembly of reactor facilities. The first 10 years of this standard procedural schedule is devoted to waiting for the decay of radioactive substances in order to minimize the dose to which workers will be exposed, in addition to the commencement of disassembly of the turbine buildings and other comparatively lightly contaminated areas. The final five years sees the commencement of disassembly of the reactor cores.

It will be essential to determine the disassembly method to be employed in the present case with consideration of the fact that due to the effects of the tsunami disaster it is highly possible that the disassembly of the reactor facilities of Fukushima Daiichi Nuclear Power Station Units 1–4 will differ from normal reactor disassembly procedures in terms of the type and amount of radioactive waste products involved. In addition, prior to commencement of disassembly procedures for the reactor facilities, it will be important to upgrade technological standards and establish a firm outlook for the disposal of the waste products produced by the disassembly. The government and TEPCO will cooperate in these areas.

Based on the above, a target of 30–40 years has been set for the completion of the disassembly of the reactor facilities of Fukushima Daiichi Nuclear Power Station Units 1–4. Work will proceed with consideration of the points listed below. The disassembly work will commence from Unit 4, in which there is no fuel debris in the reactor core.

2. Schedule for disassembly of reactor facilities

(HP4-1) Determination of method of disassembly and decontamination. Formulation of standards for disposal of waste products from disassembly

It is predicted that the type and quantity of radioactive waste products produced by the disassembly will differ from the case of a normal nuclear plant due to the effects of the tsunami disaster. Given this, the design and manufacture of the necessary devices and equipment will commence following verification of the completion of a review of standards for waste disposal, a research and development program for decontamination and reduction of the volume of waste produced, and the development of a method of disassembly that reduces exposure during the course of the work, in response to the type of radioactive substances which will be encountered.

(HP4-2) Formulation of outlook for disposal of waste produced by disassembly. Completion of necessary research and development

Disassembly procedures will be commenced when a firm outlook for disposal of the waste products from the procedures has been obtained.

(2) Radioactive Waste Processing and Disposal Plan

1. Outline

Basic guideline: Depending on the characteristics of the radioactive waste (the radionuclides it contains and its level of radioactivity), it will be subject to processing such as being sealed in containers and encased in concrete to form blocks of waste (termed "Processing" below) and transported to a waste disposal site and buried (termed "disposal" below).

The waste products produced following the tsunami disaster differ from the waste products conventionally produced by nuclear reactors in a variety of characteristics, including the fact that radionuclides originating in damaged fuel are adhering to them and they contain high quantities of salt, which will have a negative impact on the performance of the disposal sites.

Because of this, realizing the Processing and disposal of the waste will necessitate the implementation of research and development based on adequate analysis and understanding of the characteristics of the waste and the determination of a firm outlook for its safe Processing and disposal.

Safety regulations and technological standards for the Processing and disposal of the waste will be clarified via a determination of the outlook for safety and a process of examination of the necessary systemic measures.

To make it possible to install Processing equipment in the power station and commence the production of blocks of waste for transportation to the disposal sites following this process, for the present waste will continue to be stored after sorting to ensure that it does not impede the future Processing and disposal procedures. The research and development necessary for the Processing and disposal of the waste will be conducted on the basis of collaboration between the national government, TEPCO, related industries and research organizations. (For details, see "Research and Development Plan" in Supplement 1)

2. Schedule for Processing and disposal of radioactive waste

A Research and Development Plan towards the Processing and disposal of radioactive waste will be formulated in FY2012, when it is projected that the removal of the debris from the reactor buildings of Units 3 and 4 will have been completed.

In addition, because it will be necessary to proceed in stages, revising the outlook for safety based on the outcomes of research and development, the following points for judgment have been established based on the process of review concerning the disposal of radioactive waste which has been employed in Japan up to the present.

(HP5-1): Verification of applicability of existing concept of disposal to characteristics of radioactive waste

- The applicability of the adopted concept of waste disposal will be verified based on the results of research on the characteristics of the waste.
- Given that there is a possibility that it may be difficult to apply the existing concept of waste disposal to some of the waste (for example, waste with a high salt content), as necessary, new methods of Processing and disposal (construction of artificial barriers, etc.) will be examined, research and development plans will be formulated, and research will be commenced.

(HP5-2): Verification of safety of waste Processing and disposal

- The prospects for safe Processing and disposal of the waste products, etc. resulting from the tsunami disaster, will be verified based on technological viability. In addition, the information necessary for the creation of a framework for a safety system for waste Processing and disposal will be compiled.
- It is predicted that new data will be obtained concerning the characteristics of the waste products as the removal of fuel debris and disassembly work proceed. In addition, it is also possible that new waste products will be produced in the process of decontamination during the work. Given this, research will be continued as necessary in order to increase the safety of waste Processing and disposal.

(HP5-3): Determination of specifications and method of manufacture of blocks of waste

- Based on the results of research and development in relation to the Processing and disposal of radioactive waste, as necessary, the system of regulations will be revised, and the necessary conditions for Processing and disposal (specifications of blocks of waste, essential site requirements for disposal sites, design requirements for disposal sites) will be clarified.
- The specifications and method of manufacture of blocks of waste will be determined based on the above conditions.

(HP5-4): Installation of equipment for manufacture of blocks of waste and prospects for waste disposal

- The manufacture and shipment of blocks of waste will be commenced when the installation of equipment for their manufacture has been completed and firm prospects for disposal have been confirmed.

6. Establishment of Systems and Optimization of Environments for Facilitation of Work to be Performed at Fukushima Daiichi Nuclear Power Station

It is predicted that even from the first stage of the disassembly work, operations will be conducted in numerous environments with a high level of radioactive contamination. Against this background, it will be necessary to secure personnel over the long-term, while ensuring the safety of employees by limiting exposure to 100 mSv/5 years and maintaining the system of cooperation between TEPCO and its contractors, as has been the case up to the present.

This section will deal with the formulation of a Personnel Plan based on the necessary work procedures to be conducted and total potential exposure as projected at present and the evaluation of the feasibility of this plan, in addition to a Safety Plan for onsite operations which encompasses measures to increase the motivation of personnel and guidelines for the management of radioactivity.

6-1. TEPCO System of Implementation in relation to Mid-and-long-term Initiatives

Tokyo Electric Power Company will establish a full-time dedicated organization at its headquarters in order to ensure that mid-and-long-term initiatives proceed steadily. This organization will cooperate with the Fukushima Daiichi Stabilization Center, which is responsible for overseeing operations at the site, and the Fukushima Daiichi Nuclear Power Station, in activities including the formulation of basic guidelines for mid-and-long-term initiatives, and the management and design of the overall project and the obtaining of the relevant permissions.

Taking familiarity with the site and experience in proceeding to Step 2 into consideration, the system for the realization of mid-and-long-term initiatives will involve Tokyo Electric Power Company and approximately 400 contractors, and work will proceed according to the system of implementation used up to the present for site operations of the same type.

A dedicated system for integrated exposure and health management for workers of TEPCO and other companies will be established in TEPCO's headquarters, conducting procedures including the provision of health consultations and examinations in response to exposure levels.

6-2. TEPCO Personnel Plan in relation to Mid-and-long-term Initiatives

(1) Personnel Plan and feasibility of Plan

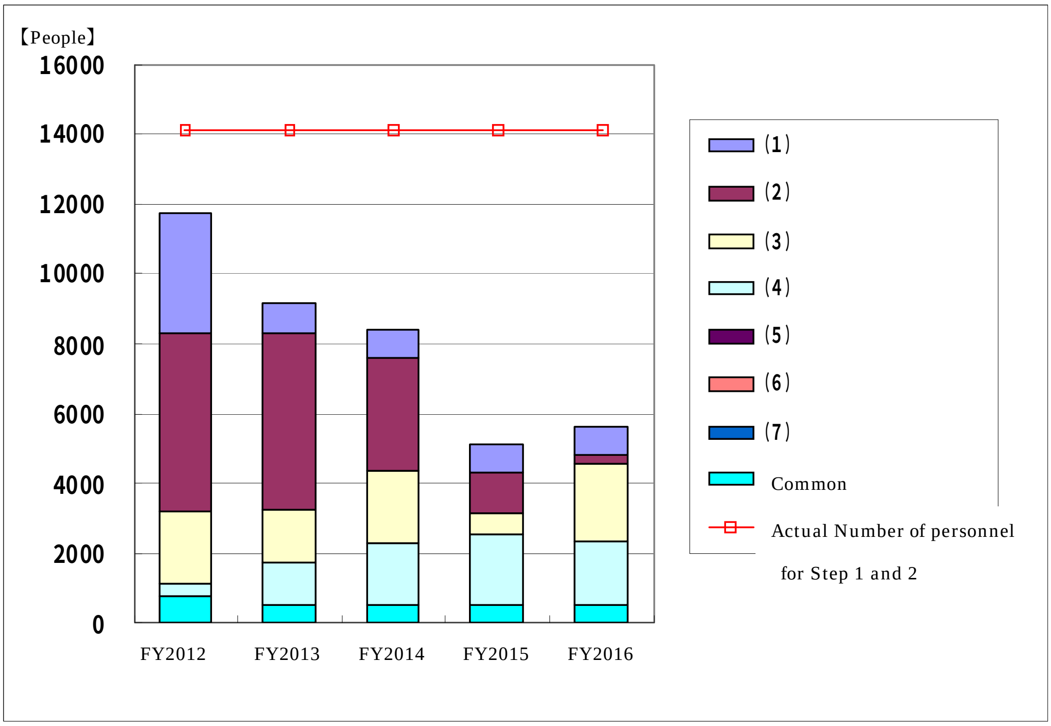
TEPCO has projected the number of personnel required for work scheduled for the next five years* and the cumulative exposure of those personnel, and has verified the feasibility of its Personnel Plan.

*: Based on factors including the accuracy of the outlook for the work to be performed and a limit of 100 mSv/5 years for exposure management, the projected period for the Personnel Plan was set at five years.

1. Essential number of workers and projected level of exposure

Taking the figure of 100 mSv/5 years into consideration, it is projected that the following numbers of workers will be required to ensure an annual level of exposure per person of 20 mSv or less (excepting certain operations entailing a higher level of exposure*).

*: Operations including increasing the reliability of the processing facilities for accumulated water and reducing the loops are expected to involve exposure to levels of 40 mSv.



(1) Plan for Maintaining Plant in an Ongoing Stable State (Improvement of reliability of circulating water cooling system, etc.)

(2) Plan to Reduce Radioactive Dosage in the Power Station as a Whole, and to Mitigate Sea Water Contamination (Construction of shielding walls, etc.)

(3) Plan for Fuel Removal from Spent Fuel Pools (Fuel removal, etc.)

(4) Fuel Debris Removal Plan (Stopping inter-building water leakage, etc.)

(5) Plan for Disassembly of Reactor Facilities and Processing and Disposal of Radioactive Waste

(6) System of Implementation/Personnel Plan

(7) Plan for Ensuring Work Safety

Common // Actual number of personnel for Steps 1 and 2

Note): This plan is based on provisional calculations performed within the scope that can presently be projected. The number of required personnel may increase or decrease in future based on changes in circumstances, for example if further procedures come to be deemed necessary as onsite surveys proceed.

Note): The actual number of personnel for Steps 1 and 2 is the number of employees of TEPCO and major companies engaged in operations at TEPCO's Fukushima Daiichi Nuclear Power Station during the relevant period (aggregated from March to November).

The actual number of personnel involved in Steps 1 and 2 was approximately 14,100, and it is projected that it will be possible to secure at least this number of personnel in the future. The required number of personnel for the first five years based on current projections (Maximum: Approximately 11,700 for the first year) is lower than that figure, and it is therefore predicted that there will be no impediment to onsite operations due to a shortage of personnel.

From 2017 onwards, in addition to continuous work for the processing of accumulated water, etc., major operations for the placing of the reactor building containers and the removal of fuel debris will be due to commence. It is therefore predicted that in the future also it will be necessary to secure a constant number of personnel, and we will continue to work to secure these personnel with consideration of employment in the local region.

2. Future initiatives to secure personnel

From 1, the actual number of personnel involved in Steps 1 and 2 exceeded the number of personnel that will be required for operations in the future, but we will also implement the following initiatives in order to increase the certainty of securing personnel.

・ Allocation of personnel based on predicted dose
  Personnel will be allocated in a planned manner based on advance predictions of the individual dose for personnel engaged in specific procedures.
・ Systematic training of personnel
  Training will be essential for particularly specialized operations, and training of personnel will therefore be carried out in a systematic manner.

－For processing of water

TEPCO will be introducing water processing equipment for the first time, and the processing system is complex. Given this, prior to the allocation of personnel, theoretical training will be provided concerning elements including the design of equipment and the positioning of devices, and hands-on training will be provided concerning the operation and maintenance of transport and processing equipment, etc.

－For management of radioactivity

We will continue the education and training programs that we presently conduct for employees of TEPCO and its contractors to foster personnel engaged in taking measurements of radioactivity, and into the future we will foster personnel involved in radiation-related procedures, given the increasing need for these personnel.

・ Measures for further reduction of exposure
  In addition to continuing measures such as the employment of shielding equipment and avoidance of areas of high radioactivity, we will engage in the development of equipment enabling procedures to be performed remotely and will ensure further decontamination of work areas.
・ In order to increase the accuracy of the Personnel Plan, we will revise the plan

on an annual basis.

(2) Measures to increase motivation

To enable TEPCO and its contractors to continue the decommissioning work into the future, conditions will be improved as follows to ensure that personnel are able to work with peace of mind.

・ Improvement of meals
  - We will continue to examine possibilities for the diversification of the food menu and the improvement of the nutritional balance provided by meals.
  - We will continue to examine the possibility for the provision of hot meals.
・ Improvement of environments
  - The Main Anti-earthquake Building, in which personnel were resident for an extended period providing directions and instructions for operations in the plant, is being made into a non-controlled area （to April 2012）. With regard to the corporate buildings, in response to the needs of contractors, while maintaining the order of precedence, radiation levels will be reduced in the buildings for which the need is most urgent within FY2012.
  - The level of radiation will be reduced in the site as a whole.
  - We will examine the establishment of rest areas which come to be required in response to changes such as changes in the scale of the work or the areas in which it is being conducted.
  - Depending on the environment, protective measures will be reduced in stages, for example by expanding areas in which no masks are required.
  - Continuing efforts will be made to improve the working environment, for example by increasing working space and offering increased benefits.
・ Monitoring of effects of improvements
  - In order to verify the effects of the improvements above, in addition to the improvements in health management discussed in 6-3(3), effects will be periodically monitored via twice-yearly questionnaires and other measures, and further improvements will be made as necessary.

6-3. Plan for Ensuring Work Safety

Work safety management and radiation management are important elements in ensuring workers’ safety and maintaining their health.

Guaranteeing safety is a prerequisite for our future mid-and-long-term initiatives. Complex operations which diverge from standard procedures will be ongoing in future, and all personnel involved will share a strong awareness of safety which stresses care in avoiding major accidents and excessive exposure, and will conduct the activities described below. In addition, we will conduct constant checks in an attempt to make continuous improvements to operations.

(1) Overall work safety

Following the tsunami disaster, up to the present we have been forced to respond to working environments and types of operations for which we had no previous experience, and this has seen us conducting advance evaluations of safety, share information and enhance cooperation with contractors, establish rest areas, and adopt measures for heat exhaustion.

Complex operations which diverge from standard procedures will be ongoing in future, and we will therefore place an emphasis on the following four items in order to prioritize safety.

- Continuous safety activities
  - To ensure safety in work operations, we will conduct continuous advance examinations of work methods, safety measures, safety education, and the effect of the work on other equipment. In particular, work that will be conducted under special conditions, and work that involves the introduction of new technologies or new methods, will be subject to deliberations by the (in-house) Advance Safety Evaluation Committee, and safety patrols and monitoring devices will be employed to check on the status of the work, in an attempt to improve safety initiatives.
- Cooperation with contractors
  - We will continue to hold safety liaison meetings with contractors working within the site (once weekly), sharing information concerning safety in order to increase safety awareness among personnel.
  - We will also attempt to improve working environments in order to facilitate communication.
- Maintenance and expansion of rest areas
  - In addition to appropriately maintaining the rest areas that we established from the stage of Step 1 and the facilities provided in these areas, we will examine the conditions for the establishment of rest areas which come to be required in response to changes such as changes in the scale of the work or the areas in which it is being conducted.
- Prevention of heat exhaustion
  - In areas in which there is concern over the possibility of heat exhaustion, we will monitor the environment using Wet-Globe Bulb temperature (WBGT) devices[8], encourage reductions in working hours and increased fluid intake, and provide cooling vests, among other measures for the prevention of the condition. We will also educate personnel concerning ways to prevent heat exhaustion.

(2) Radiation management

- Establishment of entrance and exit points
  - As the result of an increase in the level of radioactivity due to the large-scale release of radioactive substances, values for doses originating in external doses, the concentration of radioactive substances in the atmosphere, and the density of radioactive substances on contaminated wall surfaces in monitored areas exceed values for controlled areas. Because of this, at present monitored areas are being considered as areas subject to controls, requiring the same level of management as

[8] Instrument for measuring indicators that detect humidity, radiant heat, and temperature, the three elements that have the largest impact on human heat balance.

controlled areas.

  - At present, access management for areas subject to controls (screening, fitting of protective clothing and dosimeters) is being conducted in areas separated from the areas subject to controls, but in future, we will select access management areas that enable procedures to be conducted close to areas subject to controls.
- Expansion of continuous monitoring of work environments
  - Area monitoring of radiation in existing buildings is not presently functioning. However, because the frequency of entry to the buildings is low and the areas in question are limited, we are presently working to detect any abnormalities by having employees themselves measure radioactivity in the vicinity of these areas.
  - This means that in the case of work in areas subject to control, in an attempt to reduce the dose to which employees are exposed to the lowest reasonably achievable level, as necessary workers take measurements of the dose equivalent rate for external radiation and the concentration of radioactive substances in the air prior to and during the work procedures, and perform the work after identifying the procedures for which the dose is highest.
  - In future, taking the frequency of entry and the expansion of areas into consideration, we will proceed with studies to enable us, as necessary, to make the transition to management using conventional area radiation monitors. In addition, with regard to outdoor areas and buildings which have been established since the tsunami, we will position area radiation monitors in areas which personnel are using for the purposes of equipment operation, monitoring, inspection, etc., and we will conduct continuous monitoring of radiation levels to enable us to understand the status of radiation environments and share information concerning protection from exposure.
- Implementation of individual radiation management
  - In future, in addition to increasing the reliability of data management, including integrated management of issuance of dosimeters and management of individual dose histories, we will centralize data including external dose data, the results of internal dose measurements and dates of examinations for effects of ionizing radiation to enable systematic provision of whole body counts (WBC)[9] (incorporating the rationalization of evaluation frequency in line with the improvement of working environments) and management of the due dates for health checks. (to April 2012）
- Examination and implementation of measures for reduction of dose optimized for individual work operations
  - Attempting to reduce the dose to which employees are exposed to the

[9] Instrument for measuring personal internal exposure and whole-body radioactivity by measuring radioactive materials ingested in the body from outside the body.

lowest reasonably achievable level, for the performance of individual work operations, essential conditions such as the need for protective clothing and equipment, the number of personnel involved, and time limitations will be decided in advance in response to the working environment, and rational work plans will be formulated taking the individual exposure history of the employees who will be performing radiation-related duties into consideration.

- In order to enable the determination of the abovementioned essential conditions for work plans, advance training in work operations and the use of robots will be considered.

・ Reduction of protective measures

- Following the thorough implementation of dose management measures, protective measures will be reduced in stages as appropriate for the environment (for example, areas in which no masks are required will be expanded), and consistent management will be instituted.
- To enable this, it will be essential to reduce the level of radiation in the site, and decontamination operations will therefore be conducted in stages, in a systematic manner.

(3) Health management

・ Ongoing provision of healthcare system

- Until local healthcare services recover a fixed level of function, a healthcare system will be provided on a continuing basis at the Fukushima Daiichi Nuclear Power Station, the Fukushima Daini Nuclear Power Station, and J-Village in terms of personnel safety and security. Specifically, healthcare personnel including physicians will be allocated as necessary, and the necessary equipment, devices and pharmaceuticals will be procured. In addition, a system for transportation to external medical facilities will be maintained. Operational improvements will also be made constantly to ensure the optimum quality of healthcare and rapid transportation.

・ Implementation of long-term health management

- Based on “Guidelines for the protection of the health of emergency workers at the Fukushima Daiichi Nuclear Power Station” published on October 11, 2011 by the Ministry of Health, Labour and Welfare, we will institute long-term health management measures for emergency workers. In addition to operating a health consultation center, we will provide extensive support for health checkups including cancer screenings. This support will also be provided for the employees of companies which are cooperating in the work on the site.

7. Cooperation with the International Community

Viewing transparency in relation to the international community as an issue of the greatest importance, the Nuclear Emergency Response Headquarters has made available the information it has obtained rapidly and accurately, providing “Additional Report of the Japanese Government to the IAEA –The accident at TEPCO’s Fukushima Nuclear Power Stations-“reports concerning the status of the accident at the Fukushima Daiichi Nuclear Power Station to the International Atomic Energy Agency in June and September.

It is essential to bring together knowledge from all sources in responding to the Fukushima accident, and up to the present many nations around the world have offered support and cooperation. From the initial stage of the decommissioning work, we will continue to proceed on the basis of cooperation with the governments of other countries and international organizations.

In order to conduct the research and development necessary to a large-scale and long-term reactor decommissioning project effectively and efficiently, we will make extensive use of knowledge and experience gained from responses to overseas accidents and other sources, in addition to enhancing cooperation with overseas government-affiliated research organizations and private companies.

8. System of Implementation for Mid-and-long-term Initiatives

Following the tsunami disaster, the government and Tokyo Electric Power Company formulated the “Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, TEPCO”, and cooperated in initiatives for recovery from the incident while revising the Roadmap as necessary in response to the status of progress.

In implementing the new Roadmap, it is essential that the government and Tokyo Electric Power Company once again establish a strong cooperative system, ensuring transparency and securing the understanding of local residents and the broader Japanese public while proceeding steadily with efforts towards the decommissioning of the reactors on the basis of technological knowledge in a broad range of fields sourced both domestically and internationally. To this end, with the completion of Step 2, Government-TEPCO Integrated Response Office been disbanded, and Government and TEPCO’s Mid-to-Long Term Countermeasure Meeting has been created under the Nuclear Emergency Response Headquarters in order to formulate and supervise the implementation of this Roadmap.

In addition, because essential research and development in relation to the examination and implementation of mid-and-long-term measures towards the decommissioning of the reactors faces numerous complex issues which are unprecedented on a global scale, it will be necessary to proceed on the basis of cooperation from relevant domestic and overseas institutions. To enable this cooperation, it will be necessary to create a system of implementation for research and development plans and formulate concrete implementation plans for each issue involved, in addition to establishing solid linkages between onsite work and research and development projects.

9. Conclusion

Seeking to ensure the earliest possible return for local residents displaced by the accident to the Fukushima Daiichi Nuclear Power Station and to alleviate the anxiety felt both in this region and across the nation, Tokyo Electric Power Company, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency intend to commence mid-and-long-term work towards the decommissioning of Fukushima Daiichi Nuclear Power Station Units 1–4 on the basis of this Roadmap, under an appropriate cooperative framework.

At the same time, based on factors including the conditions at the site and the outcomes of research and development, Tokyo Electric Power Company, the Agency for Natural Resources and Energy, and the Nuclear and Industrial Safety Agency will periodically revise this plan, and will ensure transparency by announcing the status of mid-and-long-term initiatives.

This Roadmap compiles details of technological procedures related to decommissioning work, essential research and development, etc. No estimates of costs were made in the process of their examination.

The functions of the Nuclear and Industrial Safety Agency will be transferred to a new regulatory agency scheduled to be created in April 2012. The new agency will take on the responsibility for this Roadmap and its purport.

<Attached materials>

Attachment 1-1: Main Schedule of Mid-and-long-term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO

Attachment 1-2: Mid-term Schedule

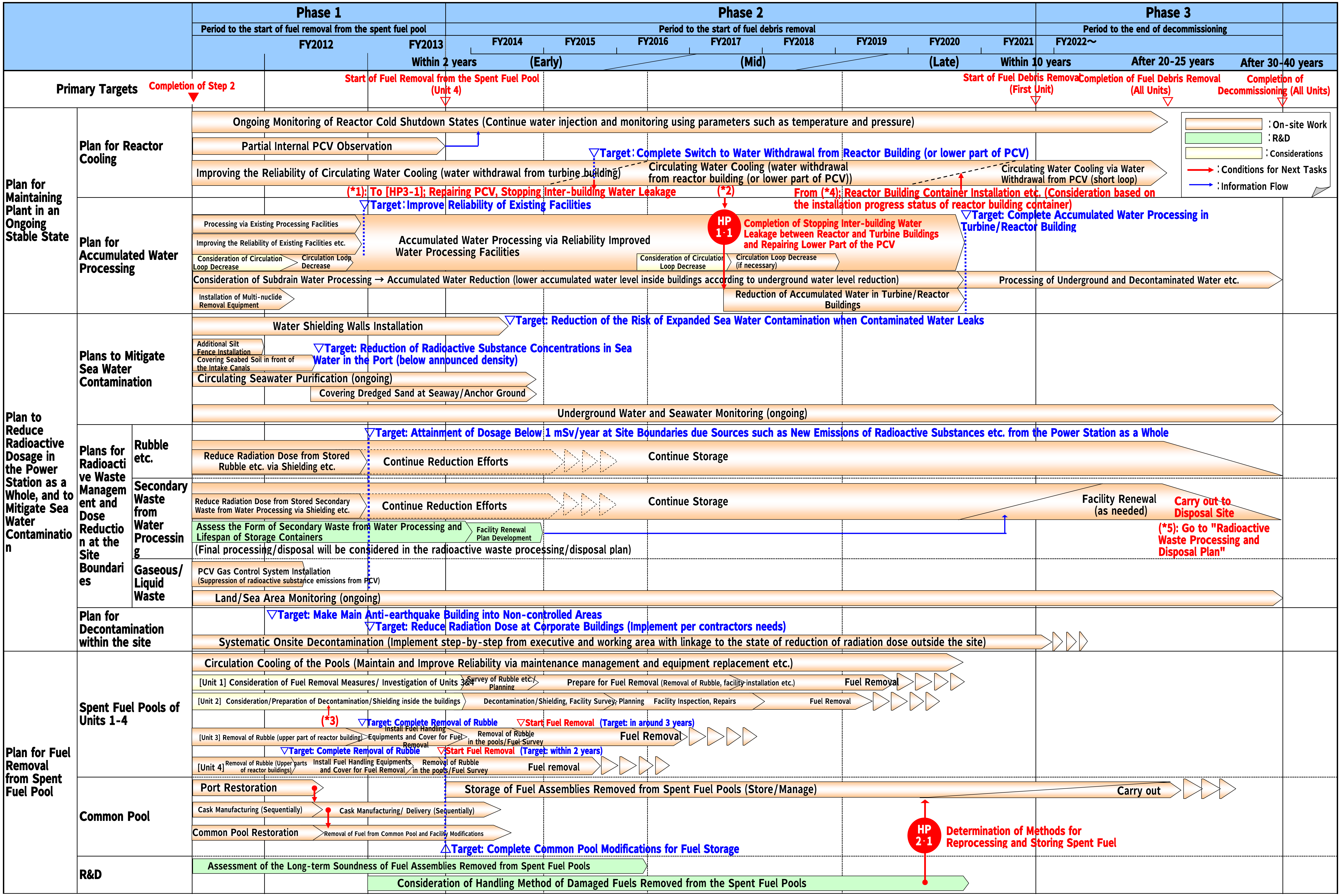
Attachment 2: Procedural Steps for the Removal of Fuel from the Spent Fuel Pools

Attachment 3: Procedural Steps for the Removal of Fuel Debris

<Supplementary materials>

Supplement 1: Concerning the Research and Development Plan related to the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO

Main Schedule of Mid-and-long-term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO

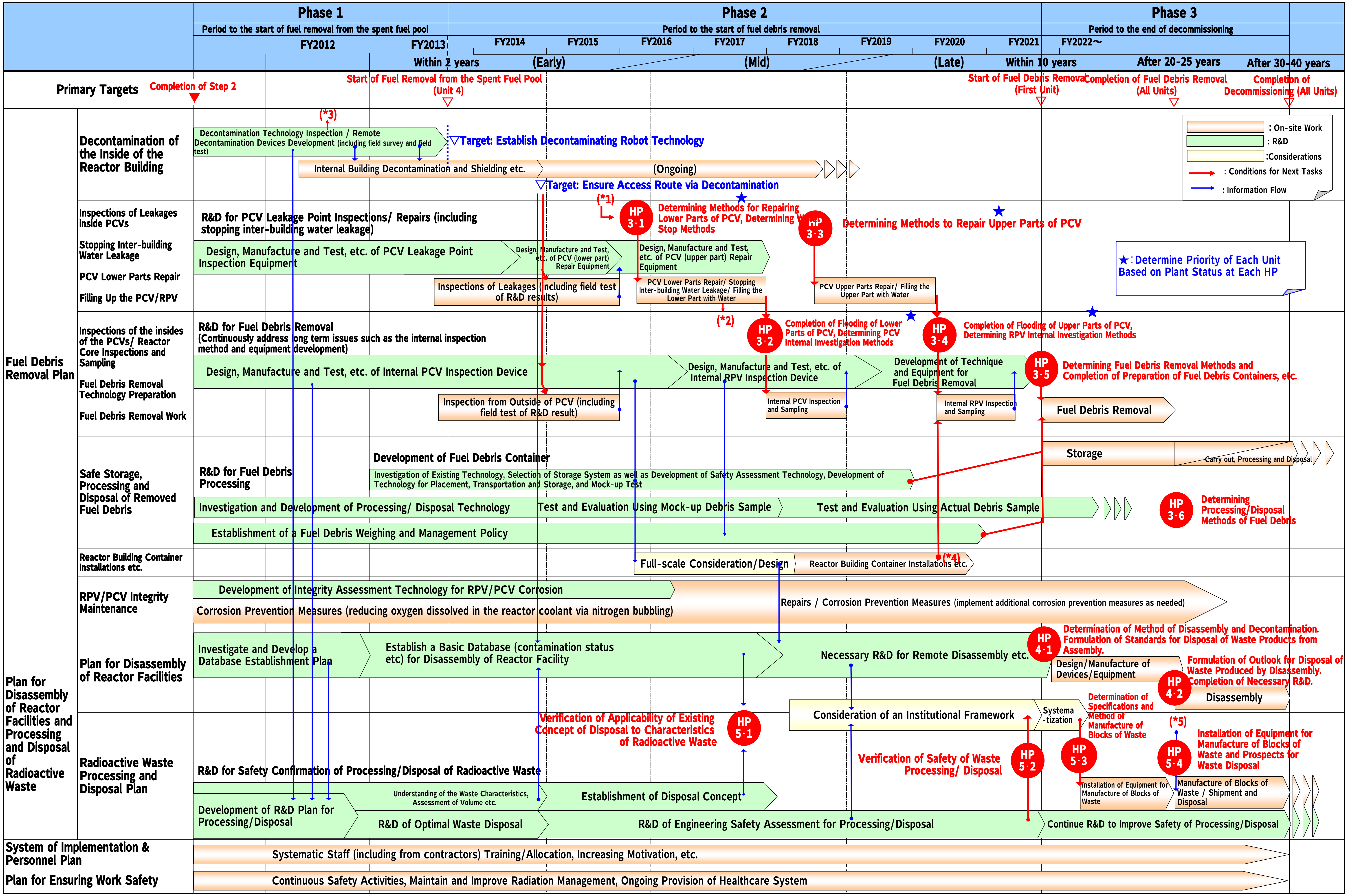


This roadmap will be updated in consideration of the on-site situation and the latest research and development results.

HP: Holding Point (Points of Judgment)

Attachment 1-1 [Provisional Translation]

Main Schedule of Mid-and-long-term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO



This roadmap will be updated in consideration of the on-site situation and the latest research and development results.

HP: Holding Point (Points of Judgment)

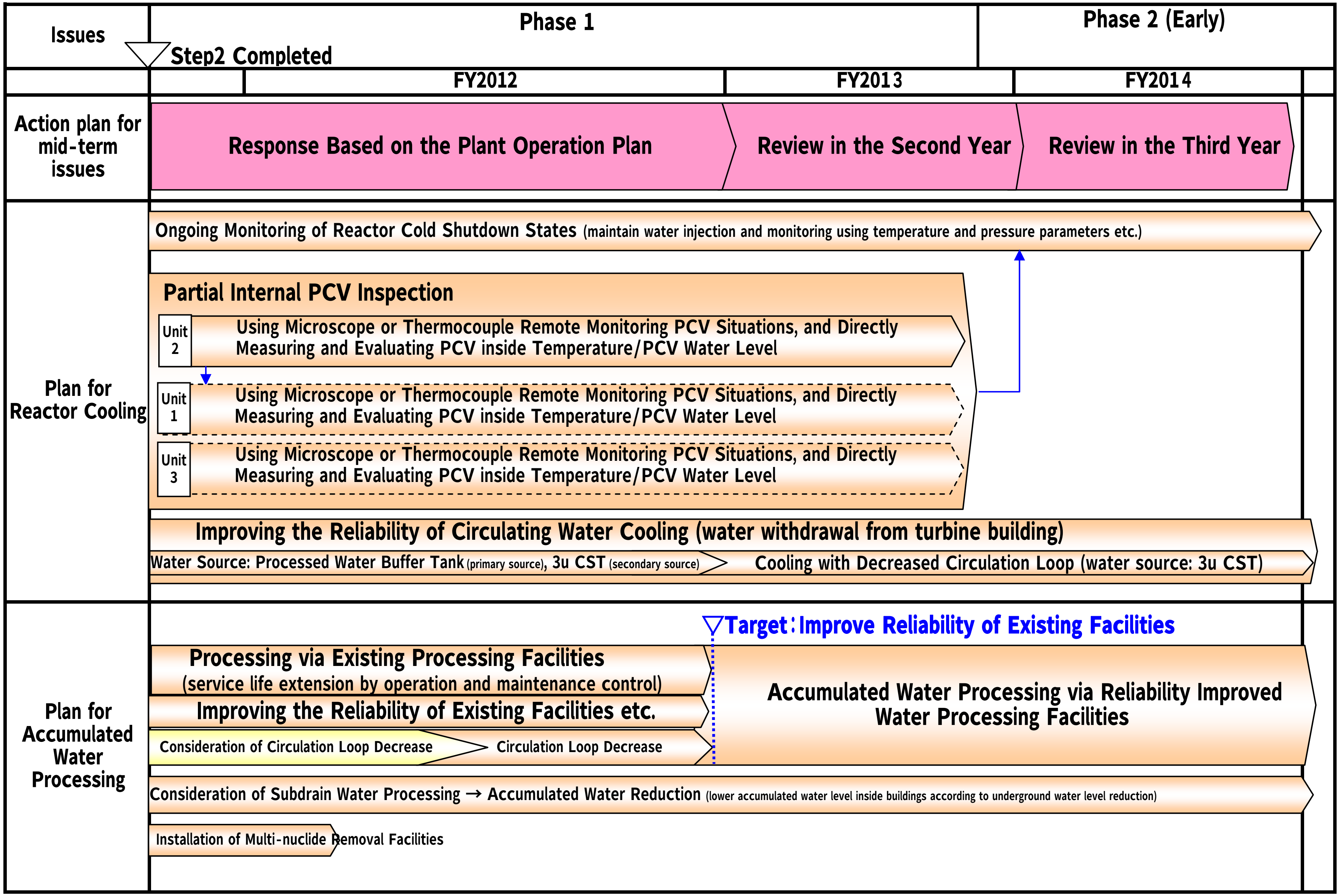
Mid-Term Main Schedule towards the Decommissioning of Fukushima Daiichi Nuclear Power Station

Phase 1: FY2012 – FY2013; Phase 2 (Early): FY2013 – FY2014. ▽ SFP Fuel Removal Start (FY2013)

Issues		Step2 Completed	FY2012 / FY2013 / FY2014
Action plan for mid-term issues		Planning Plant Operationion	Response based on the plant operation
Plan for Maintaining Plant in an Ongoing Stable State	Plan for Reactor Cooling	Condition Equivalent to Cold Shutdown	Ongoing Monitoring of Reactor Cold Shutdown States (Maintain water injection and monitoring using temperature and pressure parameters etc.) Partial Internal PCV Inspection Improving the Reliability of Circulating Water Cooling (water withdrawal from turbine building)
	Plan for Accumulated Water Processing	Reduction of total amount of Accumulated Water	Processing via Existing Processing Facilities → Accumulated Water Processing via Reliability Improved Water Processing Facilities Improving the Reliability of Existing Facilities etc. Consideration of Circulation Loop Decrease → Circulation Loop Decrease Consideration of Subdrain Water Processing → Accumulated Water Reduction (lower accumulated water level inside buildings according to underground water level reduction) Installation of Multi-nuclide Removal
Plan to Reduce Radioactive Dosage in the Power Station as a Whole, and to Mitigate	Plans to Mitigate Sea Water Contamination	Mitigate Ocean Contamination	Water Shielding Walls Installation Covering Seabed Soil in front of the Intake Canal, Circulating Seawater Purification (ongoing) etc. Underground Water and Seawater Monitoring (ongoing)
	Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries – Rubble etc.	Mitigate Scattering Storage/Management	Continue Storage Reduce Radiation Dose from Stored Rubble etc. via Shielding → Continue Reduction Efforts
	Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries – Secondary Waste from Water Processing		Continue Storage Stored Water Processing via Shielding etc. Reduce Radiation Dose from Secondary Waste → Continue Reduction Efforts Assess Characteristics of Secondary Waste from Water Processing and Storage Container Lifespan → Facility Replacement Plan Development
	Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries – Gaseous/Liquid Waste		PCV Gas Control System Installation Land/Sea Area Monitoring (ongoing)
	Onsite Decontamination	Decontamination (Start)	Systematic Onsite Decontamination
Plan for Fuel Removal from Spent Fuel Pool	SFPs of Units 1-4	More Stable Cooling	Circulation Cooling of the Pools (Improve Reliability via maintenance and replacement etc.) Removal of Rubble/Cover for Fuel Removal /Cask Procurement／Install or Repair of Fuel Handling Equipments Fuel Removal
	Common Pool		Site Harbor Restoration (crane/road) → (seawalls) → Storage of Fuel Assemblies Removed from SFP (store/manage) Cask Manufacturing (sequentially) → Cask Manufacturing/ Delivery (sequentially) Common Pool Restoration → Common Pool Fuel Removal and Facility Modifications
	R&D		Long-term Integrity Assessment of Fuel Assemblies Removed from SFPs Consider Handling Method of Damaged Fuels from the SFPs
Fuel Debris Removal Plan	Decontamination of the Inside of the Reactor Building	Condition Equivalent to Cold Shutdown	Decontamination Technology Investigation / Remote Decontaminating Equipment Development Internal Building Decontamination and Shielding etc. → (Ongoing)
	Inspections of Leakages inside PCVs		Design, Manufacture and Test, etc. of PCV Leakage Point Survey Equipment → Investigation of Leakage Points (including field test of R&D results)
	Fuel Debris Removal		Design, Manufacture and Test, etc. of Internal PCV Inspection Device → Investigate Outside of PCV (including field test of R&D results)
	Safe Storage, Processing and Disposal of Removed Fuel Debris		Development of Fuel Debris Container (investigation of existing technology, selection of storage system as well as development of safety assessment technology) Investigation and Development of Processing/ Disposal Technology Establish Measuring Method to Weigh Fuel Debris
	Reactor Building Container Installations etc.		
	RPV/PCV Integrity Maintenance		Development of Integrity Assessment Technology for RPV/PCV Corrosion Corrosion Prevention Measures (reducing oxygen dissolved in the reactor coolant via nitrogen burbling)
Reactor Dismantling & Radioactive Waste Processing/Disposal Plan	Reactor Dismantling Plan		Investigate and Develop a Database Establishment → Establish a Basic Database (contamination status etc) for Reactor Facility Dismantlement
	Radioactive Waste Processing/Disposal Plan		Development of R&D Plan for Processing/Disposal → Grasping Waste Characteristics, Assessment of Volume etc.; R&D of Optimal Waste Disposal
Organization & Staff Planning		Enhancement of Environment Improvement	Systematic Staff (including from partner companies) Training/Allocation, Improving Motivation, etc.
Worker Safety Plan		Exhaustive Radiation Dose Control	Continue to Promote Safety, Maintain and Improve Radiation Protection Measures, Continuously Maintain Medical Care System

[Provisional Translation]

Progress Status of Each Plan (1)



[Provisional Translation]

Progress Status of Each Plan (2)

Issues	Phase 1 (▽ Step2 Completed)			Phase 2 (Early)
		FY2012	FY2013	FY2014

Plans to Mitigate Sea Water Contamination

- Target: Reduction of the Risk of Expanded Sea Water Contamination when Contaminated Water Leaks ▽
- Water Shielding Walls Installation
- Additional Silt Fence Installation
- ▽Target: Reduction of Radioactive Substance Concentrations in Sea Water in the Port (below announced density)
- Covering Seabed Soil in front of the Intake Canal
- Circulating Seawater Purification (ongoing)
- Covering Dredged Sand at Seaway/Anchor Ground
- Underground Water and Seawater Monitoring (ongoing)

Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries

Rubble etc.

- ▽Target: Attainment of Dosage Below 1 mSv/year at Site Boundaries due Sources such as New Emissions of Radioactive Substances etc. from the Power Station as a Whole
- Continue Storage
- Reduce Radiation Dose from Stored Rubble etc. via Shielding (repair existing storage, install additional storage with shielding, store logged tree with cover soil) → Continue Reduction Efforts

Secondary Waste from Water Processing

- Continue Storage
- Stored Water Processing via Shielding etc. Reduce Radiation Dose from Secondary Waste → Continue Reduction Efforts
- Assess Characteristics of Secondary Waste from Water Processing and Storage Container Lifespan → Facility Replacement Plan Development

Gaseous/Liquid Waste

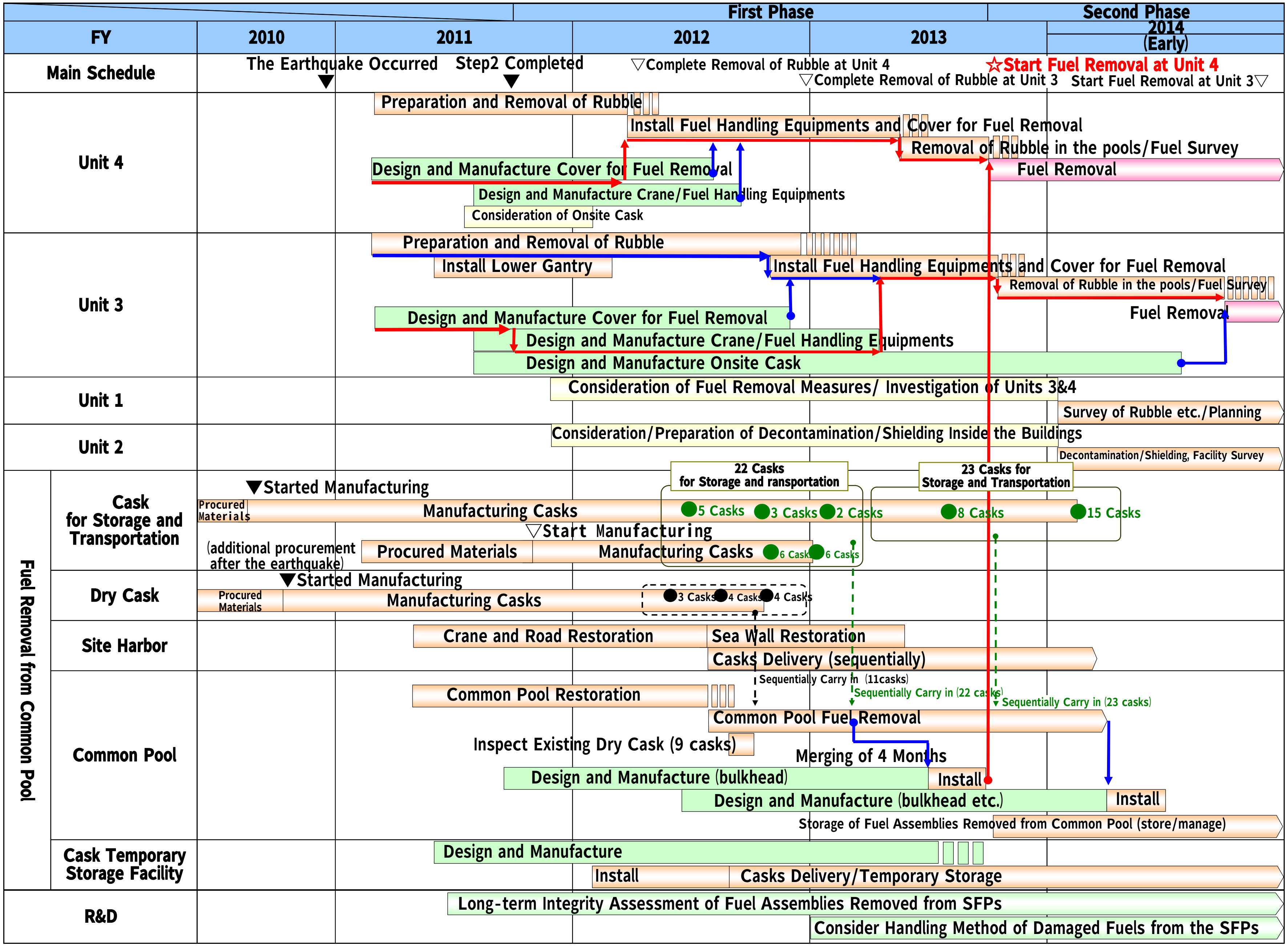
- PCV Gas Control System Installation
  - Unit 2: In Operation
  - Units 1, 3: Install → In Operation
- Land/Sea Area Monitoring (ongoing)

Onsite Decontamination

- ▽Target: Change Main Anti-earthquake Building into an Area where Radiation Controls are not Required
- ▽Target: Reduce Radiation Dose at Corporate Buildings (implement per partner companies needs)
- Systematic Onsite Decontamination (sequentially implement from executive and working area in conjunction with efforts to reduce radiation dose outside of the site)

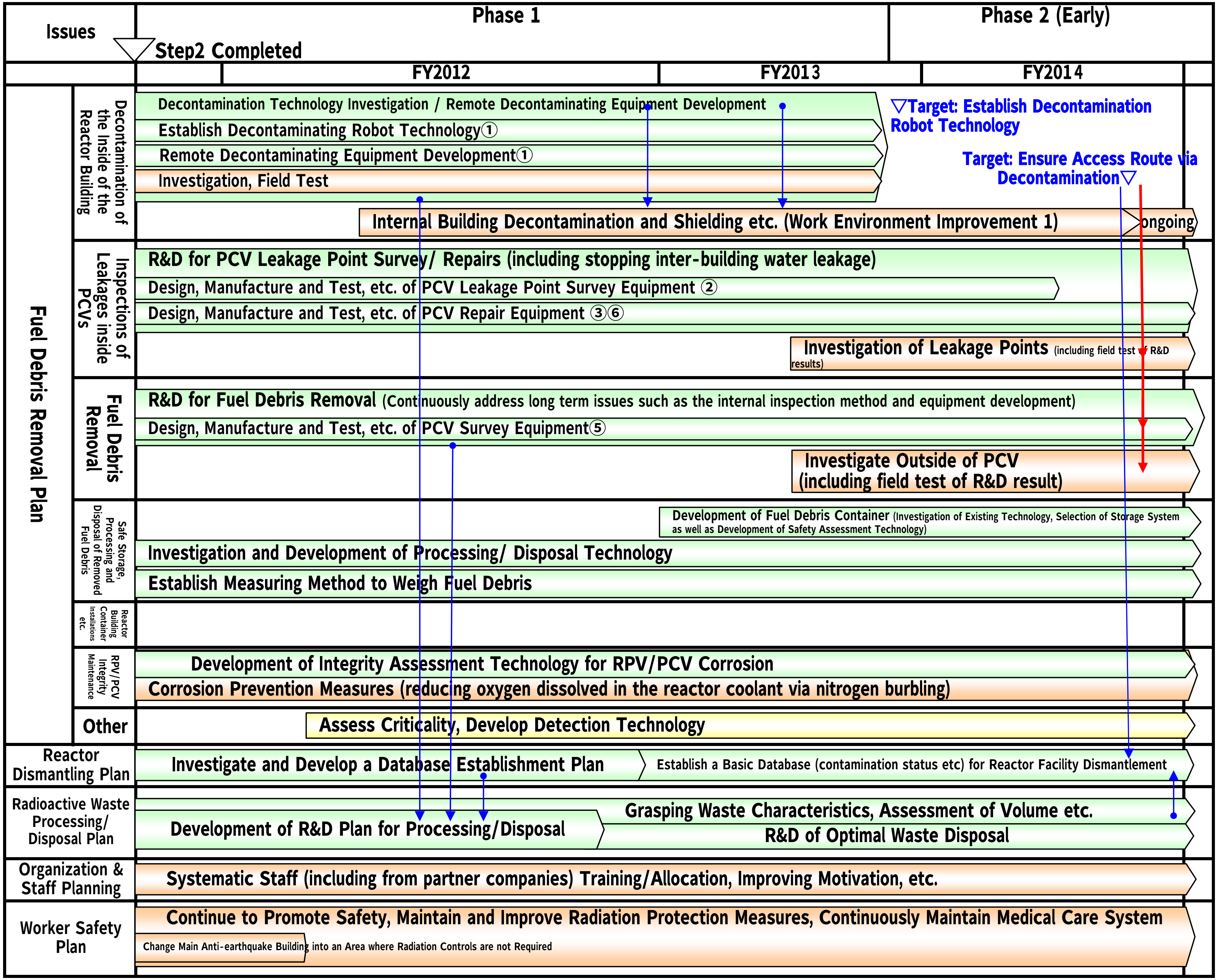
Progress Status of Each Plan (3)

[Provisional Translation]



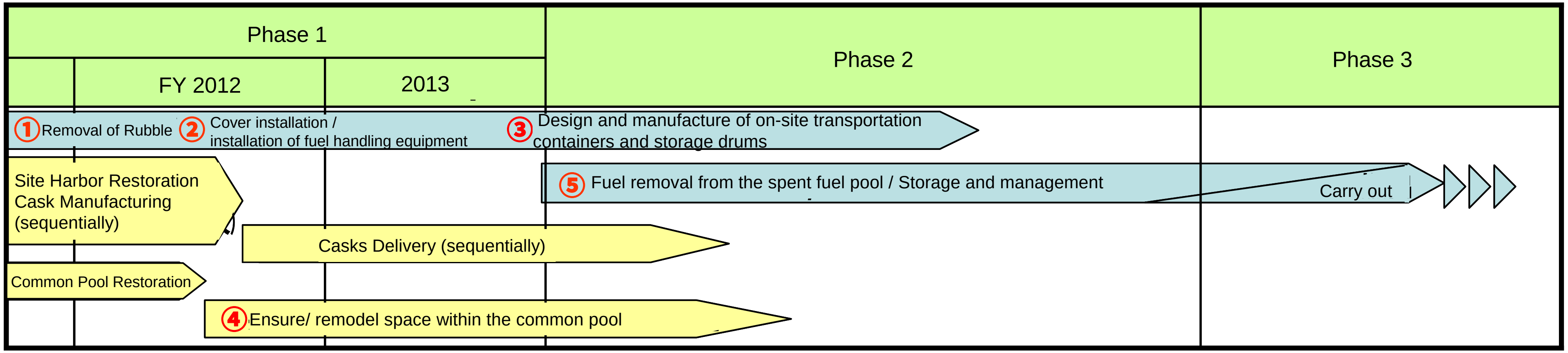
[Provisional Translation]

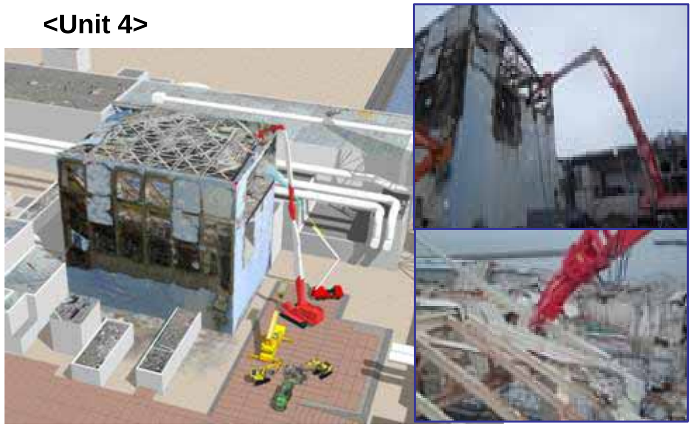
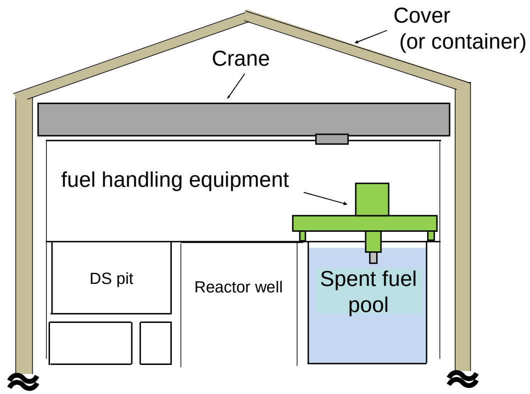
Progress Status of Each Plan (4)



Steps Involved in Fuel Removal from the Spent Fuel Pool (1/2)

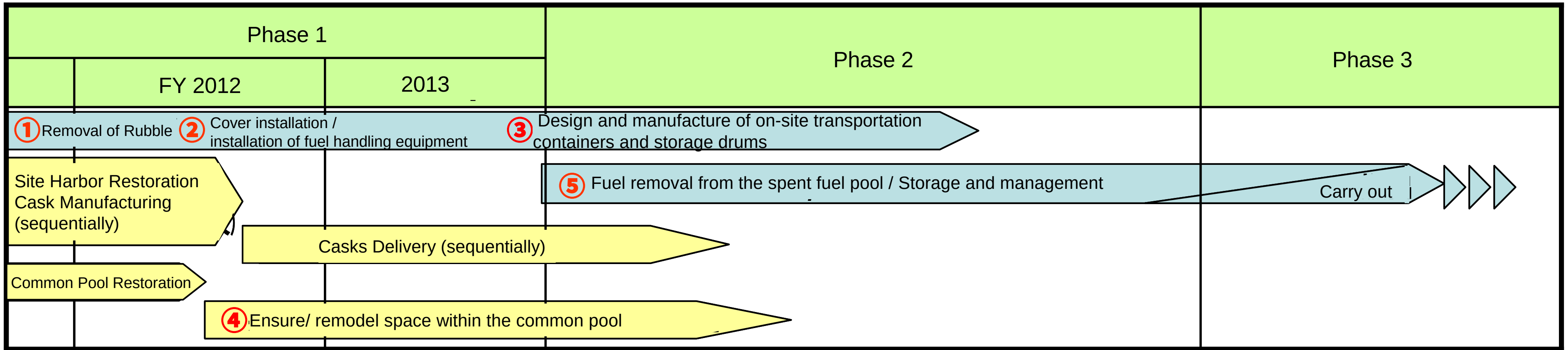
Appendix 2
[Provisional Translation]

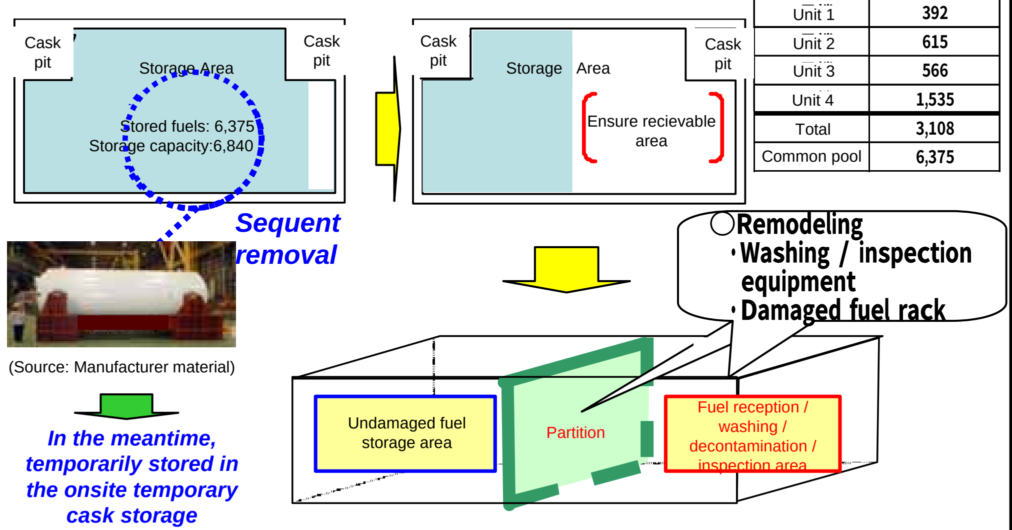
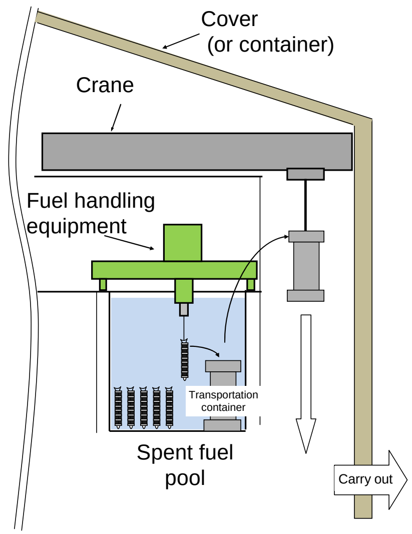


Steps	① Removal of rubble from upper parts of reactor buildings **On going at Units 3&4**	② Cover (or container) installation / installation of fuel handling equipment	③ Design and manufacture of transportation containers and storage drums
Images			**<Example of transportation containers: NH-25 >**  (Source: Manufacturer material)
Contents	Removal of rubble from upper parts of reactor buildings by the use of heavy equipment and a crane	Cover (or container) installation in order to blocking wind and rain / installation of a crane and fuel handling equipment	Design and manufacture of transportation containers and storage drums in order to move fuels from the spent fuel pools to the common pool
Points to Note on Development	–	–	–
Points to Note on Ensuring Safety	-Maintain spent fuel pool cooling in a stable state -Prevent radioactive materials scattering on removal of rubble -Environment Monitoring -Reduce workers exposure (using remote control etc.)	-Maintain spent fuel pool cooling in a stable state -Reduce workers exposure (reduce radioactivity of work area etc.)	–

Steps Involved in Fuel Removal from the Spent Fuel Pool (2/2)

[Provisional Translation]

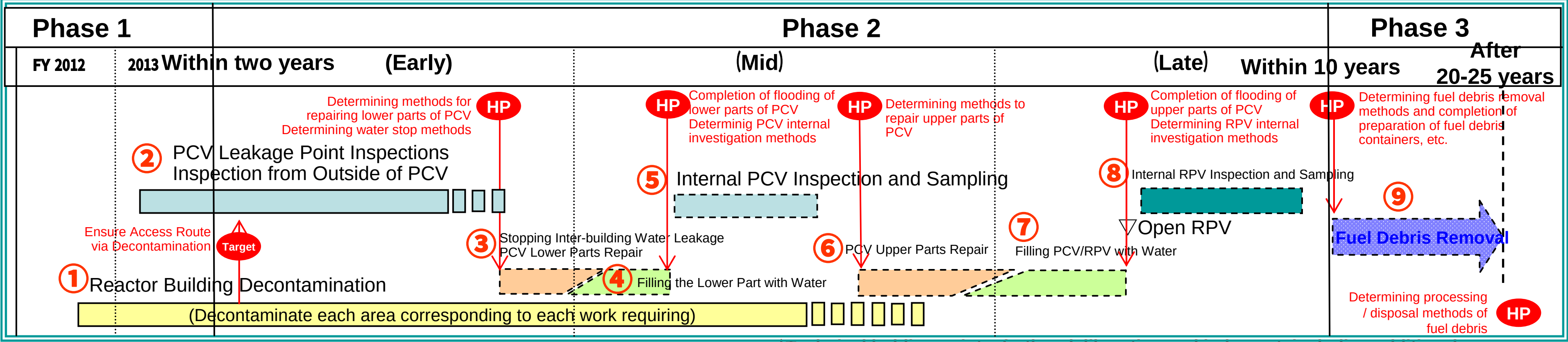


Steps	④ Ensure/ remodel space within the common pool	⑤ Fuel removal from the pool
Images		
Contents	Undamaged spent fuels currently stored in the common pool will be removed in order to ensure an area. Fuel reception partition, fuel washing and inspection equipment, and damaged fuel rack etc. will be installed.	Damaged fuels will be placed in storage drums, then placed in transportation containers in order to movement
Points to Note on Development	-Wash fuels encrusted with salt or damaged / Decontamination / Consideration of method to inspect fuels	–
Points to Note on Ensuring Safety	-Reduce workers exposure (usual management)	-Maintain spent fuel pool cooling in a stable state -Prevent fuel dropped -Reduce workers exposure (use remote equipment, reduce radioactivity of work area etc.)

Unit	Number of stored fuels
Unit 1	392
Unit 2	615
Unit 3	566
Unit 4	1,535
Total	3,108
Common pool	6,375

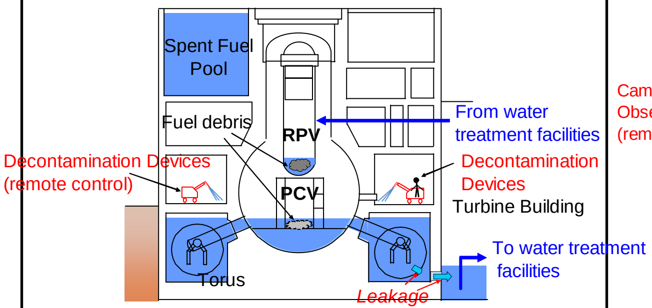
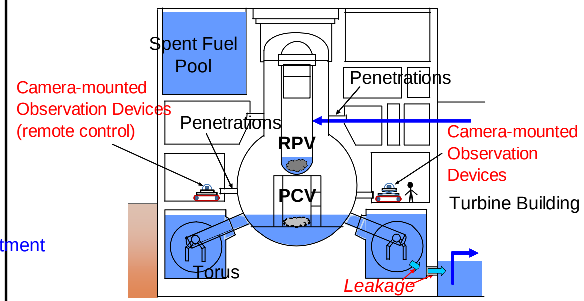
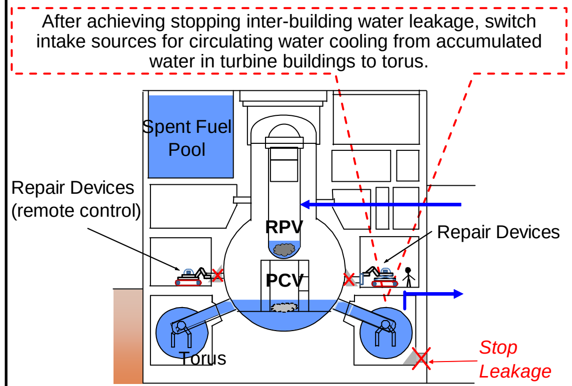
Work Steps Involved in Fuel Debris Removal (1/3)

Appendix 3
[Provisional Translation]



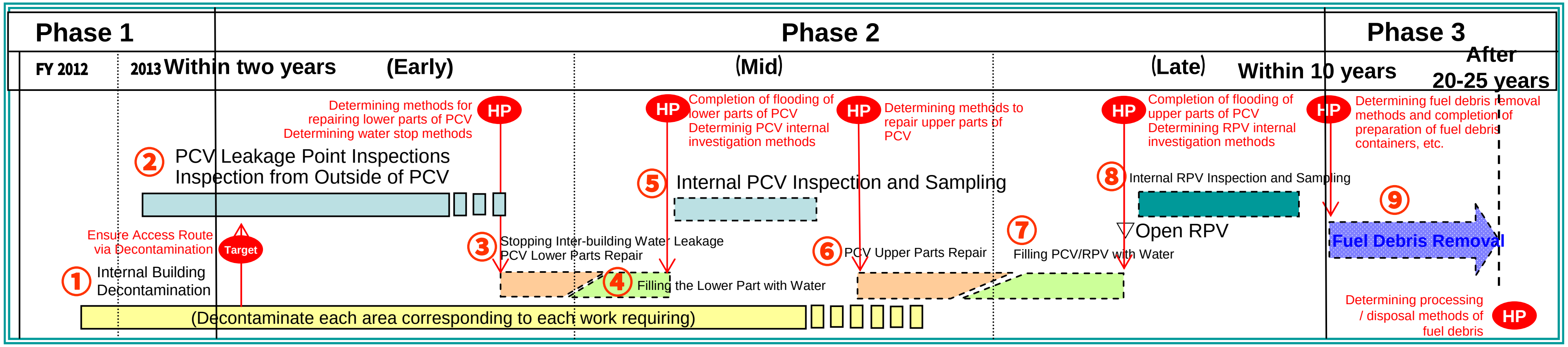
※ Work steps of removing the fuel debris underwater (as was done at TMI-2)

HP : Technical holding points. further deliberation and judgment, including additional research and development and revision of process and task content

Steps	① Reactor Building Decontamination (Decontaminate each area corresponding to each work following ② sequentially)	② PCV Leakage Point Inspections Inspection from Outside of PCV	③ Stopping Inter-building Water Leakage PCV Lower Parts Repair
Images			
Contents	In order to easily access PCVs, decontaminate work area via high-pressure washing, coating, and scraping, etc.	Inspect leakage points in the PCV and reactor building via manual or remote dose measurement, and camera, etc. Estimate and inspect the status of PCV inside via measurement of gamma ray from outside of PCV, and acoustic inspection, etc.	Repair PCV leakage points and then stop water leakage because it is believed that removing debris while underwater due to the excellent radiation shielding afforded will be the reliable method. First, repair points at lower parts of PCV for internal inspection.
Points to Note on Development	◆**The existence of areas of high dosage (several hundred to 1,000 mSv/h).** ◆**Access restriction due to rubble scattered about inside R/B.** ・Remote decontamination methods corresponding to the above need to be considered and established.	◆**Inspection areas may be located in highly radioactive environments, under contaminated water, and in narrow parts.** ・Develop leakage point inspection methods and devices. ・Develop methods and devices for internal inspection from outside of PCV.	◆**While continuing water injection for circulating water cooling, stop water leakage under highly radioactive and water running conditions.** ・Develop technologies and methods to repair leakage points and stop water leakage. ・Consider and develop alternatives.
Points to Note on Ensuring Safety	・Maintain RPV cooling in a stable state ・Prevent radioactive materials scattering during decontamination ・Reduce worker exposure (remote control, shielding, etc.)	・Maintain RPV cooling in a stable state ・Reduce worker exposure (remote control, shielding, etc.)	・Maintain RPV cooling in a stable state ・Reduce worker exposure (remote control, shielding, etc.)

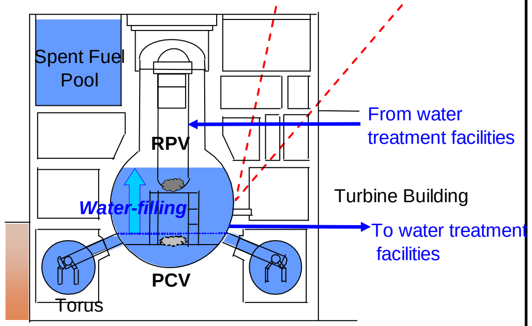
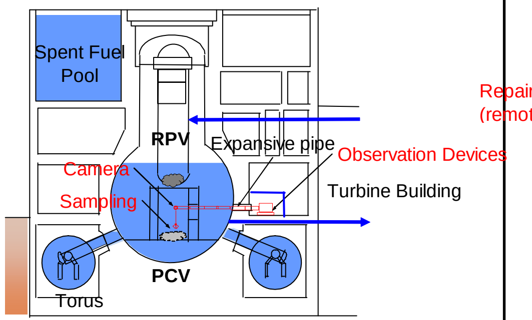
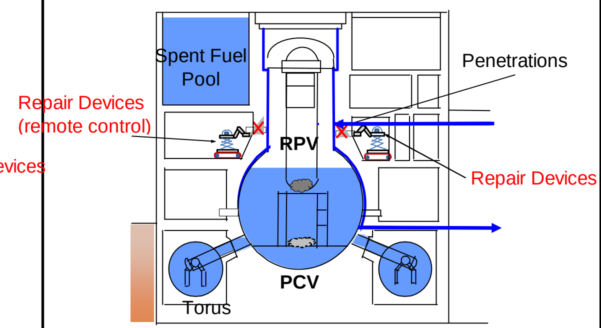
Work Steps Involved in Fuel Debris Removal (2/3)

[Provisional Translation]



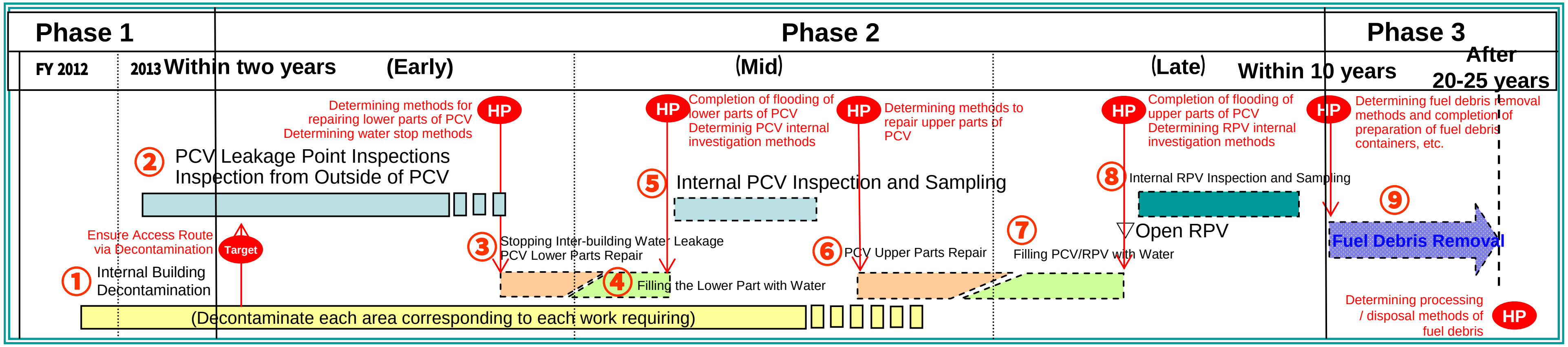
※ Work steps of removing the fuel debris underwater (as was done at TMI-2)

HP :Technical holding points. further deliberation and judgment, including additional research and development and revision of process and task content

Steps	④ Filling the Lower Part with Water	⑤ Internal PCV Inspection and Sampling	⑥ PCV Upper Parts Repair
Images	After achieving construction of boundaries at the lower parts of PCV, switch intake sources for circulating water cooling from torus to PCV. 		
Contents	Partially fill the lower parts of PCV with water before starting PCV internal inspection.	Ascertain distributions of fuel debris flowed from RPV by internal PCV inspections and samplings etc.	In order to fill the PCV full with water, repair leakage points at the upper parts of PCV by manual or remote methods.
Points to Note on Development	◆Same as ③ ・Place top priority on the construction of boundaries at the lower parts of PCV (including filling torus with grout materials).	◆ Access restriction due to high radioactive conditions and unknowing PCV internal conditions (thickness of internal water, existence of debris, etc.) ・Develop remote inspection methods and sampling methods corresponding to the above.	◆ Same as ② ・ Develop technologies and methods to repair PCV leakage points and stop water leakage (same as ③).
Points to Note on Ensuring Safety	・Maintain RPV cooling in a stable state ・Subcritical assessment	・Maintain RPV cooling in a stable state ・Subcritical assessment ・Prevent radioactive substances from PCVs releasing ・Reduce worker exposure (remote control, shielding, etc.)	・Maintain RPV cooling in a stable state ・Reduce worker exposure (remote control, shielding, etc.)

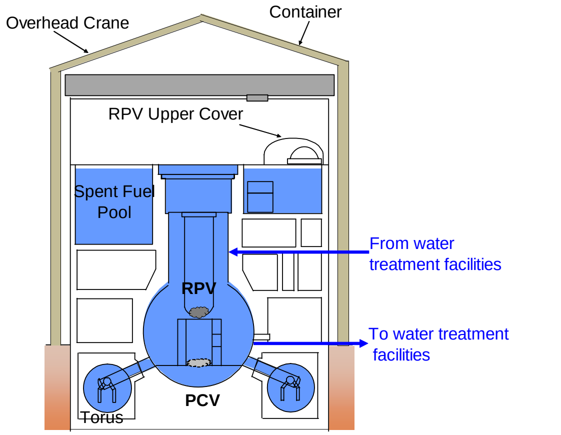
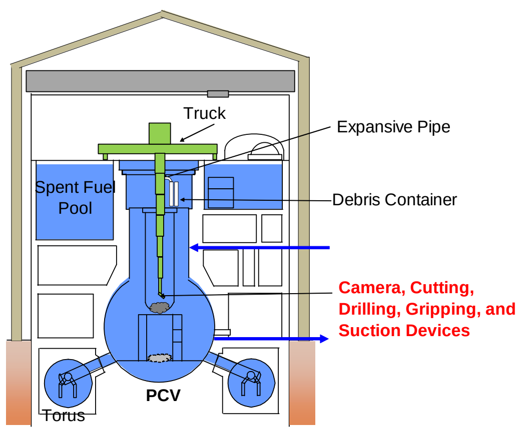
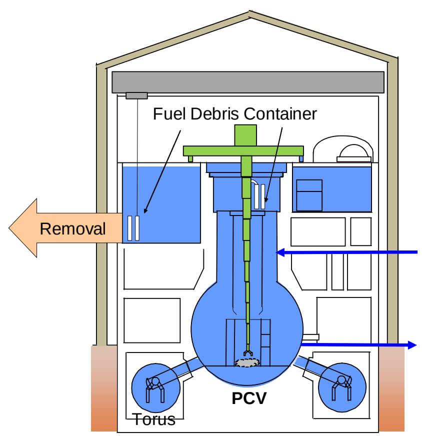
Work Steps Involved in Fuel Debris Removal (3/3)

[Provisional Translation]



※ Work steps of removing the fuel debris underwater (as was done at TMI-2)

HP : Technical holding points. further deliberation and judgment, including additional research and development and revision of process and task content

Steps	⑦ Filling PCV and RPV with Water ⇒ Open the upper cover on RPV	⑧ Internal RPV Inspection and Sampling	⑨ Fuel Debris Removal
Images			
Contents	After filling PCV/RPV with water enough to ensure shielding, open the upper cover on RPV.	Ascertain conditions of fuel debris and internal RPV structures by internal RPV inspections and samplings etc.	Remove debris inside RPV and PCV
Points to Note on Development	(Place top priority on the construction of PCV boundaries as per ⑥)	◆**Restricted access route due to high radioactive conditions and unknown internal RPV conditions (thickness of internal water, existence of debris, etc.)** ・Develop remote inspection methods and sampling methods based on the above.	◆**Expand technology development scope depending on distribution status of fuel debris (No experience of fuel removal of inside PCV at TMI)** ・Develop more sophisticated technologies and methods than those of TMI
Points to Note on Ensuring Safety	・Maintain RPV cooling in a stable state ・Subcritical assessment ・Prevent radioactive substances from PCVs releasing	・Maintain RPV cooling in a stable state ・Subcritical assessment ・Store the removed fuel debris (containment etc.) ・Reduce worker exposure (remote control, shielding, etc.)	・Maintain RPV cooling in a stable state ・Subcritical assessment ・Store the removed fuel debris (containment etc.) ・Reduce worker exposure (remote control, shielding, etc.)

Supplementary Document 1
(Provisional translation)

Research and Development Road Map for Decommissioning Units 1–4 at TEPCO's Fukushima Daiichi Nuclear Power Plant

December 21, 2011
Nuclear Emergency Response Headquarters
Government-TEPCO Med-and-long Term Response Council

Table of Contents

1. Introduction

In addressing the disaster at the Fukushima Daiichi Nuclear Power Plant, following the completion of Step 2 we will be moving from initiatives aimed at stabilizing the plant towards initiatives aimed at maintaining those conditions. At the same time, we will be taking a medium to long-term approach towards actions (removing fuel assemblies stored inside spent fuel pools, removing intra-core fuel debris, etc.) necessary for decommissioning the plant.

To this end, an expert committee was formed by the Atomic Energy Commission of Japan in August of this year to consider medium to long-term solutions. In addition to identifying the technological challenges and establishing the areas in which R&D will be performed, the committee has issued a report that establishes a goal to begin the removal of fuel debris within 10 years, while also stating that a period of more than 30 years would be required to complete the decommissioning process.

Based on the above report, on November 9 Yukio Edano, the Minister of Economy, Trade and the Industry, and Goshi Hosono, the minister in charge of nuclear accident settlement and prevention, requested that the Agency of Natural Resources and Energy, the Nuclear and Industrial Safety Agency (NISA), and TEPCO draft a R&D road map for decommissioning the facility.

In response, the Agency of Natural Resources and Energy and TEPCO devised this R&D road map in collaboration with the Ministry of Education, Culture, Sports, Science and Technology, the Japan Atomic Energy Agency, the Toshiba Corporation and Hitachi / Hitachi-GE Nuclear Energy, Ltd., which is a plant manufacturer with expertise in and experience with the design and construction of TEPCO's Fukushima Daiichi Nuclear Power Plant.

This road map is comprised of four sections: the fundamental philosophy behind the R&D, the R&D plan, the framework for conducting R&D, and the ideal state of international cooperation. All R&D required for the decommissioning of Units 1–4 at TEPCO's Fukushima Daiichi Nuclear Power Plant will be steadily carried out in accordance with this road map.

It is also anticipated that the knowledge and technology gained from this R&D will be put to extensive use in the future improvement of decommissioning techniques and safety infrastructure at nuclear facilities in Japan and around the world.

2. Fundamental philosophy behind conducting the R&D

(1) Addressing needs in the field

The goal of this R&D is to—after completing processes up to Step 2—establish methods for effectively maintaining stable conditions at the plant while at the same time place prime importance on securing the safety of those working at and residing near the facility in coming up with the necessary technological solutions required to certainly and efficiently carry out a plan to remove fuel from spent fuel pools, remove intra-core fuel debris, and complete other steps in the process of decommissioning the plant.

This R&D will differ from research normally conducted in that the results of this R&D will be used directly in work involved in the decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant. As such, the scope of this R&D will include conducting technology demonstrations in the field.

Thus, we will consistently ascertain the needs of those in the field and see that those needs are addressed in R&D at all stages of the R&D plan, from planning to execution, while also applying R&D results as quickly and accurately as possible to problems in the field.

When R&D achievements are realized, the determination as to whether or not to proceed to the next stage will be made after evaluating the feasibility and validity of the technologies developed. We will also coordinate thoroughly with related organizations concerning conditions in the field and progress made with R&D and work processes, revising plans along the way as needed.

In particular, as the results of field surveys may find it necessary to use completely different technologies, we will be looking into alternate policy ahead of time for challenges such as water cutoff technologies that could present considerable technical hurdles.

(2) Desired government involvement and support

The decommissioning of this facility will involve technical challenges the likes of which we have yet to experience. The Agency of Natural Resources and Energy will therefore be playing a lead role in R&D plan creation and project management, and will be coordinating closely with the Ministry of Education, Culture, Sports, Science and Technology as it puts together an R&D framework utilizing the expertise of those in Japan and around the world.

The Nuclear and Industrial Safety Agency (new regulatory agency) will implement safety regulations in accordance with the necessary legislative system for tests and demonstrations performed in the field as part of R&D.

As the organization that established the Fukushima Daiichi Nuclear Power Plant, TEPCO assumes responsibility for fieldwork involved in the decommissioning and will be moving steadily forward with the decommissioning plan.

(3) Open and flexible framework for action which pools wisdom from Japan and abroad

From planning to execution, at each stage we will be considering how to fully apply the technologies and knowledge of experts from Japan and other countries to the R&D we will need to conduct to carry out medium and long-term initiatives aimed at plant decommissioning.

It will be critical that we properly evaluate and assess the information and advice from, as well as the feasibility of specific collaboration with, government-affiliated organizations in other countries, international organizations, and private enterprises as we build an R&D framework that is effective and efficient.

3. Research and development road map

We have drafted an R&D road map to address the technological challenges needed to be overcome to carry out decommissioning work.

We have classified all R&D into "R&D related to the removal of fuel from spent fuel pools", "R&D related to preparation for removal of fuel debris", "R&D related to processing and disposal of radioactive waste", and "R&D concerning remote control devices" and have created the necessary R&D plans for each of these categories.

This road map, like the "Medium to Long-Term Road Map Aimed at Decommissioning Units 1–4 at TEPCO's Fukushima Daiichi Nuclear Power Plant", defines the first R&D phase as the point when Step 2 is completed up to the beginning of the removal of fuel from spent fuel pools (to be completed within two years as per the current goal). Many preparations aimed at decommissioning will be made during this phase, including preparations for beginning the removal of fuel from spent fuel pools, beginning the necessary R&D for removing fuel debris, and conducting the first field surveys.

The second phase is defined as the point when the first phase ends up to the beginning of fuel debris removal (to be completed within 10 years as per the current goal). During this period, many R&D initiatives and primary containment vessel repair processes aimed at removing fuel debris will move into full swing. The "beginning", "mid", and "end" phases will also be used for the purpose of gauging progress during this period.

The third phase is defined as the point when the second phase ends up to the end of decommissioning (30 to 40 years from now as per the current goal). During this period, all processes from fuel debris removal to decommissioning will be carried out.

As precise a timeline as possible has been established for actions to be taken following FY2015, but the timing and content of measures taken may require major revision as a result of field conditions, R&D results, etc. Because there will be numerous technical challenges involved in work performed during this period, it will be necessary to carry out work in stages based on field conditions, R&D results, and safety requirements. Thus, in determining whether or not to move onto the next process, it will be critical to consider whether or not to conduct additional R&D and to review work processes and procedures. These have been organized into holding points and are noted after each related R&D category.

Concerning R&D into remote dismantling technologies for the sake of dismantling reactor facilities, we will continue to look at the necessity of research that includes whether or not existing technology can be used after constructing a basic database containing information about contamination conditions, etc.

(1) R&D related to the removal of fuel from spent fuel pools

a. Master plan for work concerning the removal of fuel from the spent fuel pools

In the spent fuel pools installed on the top floors of the reactor buildings at Units 1–4, there are currently 3,108 fuel assemblies (of which 2,724 are spent fuel) being stored. Although the tsunami temporarily compromised cooling functions, concrete pump vehicles were able to inject coolants to the pools, allowing fuel in spent fuel pools to continue to be cooled.

At the beginning, seawater was injected to the spent fuel pools at Unit 2-4 as emergency measure. Hydrogen explosion at Unit 1, 3, 4 severely damaged the reactor buildings. And it is also possible that fuels in the spent fuel pools were damaged by falling rubbles.

Currently, the following steps are planned for the fuel removal process.

1. Remove rubbles from the upper sections of reactor buildings
2. Install covers (or containers) and install or repair equipment for handling fuel
3. Design and manufacture in-site transport casks and storage canisters
4. Secure open space in the common storage pool and perform the necessary restoration
5. Remove fuel from spent fuel pools
6. Store and manage the removed fuel

While work involving the removal of fuel from spent fuel pools can be accomplished by using existing technology, it will be necessary to conduct an examination of how to safely store for the long-term spent fuel that has been submerged in seawater or deformed / damaged. And what would result should it be reprocessed, in order to make decisions about how to handle spent fuel going forward. We therefore are conducting the below R&D.

b. Areas of research and development

(1-1) Evaluation of the Long-term Integrity of Fuel Assemblies Removed from the Spent Fuel Pool (FY2011–2015)

<Objective>

✧ As fuel assemblies in spent fuel pools were exposed to seawater and possibly damaged, assessment of the impact of safe and long-term storage is required.

<Overview>

✧ Based on the actual condition of removed fuel assemblies, we will perform an assessment of the structural integrity of assemblies exposed to seawater through corrosion testing and devise anticorrosion measures.

(1-2) Examination of Methods for Processing Damaged Fuel, etc. Removed from the Spent Fuel Pool (FY2013–2017)

<Objective>

✧ Fuel assemblies (Units 2–4) stored in spent fuel pools were exposed to seawater, and those at Units 1, 3, and 4 are possibly damaged due to falling rubbles. It will be necessary to examine the impact on reprocessing operation, such as the preprocessing and chemical treatment processes.

<Overview>

✧ Investigating the impact of spent fuel that was damaged or exposed to seawater on the chemical treatment, waste treatment, and product collect processes. Examining processing methods, and establishing criteria for the feasibility of preprocessing and reprocessing will facilitate investigation into methods of processing these fuel assemblies.

(HP-1) Determination of methods for reprocessing and storing spent fuel

○ Future processing and storage methods for spent fuel removed from the spent fuel pools will be decided on the basis of assessment of its long-term soundness and the results of research and development into its reprocessing. [Second Phase (end)]

(2) R&D related to preparation for removal of fuel debris

a. Master plan for work concerning fuel debris removal preparations

Core meltdown is suspected to have occurred at Units 1–3 at the Fukushima Daiichi Nuclear Power Plant. That is, the possibility exists that nuclear fuel melted together with core internals and re-solidified (became fuel debris) and that such debris is present in the bottom sections of reactor pressure vessels and inside primary containment vessels.

Collaborating organizations are currently using numerical calculation simulations of reactor conditions to analyze the degree of fuel debris present while working to further improve the precision of these efforts. It will be critical to use the results of these analyses as a reference and verify actual field conditions and samples.

While we do not yet have a detailed picture of the location or characteristics of fuel debris, or of where damage has been done to primary containment vessels and reactor pressure vessels, operational procedures aimed at removing fuel debris will be similar to those employed at Unit 2 of the Three Mile Island Nuclear Generating Station (hereinafter "TMI-2"). That is, we drafted the R&D plan with the underlying intent to remove fuel debris after submerging it in water in order to reduce radiation exposure as work is performed.

The following are the fuel debris removal procedures planned at the present time.

1. Decontamination of the reactor building interiors
2. Inspections of areas with leakages inside primary containment vessels
3. Reactor building water cutoff, and primary containment vessel underside repair
4. Partially filling up the primary containment vessels with water
5. Inspections and samplings of primary containment vessel interiors
6. Repairs to the upper sections of primary containment vessels
7. Filling up primary containment vessels and reactor pressure vessels with water
8. Reactor core internal investigation and sampling
9. Fuel debris removal technology preparation, and removal work
10. Safe storage, processing, and disposal of removed fuel debris

b. Areas of research and development

<R&D aimed at the removal of fuel debris>

1. Fuel debris removal using remote control equipment and devices

In order to perform work in the currently highly radioactive interiors of reactor buildings at Units 1–3 at the Fukushima Daiichi Nuclear Power Plant, decontamination procedures will need to be performed. We will also need to identify and repair damaged areas in primary containment vessels in harsh environments that are narrow and highly radioactive in order to remove fuel debris while underwater. To this end, in addition to developing new technologies and work methods, we will also be developing methods and equipment that will help to determine the locations and conditions of fuel debris and to remove this debris.

(2-(1)-1) Development of Technologies for Remote Decontamination of the Reactor Building Interior (FY2011–2013)

<Objective>

- ✧ Exposure must be minimized while making it possible for workers to access certain areas to conduct investigations of leakages, perform repairs, and carry out other work necessary to remove fuel debris.

<Overview>

- ✧ As far as field conditions and other factors allow, in addition to estimating and evaluating the extent of contamination, we will be performing decontamination testing via simulated contamination after determining which decontamination technologies can be used. We will develop decontamination systems alongside the development of remote control devices, conduct verification tests on actual equipment through mock-up tests, assess their ability to remove contamination, and make any needed improvements to actual equipment.

(2-(1)-2) Development of Technologies for Identifying Leak Areas in the PCV (FY2011–2014)

<Objective>

- ✧ Performing the underwater fuel debris removal will require repairing leaks in primary containment vessels and filling them up with water. Before this, inspections will be conducted to identify primary containment vessel leakages.

<Overview>

- ✧ As leakages are expected to be in areas that may be highly radioactive, underwater and in narrow sections, we will be developing technologies for accessing these areas via remote control and technologies for detecting leakages.

(2-(1)-3) Development of PCV Repair Technologies (FY2011–2017)

<Objective>

- ✧ We will repair any identified leakages, stop any leakages between the reactor buildings and turbine buildings, and set up boundaries for partial filling up of the bottom sections of primary containment vessels.

<Overview>

- ✧ As leakages are expected to be in areas that may be highly radioactive, underwater and in narrow sections, we will be developing technologies and methods for accessing and repairing these leakages via remote control. The development of methods for repairing primary containment vessels will be a necessary step in the process of removing fuel debris, and we assume there will be major technological difficulties involved. We therefore assume difficulties will be encountered in the development of repair technologies based on the results of inspections of primary containment vessel leakages, and will be moving forward with the development of repair methods as we look at alternative methods along the way.

(HP-2): Determination methods for repairing lower parts of PCV, determining water stop method

- ○ Through inspections of primary containment vessel leakages, we will identify leaks and conditions present in the lower parts of primary containment vessels and building basement levels and verify that the development of the methods and equipment required to repair these parts has been completed. At the same time, we will verify the extent to which these technologies can be used, and that circulating coolant can be removed from these areas, etc. before determining when to begin repair work (water cutoff) in these areas.
- ○ At this time, we will also decide the Unit order for the repair of these parts based on the locations of leakages, which will allow us to conduct primary evaluations of Unit order for the removal of fuel debris. [Second Phase (beginning)]

(HP-4) Determining methods to repair upper parts of PCV

- ○ Once the areas requiring repair in these sections are identified and we verify that the development of the necessary methods and equipment has been completed, we will determine when to begin repair work on the upper parts of the primary containment vessels. Depending on R&D progress and on site conditions and number of personnel required, it may be possible to perform these repairs in tandem with repairs to the bottom parts of primary containment vessels. [Second Phase (mid)]

(2-(1)-4) Development of Technologies for Investigation of the PCV Interior (FY2011–2016)

<Objective>

- ✧ As the current amount of fuel debris is unknown, we will need to survey the locations and conditions of fuel debris inside primary containment vessels in preparation for removing said debris while verifying the status of pedestals, etc. supporting reactor pressure vessels.

<Overview>

- ✧ In our surveys to determine the locations and conditions of fuel debris, we will be making estimates about certain factors using plant parameter measurements, simulation analyses, etc. In the development of technologies for surveying primary containment vessel interiors, we will be taking into account the environment (narrow spaces, high radioactivity, etc.) in designing and manufacturing inspection equipment after determining the kinds of technologies that can be used. Concurrently, we will examine measures for ensuring no radioactive substances are dispersed while surveying work is being performed.

(HP-3) Completion of flooding of lower parts of PCV, determining PCV internal investigation methods

- ○ In determining when to begin internal investigations of PCVs, we will first verify that both the repair of any leakages present in the lower parts of the primary containment vessels and the filling of these vessels have been completed, and that internal investigation methods and the development of any necessary equipment has been completed. [Second Phase (mid)]

(2-(1)-5) Development of Technologies for Investigation of the RPV Interior (FY2013–2019)

<Objective>

- ✧ We need to ascertain conditions inside reactor pressure vessels (concerning fuel debris, damage to reactor interiors, status of decontamination equipment, etc.) in preparation for removing fuel debris.

<Overview>

- ✧ In order to survey fuel debris conditions and other aspects of reactor pressure vessel interiors, we will be looking at technologies that can be used in the expected environments (highly-radioactive, high-temperature, highly-humid, etc. environments). We will design and manufacture devices for surveying pressure vessel interiors based on the results of primary containment vessel interior surveys.

(HP-5) Completion of flooding of upper parts of PCV, determining RPV internal investigation methods

- ○ In determining when to begin opening of the top lids on RPVs and reactor inspections, we will first verify that water has been pumped in up to the upper parts of PCVs (including the reactor pressure vessels), that reactor building containers have been created or covers modified to create confined spaces, and that the development of methods and equipment for inspecting reactors has been completed [Second Phase (end)]

(2-(1)-6) Development of Methods and Devices for the Removal of Fuel Debris and Internal Structures in the Reactor (FY2015–2021)

<Objective>

- ✧ We will use TMI-2 as a reference in proceeding with fuel debris removal work. However, whereas the Fukushima Daiichi Nuclear Power Plant has boiling water reactors (BWR), TMI-2 has pressurized water reactors (PWR). As we anticipate that there is a large amount of core structures inside reactor pressure vessels and that some fuel debris has moved into primary containment vessels, we will need to develop technologies aimed at methods for removing this fuel debris.

<Overview>

- ✧ After determining the technologies that can be used by looking at TMI-2 and other events, we will examine methods for removing fuel debris at the Fukushima Daiichi Nuclear Power Plant and design and manufacture the necessary devices based on the results of investigations of reactor pressure vessel interiors. Following our mock-up tests, we will use these devices in fuel debris removal procedures as we continue to assess and improve their performance.

(2-(1)-7) Development of Technologies for the Containment, Transport and Storage of Reactor Fuel Debris (FY2013–2019)

<Objective>

- ✧ Unlike the situation at TMI-2, fuel debris at the Fukushima Daiichi Nuclear Power Plant has been submerged in seawater the degree of burn up is high. We will therefore need to develop new storage containers in light of the unique characteristics of this fuel debris.

<Overview>

- ✧ We will investigate the technologies that can be used to contain, transport, and store fuel debris that has been submerged in seawater and choose the materials to be used for the containers. We will examine storage methods appropriate for the form of the fuel debris as well as its molten state, manufacturing equipment to handle it and containers to store it in and conducting mock-up tests. After examining methods for efficiently transporting and storing the fuel debris and designing and manufacturing the required equipment, we will conduct a mock-up tests while conducting assessments and making improvements.

(HP6) Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.

- ○ In determining when to begin fuel debris removal, we will first look at the results of internal inspections of PCVs and reactor pressure vessels to verify that the development of fuel debris removal methods and equipment, as well as storage containers (storage canisters) needed for removal, has been completed and that there are places to store the removed fuel debris. [Goal: within 10 years]

(2-(1)-8) Development of Technologies for Assessment of RPV/PCV Integrity (FY2011–2016)

<Objective>

- ✧ We anticipate that reactor pressure vessels and primary containment vessels exposed to seawater will continue to remain in diluted seawater environments for a long time to come. We will need to ensure the health of equipment up until fuel debris removal while continuing to provide stable cooling.
- ✧ We will also need to verify the impact of the history of high temperatures and seawater immersion on reinforced concrete structures supporting reactor pressure vessels and primary containment vessels.

<Overview>

- ✧ We will acquire corrosion data necessary for making suitable assessments and forecasts concerning the progress of corrosion degradation related to reactor pressure vessels and primary containment vessels. Workers will acquire data on reinforcement corrosion and concrete degradation for reinforced concrete structures and perform structural integrity assessments. We will also apply measures to control corrosion and degradation and verify the results.

(2-(1)-9) Development of Technologies for Controlling Fuel Debris Criticality (FY2012–2018)

<Objective>

- ✧ Criticalities will need to be prevented for even situations where water levels or the form of fuel debris have changed as a result of water injection or removal work. This therefore requires we develop pre-criticality assessment and monitoring technologies.

<Overview>

- ✧ We will develop analysis methods that allow criticality assessment in response to changes concerning water injection requirements or intra-reactor conditions. We will also develop a criticality monitor that can be used in effluent treatment and cooling. Based on results of primary containment vessel interior investigations, we will develop as needed a criticality monitor via neutron detection for reactor interiors. We will also develop a neutron absorption material that can be used during work involving the removal, transport, and storage of fuel debris as we examine methods for using it.

2. Ascertaining and analyzing reactor core status
While damaged fuel is currently being cooled in a stable manner, a means to estimate the extent of damage done to the actual reactor cores will provide information required to plan medium and long-term countermeasures and devising safety measures. Unfortunately, direct observation of reactor damage is problematic due to high radioactivity, and there is a high level of uncertainty with current numerical calculation simulations. We will thus need to continue developing technologies for improving the precision of numerical calculation simulation estimates.

(2-(2)-1) Further Advancement of Technologies for Analysis of Accident Progression to enable Understanding of Status of Reactor Interiors (FY2011–2020)

<Objective>

- ✧ In the course of examining methods for investigating and removing fuel debris, it will be advantageous to conduct assessments beforehand based by means of analysis codes. We will enhance and standardize severe accident analysis codes by using plant behavior analyses and analysis codes to conduct accident progression analyses and tests to elucidate phenomena based on actual data from the Fukushima Daiichi Nuclear Power Plant. This will allow us to conduct assessments of the positioning and distribution of fuel debris through investigations into core meltdown behavior and primary containment vessel interior behavior and ascertain detailed information about conditions inside the reactors.

<Overview>

- ✧ We will incorporate the results of accident progression analyses and surveys concerning reactor pressure vessel and primary containment vessel interiors into model development and conduct thorough validation necessary for standard severe accident analysis codes.

3. Ascertaining the characteristics of and preparing to process fuel debris

R&D into processing fuel debris will move into actual operation after we are able to remove some of the debris. To do this, it will be best to acquire basic and fundamental data after first prediction on the characteristics of the debris. Acquiring basic data will take time therefore; we will need to proceed with systematical development.

(2-(3)-1) Study of Characteristics using Simulated Fuel Debris (FY2011–2015)

<Objective>

- ✧ Before beginning actual fuel debris removal and processing, we believe it will be beneficial to first examine specific methods for removing, processing and performing assessments using simulated debris. As the circumstances of the accident that occurred at Fukushima Daiichi Nuclear Power Plant differs from those at TMI-2 (seawater exposure, duration of meltdown, etc.), we will need to manufacture simulated fuel debris based on past studies.

<Overview>

- ✧ We will manufacture simulated fuel debris based on past accidents at the Fukushima Daiichi Nuclear Power Plant and acquire data concerning fuel debris characteristics (mechanical and chemical characteristics). We will also compare these characteristics with TMI-2 debris and consider the information that will be useful for actual fuel debris removal.

(2-(3)-2) Analysis of Properties of Actual Fuel Debris (FY2015–2020)

<Objective>

✧ When examining the safety of long-term storage of fuel debris and how to process and dispose of it after it is removed, we will need to ascertain the solubility, chemical stability, and other chemical characteristics of the fuel debris.

<Overview>

✧ We will conduct analyses of the mechanical and chemical characteristics of actual fuel debris removed from inside and outside of reactor cores.

(2-(3)-3) Development of Technologies for Processing of Fuel Debris (FY2011–2020)

<Objective>

✧ To gain insights into how best to process and dispose of fuel debris after it is removed, we will need to examine the feasibility of using existing processing technologies and look at disposal technologies.

<Overview>

✧ We will evaluate the feasibility of both wet and dry processing using simulated debris and actual debris sample. We will examine whether or not to create waste form from both waste which generated through processing and that of directly disposal of, as well as the applicability of disposing of such wastes.

(HP-7) Determination methods for treatment and disposal of fuel debris

○ We will act in conformity with any related R&D and national policy in devising methods for the future processing and disposal of removed fuel debris. [Third Phase]

(2-(3)-4) Establishment of a new accountancy method for Fuel Debris (FY2011–2020)

<Objective>

✧ With fuel debris, the standard nuclear material accountancy method where 1 fuel assembly = 1 unit does not apply. Before removing and storing fuel debris, a new nuclear material accountancy method should be developed for the transparent and efficient removal of fuel debris.

<Overview>

✧ After analyzing the existing nuclear material management technologies and methods used during the TMI-2 and Chernobyl accidents, measurement technologies and accountancy method should be developed for assessing the weight of nuclear material inside the fuel debris. We will be coordinating closely with the IAEA and other related organizations in this scheme.

＊ Nuclear material accountancy: a method for accurately controlling the shape, volume, and transferring during a fixed period of nuclear material inside nuclear facilities to prevent it from being used in nuclear weapons.

(3) R&D related to processing and disposal of radioactive waste

a. Master plan for work concerning the processing and disposal of radioactive waste

Hydrogen explosions at the Fukushima Daiichi Nuclear Power Plant have produced highly contaminated rubble both inside and outside the buildings, and radioactive waste (zeolite waste, sludge, etc.) is being generated as a result of processing the contaminated reactor core coolant that has leaked out. As this waste is characteristically different from that usually produced, we will first analyze and understand these characteristics and then work to safely process and dispose of it based on our findings. We expect this processing and disposal to require an extended period of time, and so will be properly storing and managing the waste in the meantime.

Dismantling waste generated as a result of future decommissioning will also be processed and disposed of based on surveys into facility contamination conditions and examinations of dismantling methods.

b. Areas of research and development

We will need to set a projection concerning technologies for processing and disposing of rubble and secondary waste being generated from contaminated water processing while also establishing a policy for safely storing it in the long term. We will look into the feasibility of applying existing disposal methods in this endeavor, and will need to develop new technologies for the processing and disposal of any waste for which existing methods cannot be used.

Concerning the processing and disposal of all waste resulting from the above and from reactor facility dismantling, we will draft an R&D plan that will ensure a rational flow to the entire process, after which we will conduct R&D in line with the plan presented here.

(3-1) Development of Technologies for the Processing and Disposal of Secondary Waste produced by the Treatment of Contaminated Water (from 2011 on)

<Objective>

- ✧ Secondary waste generated from contaminated water treatment will need to be turned into waste package and disposed of after intermediate storage. In order to safely and rationally process and dispose of radioactive waste, we will be conducting R&D focused on waste disposal. This will include evaluating the characteristics and safety implications of any secondary waste generated, examining the idea of waste conditioning, and determining optimal disposal methods.

<Overview>

- ✧ In addition to assessing characteristics (amount produced, chemical composition, radioactive concentration, heat release value, etc.) of secondary waste in the form of zeolite waste, sludge, and concentrated liquid waste, we will examine methods for the long-term storage of this waste while taking into account safety evaluation for hydrogen gas generation and heat generation, seawater exposure, and high radioactivity, etc. We will also look into turning waste into waste bodies and evaluating the characteristics of these packages (their strength, leaching behavior, heat resistance) as we examine a scheme for their disposal.

(3-2) Development of Technologies for the Processing and Disposal of Radioactive Waste (from 2011 on)

<Objective>

✧ Debris, dismantling waste produced from future plant decommissioning, and decontamination effluents produced in the course of building and system decontamination at the Fukushima Daiichi Nuclear Power Plant significantly differ from the radioactive waste normally produced in terms of characteristics and composition, requiring that we conduct studies and R&D into technologies needed to dispose of this waste.

<Overview>

✧ Just as we will be developing technologies for the processing and disposal of secondary waste resulting from contaminated water treatment, we will be looking into developing technologies to turn waste into waste packages and examining the potential for applying existing disposal concepts.

✧ There is a possibility that existing disposal concepts may not be applicable for rubble, secondary waste resulting from water treatment, dismantling waste, decontamination effluents and other radioactive waste to be processed and disposed of. We will thus be conducting R&D into new processing and disposal technologies, a process that will include devising new disposal concepts as the case may require.

(HP-8) Verification of applicability of existing concepts in response to waste characteristics

○ Based on the results of research into waste characteristics, we will be verifying the possibility of applying previously examined disposal concepts to the situation.

○ As it may be problematic to apply existing disposal concepts to some waste, including highly-saline waste, we may need to examine new waste processing and disposal strategies (constructing engineered barriers, etc.), devise R&D plans, and begin researching. [Second Phase (mid)]

(HP-9) Verification of prospects for safety of waste during processing and disposal

○ We will verify that safety can be assured concerning the processing and disposing of waste generated after the accident based on the possibility of completing development of required technologies. We will also be gathering information needed to construct a safety regulation framework for waste processing and disposal.

○ We anticipate that fuel debris removal and dismantling work will yield new information concerning waste characteristics. As it is also possible that decontamination performed during work will produce new waste, we will continue with R&D and improve the safety of processing and disposal methods as the situation requires. [Second Phase (end)]

(HP-10) Determination of specifications / method to produce of waste packages

- ○ Based on the results of R&D into radioactive waste processing and disposal, we will be constructing a regulatory framework and outlining conditions (waste packages specs, site requirements demanded by disposal sites, and disposal site design requirements) for waste processing and disposal, as the case requires.
- ○ We will then establish specifications and conditioning methods for waste packages based on the above conditions. [Third Phase]

(HP-11) Installation of equipment for production of waste packages and securing of firm prospects for disposal

- ○ After completing the installation of production equipment for producing waste packages and verifying the ability to dispose of them, we will begin production and carry them out of the facility. [Third Phase]

(4) Research and development into remote control equipment and devices

We expect a variety of work focused on preparing to remove fuel debris (decontamination, various surveys, repairs, etc.) will need to be performed inside reactor buildings. However, as there are currently numerous highly radioactive areas to which workers have only limited access, remote control devices and technologies will need to be developed to enable work to be conducted in this environment as planned.

Due to the fact that these remote-control technologies will be applied to a variety of different work inside reactor buildings, it will be critical to identify individual work needs, construct a shared platform (consisting of shared elemental technologies and basic technologies) and take a holistic approach.

In the event that the development of a shared technology platform required to develop remote-control equipment and devices is conducted at a specialized R&D institute or other such organization, we will work closely with these institutions and make use of the resulting technologies.

4. Framework for conducting research and development

(1) Fundamental philosophy behind the framework for conducting research and development

The tasks to be undertaken will present major challenges almost completely without precedent in the world. As such, we will be pooling the wisdom of experts in the industry internationally and constructing a framework to enable a flexible and agile approach to these issues.

To make steady and effective progress forward with individual R&D projects, we will put together an organization tasked with overall management which will conduct appropriate assessments of all R&D projects and take a flexible approach to reviewing and partially revising or abolishing plans or the project framework based on overall progress.

We will also need to quickly and appropriately share information about situations in the field at the Fukushima Daiichi Nuclear Power Plant as well as project needs and the results of applying newly developed methods and other technologies as we flexibly review plans to tackle individual R&D challenges.

(2) Research and development action framework

1. Objectives and roles

In order to give comprehensive and intensive focus to R&D involving medium and long-term measures aimed at the decommissioning of Units 1–4 at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant, we have formed the "Research and Development Headquarters" (hereinafter "R&D Headquarters") which will be planning and performing overall fine-tuning of R&D efforts.

2. R&D Headquarters Composition

The R&D Headquarters is comprised of the Agency of Natural Resources and Energy, the Ministry of Education, Culture, Sports, Science and Technology, the Japan Atomic Energy Agency (JAEA), TEPCO and the Toshiba Corporation and Hitachi ,Ltd / Hitachi-GE Nuclear Energy, Ltd., which are a plant manufacturer with extensive expertise in and experience with the design and construction of TEPCO's Fukushima Daiichi Nuclear Power Plant, in addition to other persons with relevant knowledge and experience.

As the administrative organization of the R&D Headquarters, the Japanese government will assign a suitable individual to the position of the Director of R&D Headquarters, whose role will be to provide R&D management. It will also appoint a deputy director of R&D Headquarters to assist the Director. It will also establish in the R&D Headquarters offices needed to carry out the duties of the abovementioned R&D projects.

In addition to drafting an overall R&D plan, the R&D Headquarters will perform comprehensive assessments of evaluations of progress made by working teams in each field, conduct research project prioritization and budgetary allocation, and make decisions that will have profound impact on how projects are run and on the overall coordination of the challenges being addressed by each team.

3. Working teams

Japanese Government and TEPCO will establish the below working teams and sub working teams in the R&D Headquarters while planning and providing overall coordination of R&D in each field.

With a view to providing across-the-board management of R&D projects for each field, we will draft R&D plans for these fields in addition to providing the necessary instruction for each of these projects. Specifically, we will approve action plans being considered for each R&D project and assess progress while requesting revisions as needed.

(A) Working team for spent fuel pool countermeasures

(B) Working team for preparation of fuel debris removal

- Sub-working team for equipment/device development, etc.
- Sub-working team for core status assessment and analysis
- Sub-working team for fuel debris property assessment and treatment preparation

(C) Working team for radioactive waste processing and disposal

(D) Joint task force for remote technologies (cross-field matters)

4. Administrative office

We will establish an administrative office which will be comprised of representatives from related organizations and which will oversee clerical work pertaining to overall management of R&D. The Agency of Natural Resources and Energy will act as executive secretary.

As it will also be important to coordinate closely with workers in the field, administrative offices for each working team will be supervised by TEPCO, which oversees work in the field.

We will also assign supervisors for each working team who will carry out information infrastructure building activities to facilitate the effective and efficient execution of R&D projects. While coordinating with administrative office personnel, the supervisors will manage the collection, organization, and sharing of information concerning both internal and external related technologies and will perform duties including coordinating cooperative efforts with related research institutions and other overseas organizations.

5. Ideal state of international cooperation

As stated above, it will be necessary to pool both domestic and international wisdom in order to efficiently and effectively execute medium and long-term strategies aimed at decommissioning Units 1–4 at the Fukushima Daiichi Nuclear Power Plant. To this end, in addition to acquiring technical knowledge from a wide variety of fields in Japan, as collaborating with international organizations will be critical, we will also be utilizing the expertise and experience of these organizations concerning measures taken with the TMI-2 and Chernobyl accidents.

- To apply the world's expertise to a host of unprecedented and difficult challenges, we will be publicizing and sharing in a timely fashion a wide array of information concerning the status of plans and initiatives regarding all medium and long-term measures including R&D challenges.
- We will be accurately assessing the possibility of concrete collaborative efforts with foreign governmental organizations, international organizations, and private enterprises to receive information and advice as well as financial support, and will work to conduct R&D effectively and efficiently. We will also be taking a flexible and agile approach to incorporating devices and systems that have proved useful overseas. However, we will not be merely purchasing equipment and systems from overseas; full consideration will be given to long-term reliability and

achieving compatibility with domestic technologies.

- The wisdom and expertise acquired through R&D will contribute to the technological capabilities of participating domestic corporations and research institutions. It will also be of benefit not only in responding to the Fukushima Daiichi Nuclear Power Plant accident, but also in reinforcing a safety infrastructure for future nuclear facility decommissionings internationally. For these reasons, this wisdom and expertise will be treated as achievements that include intellectual property.

At the same time, we recognize our responsibility to the international community for the accident our country has caused and the obligation to proactively share information with the world so that we can gather knowledge from Japan and abroad and apply it towards the many issues we will face as we move forward. To this end, it will be vital that we share research plans and achievements at international conferences and other such events. We may also establish an international R&D center which we will take full advantage of in seeing these initiatives through.

There are a number of areas of research where leading researchers from around the world could be invited to Japan to work on. In decommissioning work, for example, there is a need to develop technologies to analyze the characteristics of and process fuel debris, technologies to perform environmental analyses and radioactive substance diffusion surveys for soil and seawater in areas around power plants, and environmental cleanup technologies.

The resulting R&D base could also become one of the world's leading international centers for developing remote-control equipment and devices because the harsh environments of Fukushima Daiichi are the only place where such technologies can be demonstrated.

Over the course of about a year, we will continue to examine the specifics of a concept for constructing an R&D base as we take concrete action in beginning R&D.

<Attached Documentation>

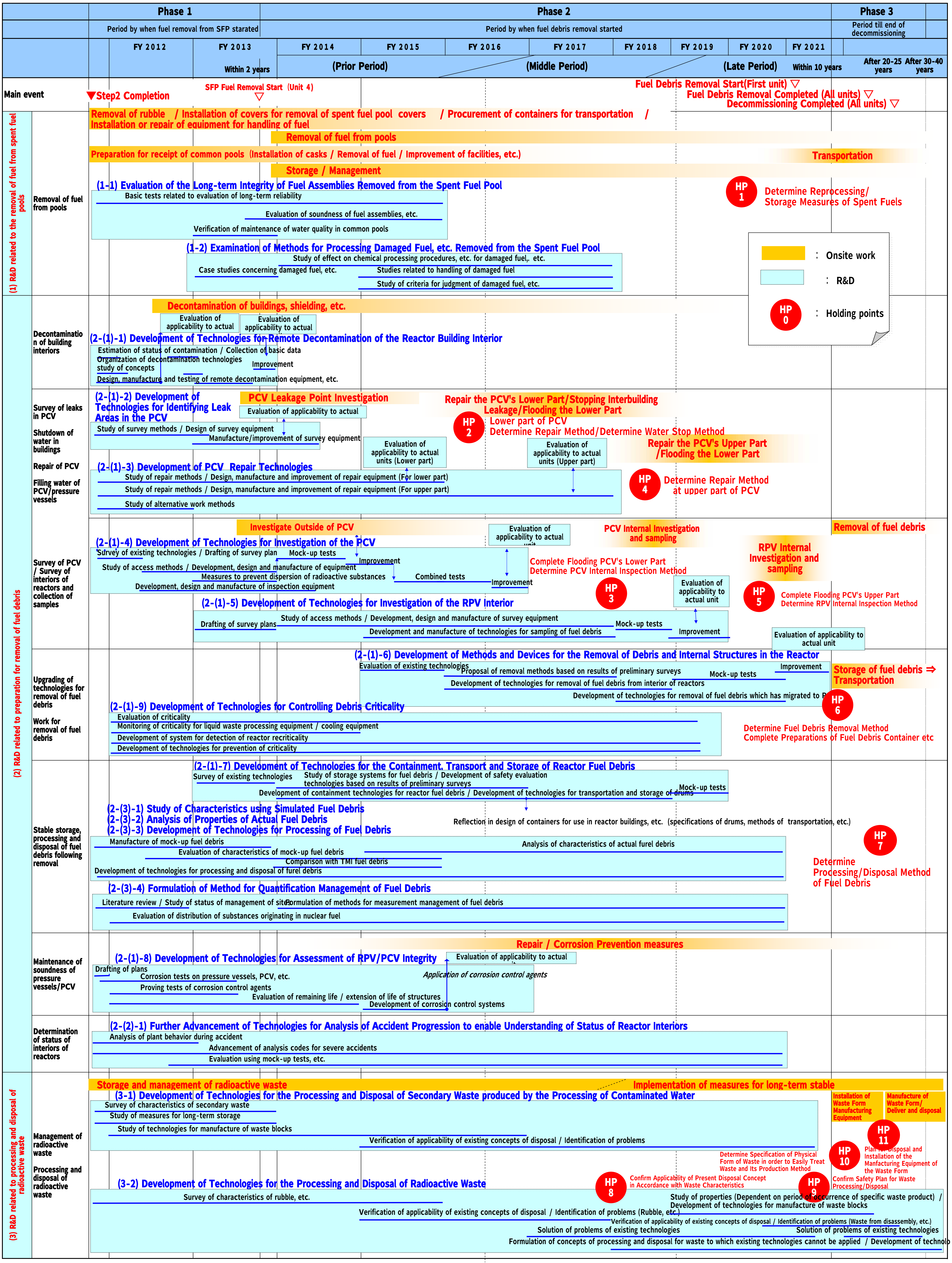
Attachment 1: R&D Master Plan
Attachment 2: Image of Main R&D Issues Related to Fuel Debris Removal
Attachment 3: Image of R&D Issues Related to Radioactive Waste Processing and Disposal
Attachment 4: R&D Headquarters Framework
Attachment 5: Areas of R&D (one page per area)

- (1-1) Evaluation of the Long-term Integrity of Fuel Assemblies Removed from the Spent Fuel Pool
- (1-2) Examination of Methods for Processing Damaged Fuel, etc. Removed from the Spent Fuel Pool
- (2-(1)-1) Development of Technologies for Remote Decontamination of the Reactor Building Interior
- (2-(1)-2) Development of Technologies for Identifying Leak Areas in the PCV
- (2-(1)-3) Development of PCV Repair Technologies
- (2-(1)-4) Development of Technologies for Investigation of the PCV Interior
- (2-(1)-5) Development of Technologies for Investigation of the RPV Interior
- (2-(1)-6) Development of Methods and Devices for the Removal of Fuel Debris and Internal Structures in the Reactor
- (2-(1)-7) Development of Technologies for the Containment, Transport and Storage of Reactor Fuel Debris
- (2-(1)-8) Development of Technologies for Assessment of RPV/PCV Integrity
- (2-(1)-9) Development of Technologies for Controlling Fuel Debris Criticality
- (2-(2)-1) Further Advancement of Technologies for Analysis of Accident Progression to enable Understanding of Status of Reactor Interiors
- (2-(3)-1) Study of Characteristics using Simulated Fuel Debris
- (2-(3)-2) Analysis of Properties of Actual Fuel Debris
- (2-(3)-3) Development of Technologies for Processing of Fuel Debris
- (2-(3)-4) Formulation of Method for Quantification Management of Fuel Debris
- (3-1) Development of Technologies for the Processing and Disposal of Secondary Waste produced by the Treatment of Contaminated Water
- (3-2) Development of Technologies for the Processing and Disposal of Radioactive Waste

[Provisional Translation]

Research and Development Roadmap for the Decommissioning of Units 1-4 of Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station

Attachment 1



* This roadmap will be updated in consideration of the on-site situation and the latest research and development results.

Image of Main R&D Issues Related to Fuel Debris Removal

■ Development of technologies for remote decontamination of the reactor building interior

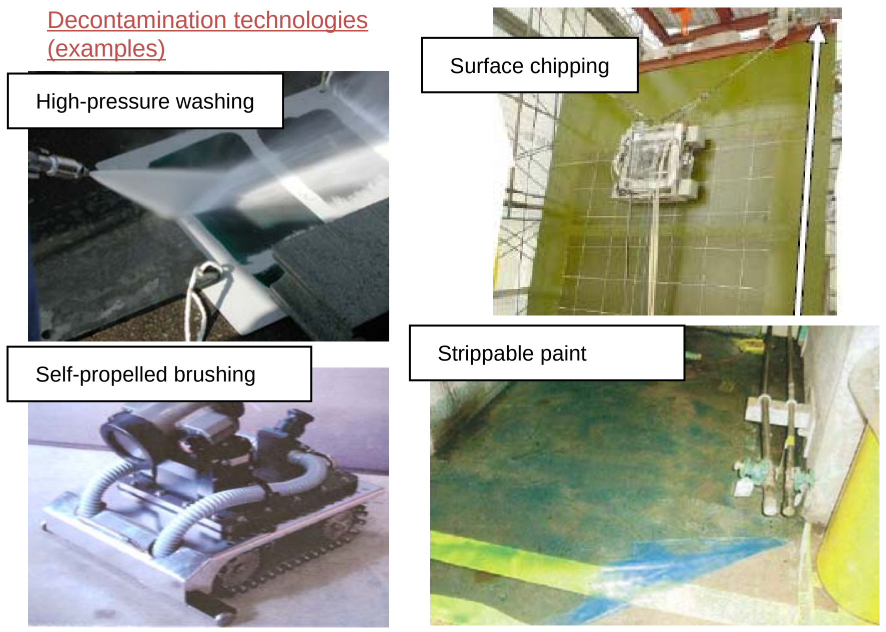
◆ Overview

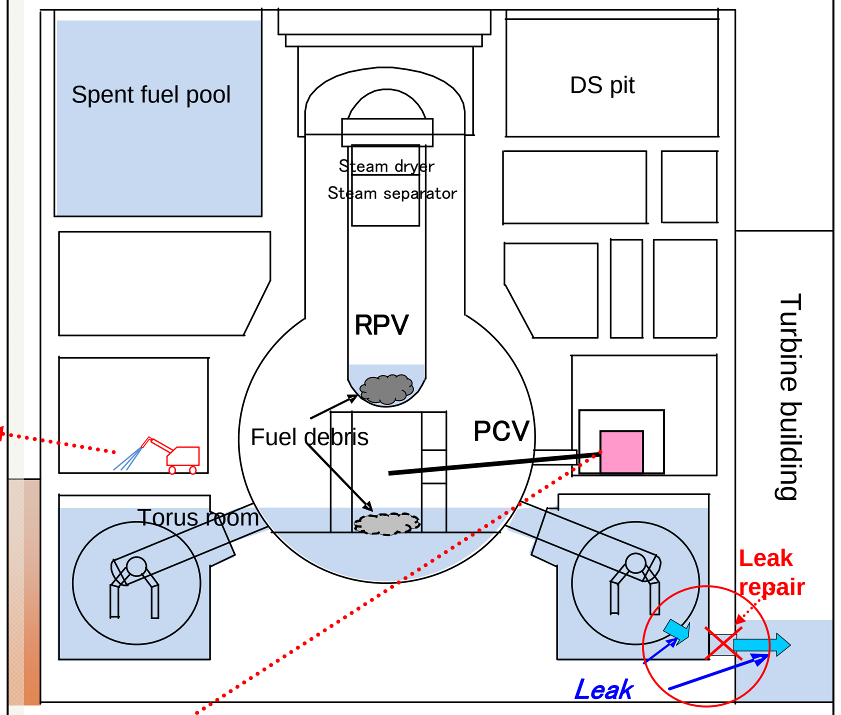
Remote decontamination devices that match onsite contamination conditions will be developed to improve the work environment for surveying and repairing leak areas, etc.

◆ Technical development issues

- Assessment and development of effective decontamination technologies in response to contamination type
- Development of remote decontamination devices for severe environments, such as high-dose areas, narrow spaces, etc.

Decontamination technologies (examples)





■ Development of technologies for identification of leak areas in the PCV

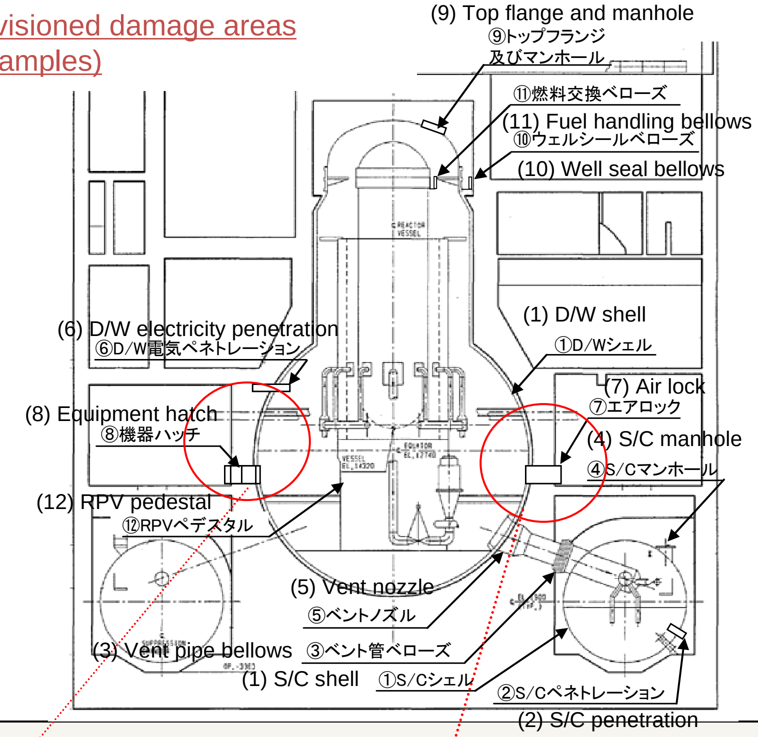
◆ Overview

Technologies for remote identification of leak areas in the PCV, etc. will be developed.

◆ Technical development issue

• Development of remote survey technologies for severe environments, such as high-dose areas, narrow spaces, etc.

Envisioned damage areas (examples)



■ Development of technologies for investigation of the PCV interior

◆ Overview

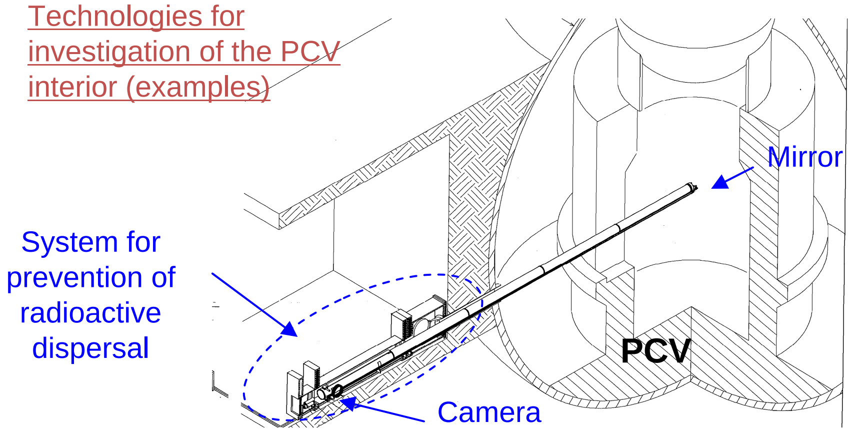
Remote investigation methods and devices will be developed to grasp the conditions and the state of fuel debris inside the PCV.

◆ Technical development issues

• Development of remote investigation technologies for high-temperature, high-humidity, and high-dose environments

• Development of a system to prevent the dispersal of radioactive materials

Technologies for investigation of the PCV interior (examples)



■ Development of PCV Repair Technologies

◆ Overview

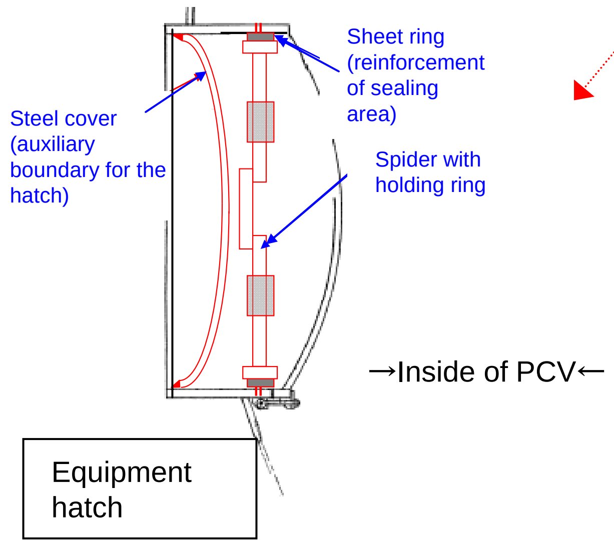
Remote measures and technologies will be developed to repair and stop leaks in leaking areas (Torus room, PCV, etc.).

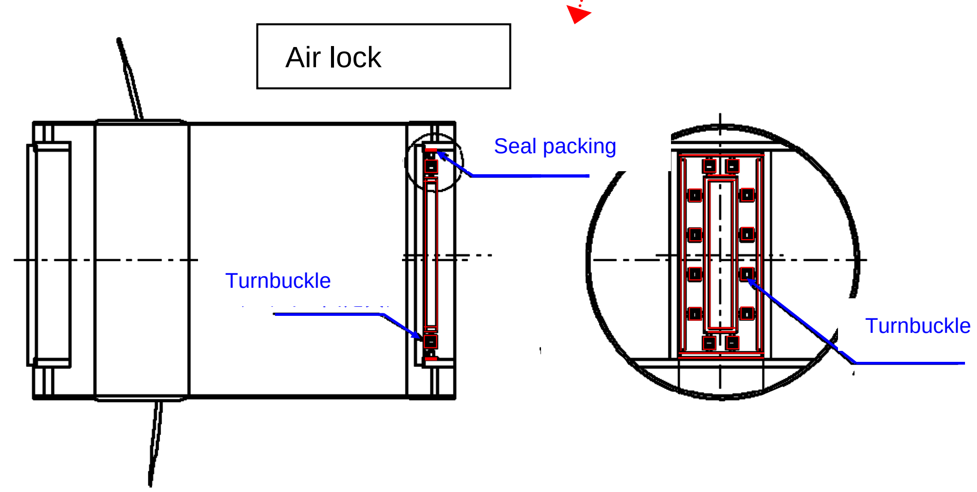
◆ Technical development issues

• Development of remote repair technologies for severe environments, such as high-dose areas, narrow spaces, etc.

• Repair technologies applicable to underwater environments (lower part of the PCV, etc.)

Penetration hole repair technologies (examples)





Attachment 3[Provisional Translation]

Image of R&D Issues Related to Processing and Disposal of Radioactive Waste

→ Output flow

1. Properties investigation

Investigation issues
• Properties differ from conventional waste, such as rubble, sludge, and decontaminated waste liquid (nuclide composition, chloride content, etc.)
• Basic information needs to be assessed for development of each technologies

Examples of differences with conventional waste
• Main nuclides: Co-60, C-14, etc.
  →Fukushima Daiichi: Cs-137, Sr-90, etc.
• Sodium concentration is 5 times that of the TMI case due to 50-90% contamination by seawater
  →Lower Cesium absorption performance, increased waste generation
• Presence of sludge and other materials of unknown chemical composition
  →Need to identify these materials through analysis

Sludge sample (made by JAEA)

Zeolite sample

Outputs
• Radioactive concentration of each type of nuclide
• Component content
• Physicochemical characteristics etc.

The installation of a hot lab near 1F must also be considered, as large volumes of high-dose, untransportable samples are expected to be generated accompanying decontamination and fuel debris removal.

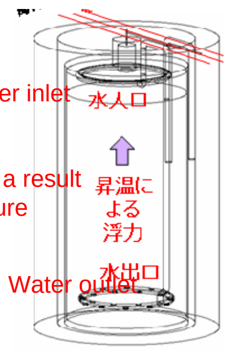
2. Long-term storage technologies

Stabilized storage is necessary until processing/disposal technologies are established.

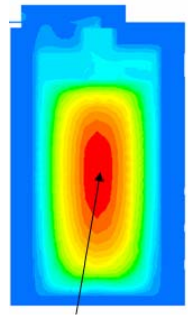
Technical development issues
• Impact of chloride (corrosion) and high radioactivity (heat generation, hydrogen, surface radiation)
• Term of storage: how long should it be?
• Is treatment necessary before storage?

Facility for secondary waste storage after water treatment (example)

Cross section B , A, C



A-A cross section
Temperature distribution



Temperature of zeolite layer
Approx. 170˚C max.

Evaluation of temperature and hydrogen distribution in a KURION absorption vessel (by JAEA)

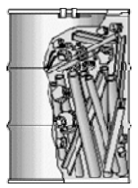
Output
• Long-term storage method for each type of waste

3. Processing technologies

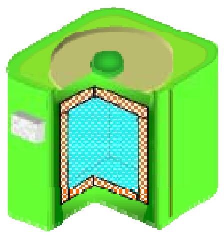
Technical development issues
• Base new technologies on existing processing technologies be applied?

Processing means that waste is placed into the vessel and solidified (cementation ,etc.), so that it can be buried in the disposal site.

Examples of waste package

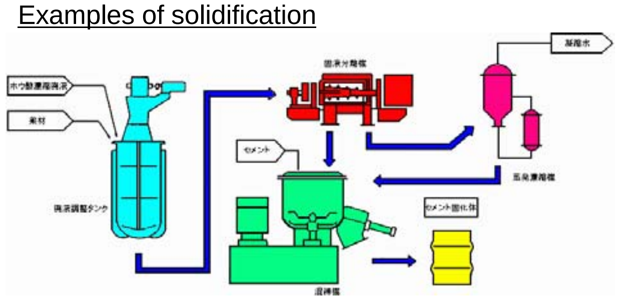


Drums



Square vessels

Examples of solidification



Basic flow in a cementing facility

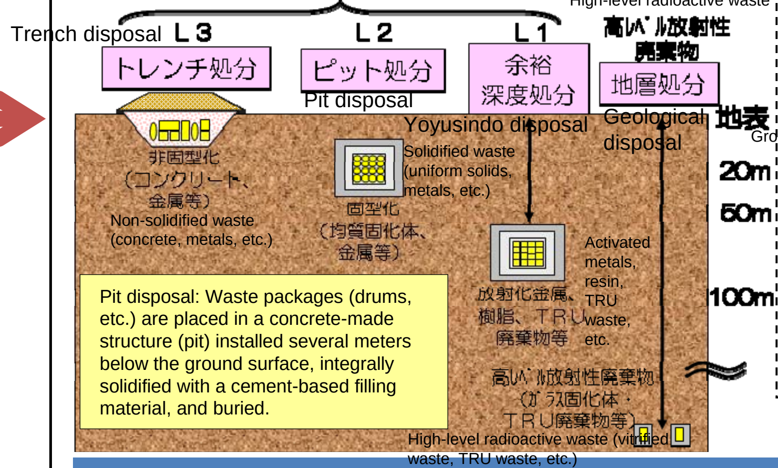
Source: Japan Atomic Industrial Forum Inc. (ed.), *Radioactive Waste Management: Technical Development and Plans in Japan*, July 1997, p.81.

Outputs
• Treatment methods for storage
• Methods for production of waste packages
• Performance of waste packages

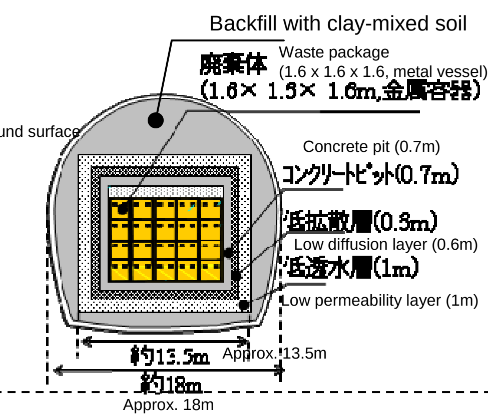
4. Disposal technologies

Technical development issues
• Base new technologies on the existing disposal concept
• Extract and address issues related to safety evaluation and find a solution

Existing concept

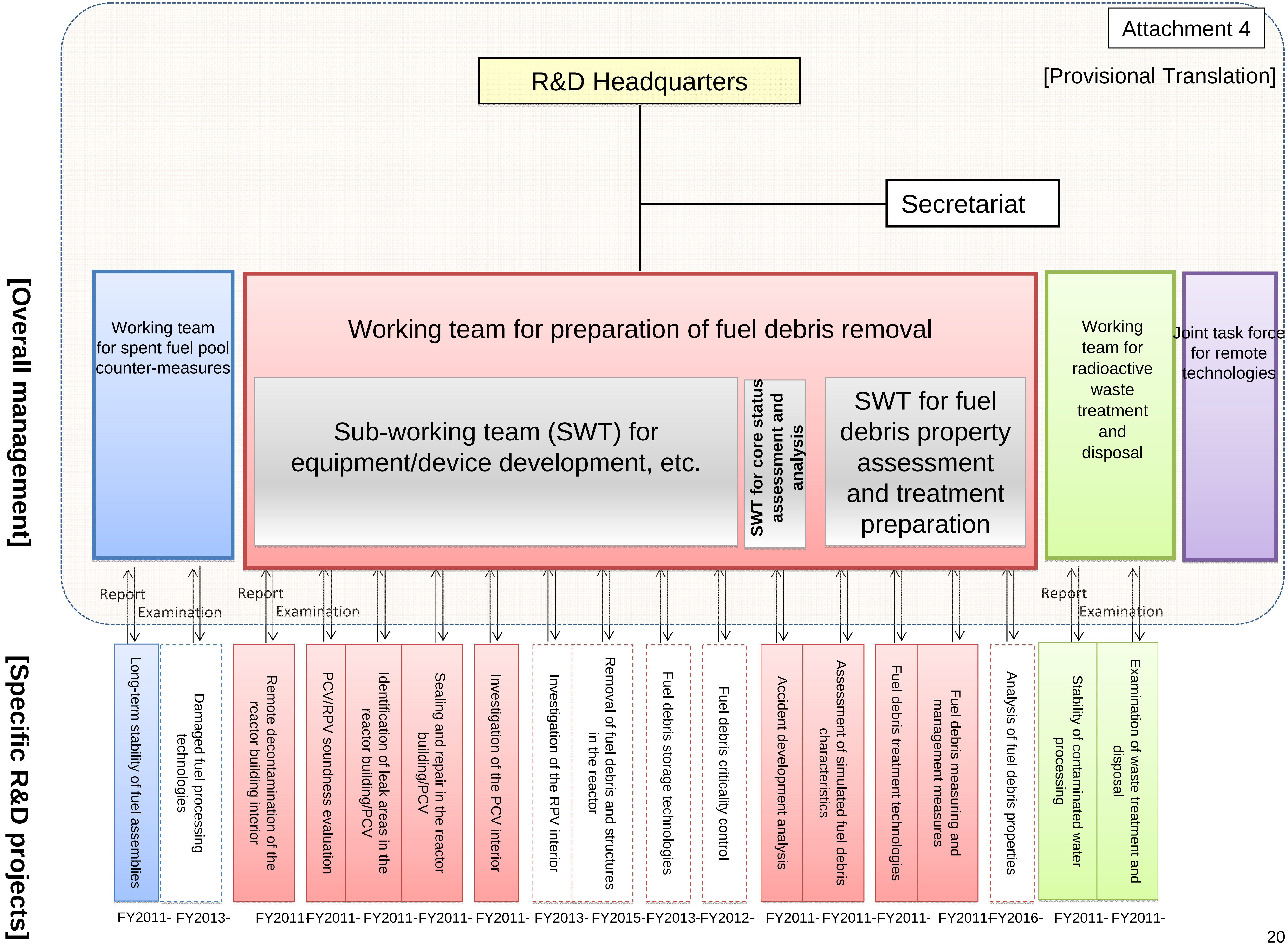


Example of an engineered barrier
(Yoyusindo disposal)



Output
• Waste disposal methods (required burial depth, construction of an engineered barrier, etc.)

New technologies need to be developed for radioactive waste that are difficult to treat with existing technologies, including a new disposal concept.


Attachment 4
[Provisional Translation]
R&D Headquarters
Secretariat
[Overall management]
Working team for spent fuel pool counter-measures
Working team for preparation of fuel debris removal
Sub-working team (SWT) for equipment/device development, etc.
SWT for core status assessment and analysis
SWT for fuel debris property assessment and treatment preparation
Working team for radioactive waste treatment and disposal
Joint task force for remote technologies
Report
Examination
Report
Examination
Report
Examination
[Specific R&D projects]
Long-term stability of fuel assemblies
Damaged fuel processing technologies
Remote decontamination of the reactor building interior
PCV/RPV soundness evaluation
Identification of leak areas in the reactor building/PCV
Sealing and repair in the reactor building/PCV
Investigation of the PCV interior
Investigation of the RPV interior
Removal of fuel debris and structures in the reactor
Fuel debris storage technologies
Fuel debris criticality control
Accident development analysis
Assessment of simulated fuel debris characteristics
Fuel debris treatment technologies
Fuel debris measuring and management measures
Analysis of fuel debris properties
Stability of contaminated water processing
Examination of waste treatment and disposal
FY2011- FY2013- FY2011FY2011- FY2011-FY2011- FY2011- FY2013- FY2015-FY2013-FY2012- FY2011-FY2011-FY2011- FY2011FY2016- FY2011- FY2011-

[Provisional Translation]

(1-1) Evaluation of the Long-term Integrity of Fuel Assemblies Removed from the Spent Fuel Pool

Necessity

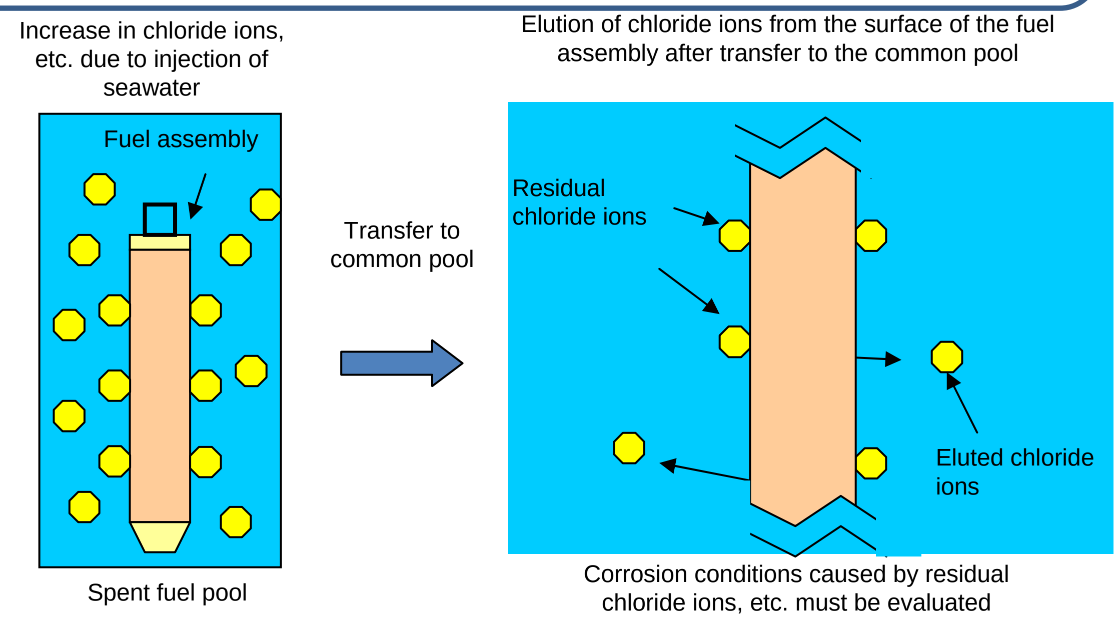
The fuel assemblies in the spent fuel pool will be transported and stored in a common pool set up on the site of Fukushima Daiichi Nuclear Power Station until a final repository is decided. Impurities such as chloride ions are thought to be adhered to the fuel assemblies due to the injection of seawater into the spent fuel pool, and would be almost impossible to completely remove even if the fuel assemblies are washed with water before being transferred to the common pool. For this reason, it is necessary to assess the possible impact that corrosion caused by such adhered matter could have on the integrity of the fuel assemblies and structures in the common pool during long-term storage, and to take proper measures to secure their integrity.

Specific actions

1. Assessment of the impact of transporting the fuel assemblies on water quality
   (1) Detailed analysis of water in the spent fuel pool
   Pool water from each reactor at Fukushima Daiichi Nuclear Power Station will be sampled and analyzed in detail to extract substances that might be adhered on the fuel assemblies.
   (2) Analysis of adhered matter accumulated on spent fuel assemblies by immersion in a simulated fuel pool environment
   The type and condition of adhered matter will be examined by immersing the main portion of a spent fuel assembly that has been stored in a test facility after irradiation, in an environment simulating the water quality of the spent fuel pool at Fukushima Daiichi Nuclear Power Station.
   (3) Test, analysis and evaluation of the dissolution of adhered matter in pure water
   The elution and volume of eluted matter will be evaluated by immersing in pure water the main portion of a spent fuel assembly that has been placed in an environment simulating the water quality of the spent fuel pool at Fukushima Daiichi Nuclear Power Station, and observations will be made to confirm whether the specific water quality of the common pool could be maintained by the equipment.
2. Evaluation of the long-term integrity of fuel assemblies and component structures of the common pool
   (1) Evaluation of the long-term integrity of the materials of the fuel assemblies in the common pool
   The main portion of fresh and spent fuel assemblies will be immersed in an environment simulating the water quality of the spent fuel pool at Fukushima Daiichi Nuclear Power Station and washed with water to evaluate changes in corrosion conditions if the fuel assemblies were to be stored in the common pool.
   (2) Evaluation of the long-term corrosion of component structures of the common pool
   The same materials as the component structures of the common pool will be immersed long-time in water that has the same quality as the common pool to evaluate corrosion conditions.
   (3) Proposals of countermeasures and evaluation of effects for maintenance of integrity
   Based on the results of the above corrosion test, countermeasures will be examined, and potential effects will be tested for confirmation and evaluated.
3. Basic tests related to the evaluation of long-term integrity
   Basic tests will be performed to acquire necessary data in consideration of the required radioactivity environment according to the above evaluation of integrity.

Implementation schedule

Item/Year	Phase 1			Phase 2	
	2011	2012	2013	2014	2015 (beginning)
(1) Assessment of the impact of transporting fuel assemblies on water quality (2) Evaluation of the integrity of fuel assemblies, etc. in the common pool (3) Basic tests related to the evaluation of long-term integrity			Confirmation of water quality in the common pool Long-term corrosion countermeasures		



(1-2) Examination of Methods for Processing Damaged Fuel, etc. Removed from the Spent Fuel Pool

Necessity

Fuel in the nuclear reactor building pool is thought to be contaminated with saline from seawater, and part of the fuel may even be damaged or leaking due to the collapse of concrete fragments. For these reasons, it is necessary to investigate and examine technical issues for reprocessing such damaged fuel and to establish an indicator for determining whether or not reprocessing is possible.

Specific actions

1. Study of past cases related to damaged fuel, etc.
- Past cases in Japan and abroad regarding the handling of damaged fuel will be studied.

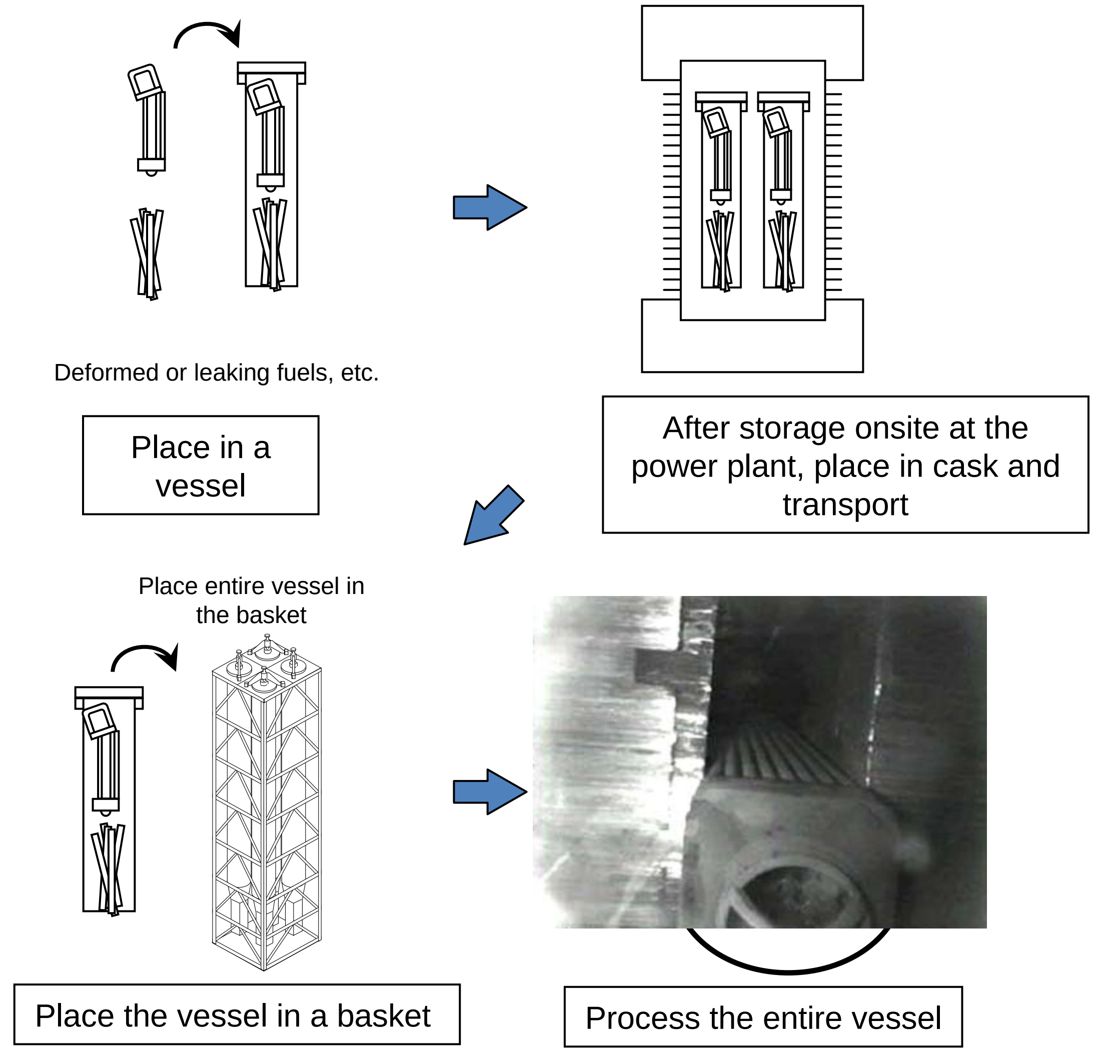
2. Examination of the impacts of damaged fuel, etc. on chemical processing and other processes
- The impacts of impurities (saline from seawater, etc.) absorbed to damaged fuel on chemical processing, waste treatment, and product recovery processes will be assessed to examine potential processing methods.

3. Examination regarding the handling of damaged fuel
- For fuel that is severely damaged and cannot be handled by existing reprocessing facilities, methods for their acceptance, storage, and shear treatment will be examined.
- Simulated damaged fuel samples will be prepared and used to perform processing tests.

4. Examination of judgment indicators for damaged fuel, etc.
- The above examination results will be sorted, to establish an indicator for judging whether or not reprocessing is possible.

Examples of prospective technologies

Elemental technology	Application example
Chemical processing of damaged fuel, etc.	–
Handling of damaged fuel	Pinhole fuel processing



Implementation schedule

Item/Year	Phase 1	Phase 2			
	2013	2014	2015	2016	2017
		(beginning)			(mid)
1. Study of past cases related to damaged fuel, etc. 2. Examination of the impacts of damaged fuel, etc. on chemical processing and other processes 3. Examination regarding the handling of damaged fuel 4. Examination of judgment indicators for damaged fuel, etc.					

(2-(1)-1) Development of Technologies for Remote Decontamination of the Reactor Building Interior

Necessity

To work inside the reactor building, it is of primary importance to decontaminate all contaminated areas to minimize radiation exposure. Decontamination methods need to be selected based on a comprehensive evaluation of their performance, applicability, exposure and secondary waste treatment characteristics. However, there is presently little data available on the state of contamination and the performance of decontamination methods, so an evaluation of their applicability is needed. Furthermore, because the primary containment vessel (PCV) and other areas for decontamination are subject to high-dose radiation, remote devices need to be used. For these reasons, it is also necessary to evaluate the applicability of remotely operated devices for use also around the PCV.

Specific actions

1. Estimation of contamination status and acquisition of basic data
   As it is necessary to establish contamination conditions before examining decontamination principles, the contamination status in target areas will be estimated and investigated to acquire a basis for examination. Firstly, the contamination status of the area around the PCV (first floor of the nuclear reactor building) will be investigated, followed by an investigation of other areas (representative contamination sources in each building). Remotely operated devices will be necessary for these investigations, so specific devices will be examined, manufactured, and used to conduct investigations of contamination status.

2. Assessment of decontamination technologies and examination of decontamination principles
   Decontamination technologies will be assessed in terms of their performance, the amount of time needed for decontamination, the generation and treatment characteristics of secondary waste, potential for combined usage with remote devices, etc. Additionally, based on the results of onsite investigations of contamination status, decontamination technologies for each target area will be selected in consideration of decontamination principles and equipment applicability.

3. Decontamination testing using simulated contamination
   Candidate decontamination technologies will be tested, to create a database of contamination status and applicable technologies. Samples for the test will be made by simulating the contamination status revealed by the onsite contamination investigations.

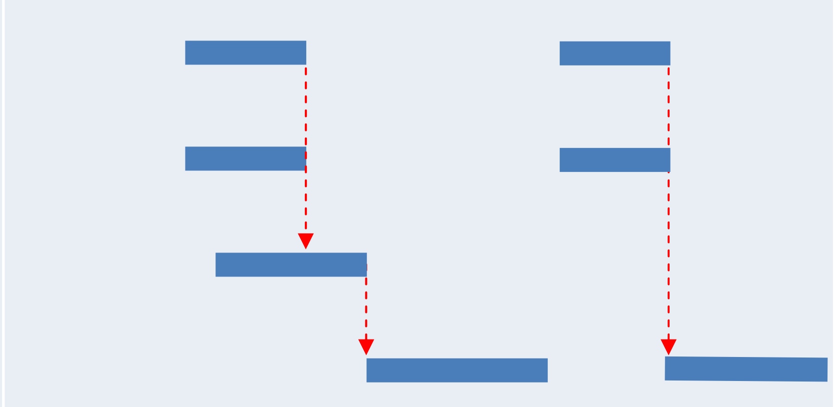
4. Demonstration of decontamination technologies
   A demonstration test of decontamination technologies will be performed by constructing decontamination devices and combining them with a remote operation function.

Examples of prospective technologies

Elemental technology	Application example
Assessment of decontamination technologies and their applicability to the contamination status	Each power plant
Measurement technologies for investigating contamination status	Each power plant
Incorporation of robot functions to decontamination technologies	TMI, etc.
Decontamination robots and traveling carriages (remote unmanned operation under severe environments)	TMI, etc.

Implementation schedule

Item/Year	Phase 1		
	FY2011	FY2012	FY2013
1. Estimation of contamination status and acquisition of basic data			
2. Assessment of decontamination technologies and examination of decontamination principles			
3. Decontamination testing using simulated contamination			
4. Demonstration of decontamination technologies			

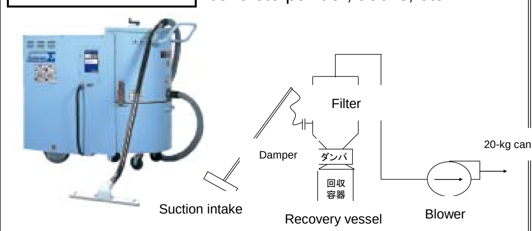


Note) FY2011-2012: Demonstration in reference to areas of relatively easy access, such as the passageways of nuclear reactor buildings
FY2013: Demonstration in reference to relatively inaccessible areas, such as inside the rooms and upper floors
The decontamination testing using simulated contamination will be performed collectively in FY2011-2012.

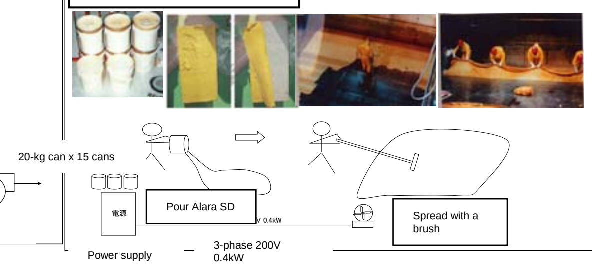
Prospective decontamination technologies

Suction recovery

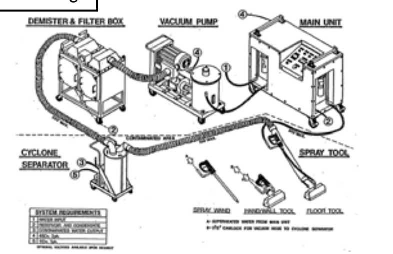
Suction recovery of accumulated concrete powder, debris, etc.



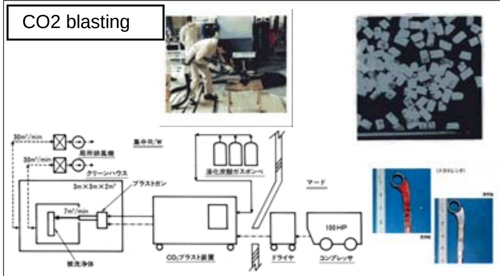
Strippable paint



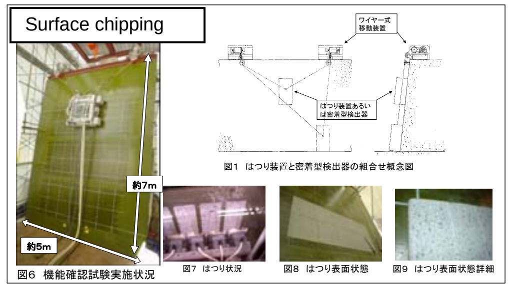
Steam washing



CO2 blasting



Surface chipping



(2-(1)-2) Development of Technologies for Identifying Leak Areas in the PCV

Necessity

In order to remove the reactor fuel when the boundary function between the nuclear reactor pressure vessel (RPV) and primary containment vessel (PCV) has been lost, firstly the PCV must be repaired and the boundary reconstructed to ensure shielding, and the inside of the PCV and RPV needs to be filled with water. However, the area around the PCV is subject to high-dose radiation and is extremely narrow in some places, and the lower part of the PCV (pressure control room, etc.) is flooded. Technologies for identifying damage areas in this type of environment have yet to be established. For this reason, it is necessary to develop inspection methods and devices that could be applied to high-dose areas, narrow spaces, and underwater environments.

Specific actions

1. Examination of inspection methods and designing of devices
• Methods for identifying leak areas in the PCV and reactor building will be examined, and appropriate devices will be designed.

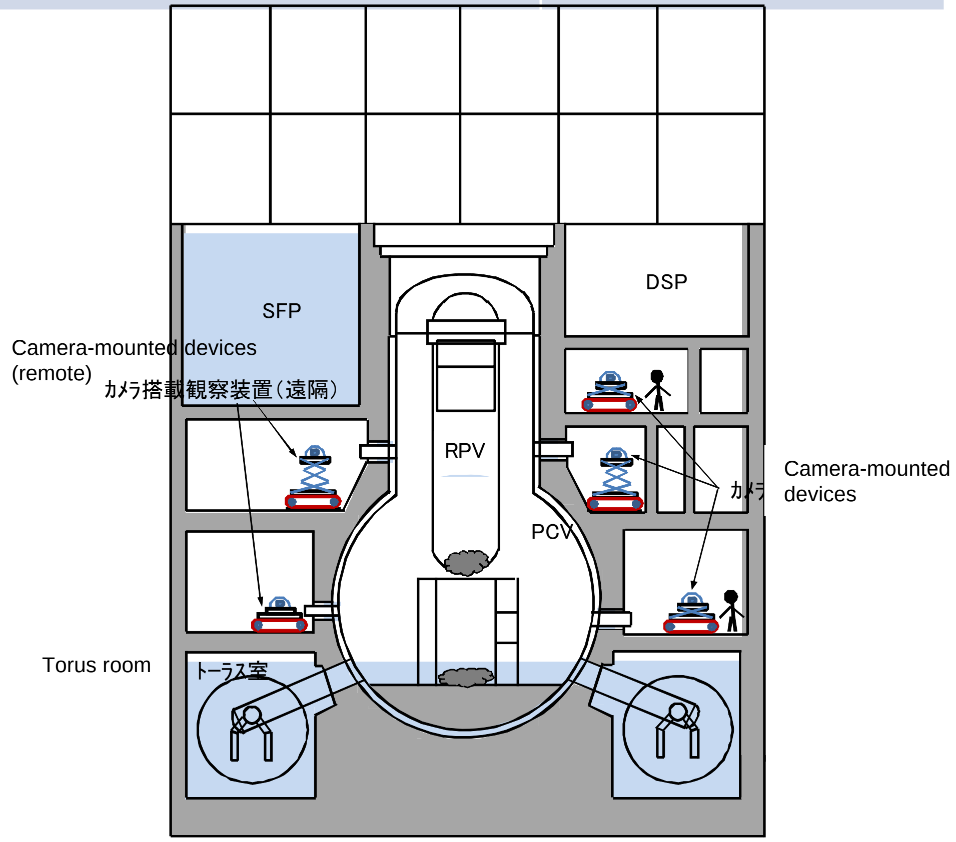
2. Construction and improvement of inspection devices
• Devices for identifying leak areas in the PCV and reactor building will be constructed, the applicability of the devices will be evaluated (field test), and improvement will be made as necessary.

Examples of prospective technologies

Elemental technology	Application example
Inspection of the PCV exterior by camera measurement (exposed parts, immersed parts)	Fuel inspection VT in reactor
Atmospheric measurements (temperature, humidity, explosive gases, radiation, etc.)	Atmospheric measurement Radiation measurement
Remote robotic technologies (for inspection of the torus, PCV penetrations, etc.)	Crawler vehicles Boring equipment
PCV leak identification technologies (radiation measurement, acoustic sensors, infrared monitoring, ultrasonographic technology, etc.)	Visualization of radiation sources Acoustic diagnosis Visualization of heat sources
Robots for remote inspection of areas around the PCV	Crawler vehicles

Implementation schedule

Item/Year	Phase 1			Phase 2
	2011	2012	2013	2014 (beginning)
1. Examination of inspection methods and designing of devices	━	━	━	
2. Construction and improvement of inspection devices			━	━



Conceptual diagram of the investigation of leak areas in the PCV

[Provisional Translation]

(2-(1)-3) Development of PCV Repair Technologies

Necessity

In order to remove the reactor fuel when the boundary function between the nuclear reactor pressure vessel (RPV) and primary containment vessel (PCV) has been lost, firstly the PCV must be repaired and the boundary reconstructed to ensure shielding, and the inside of the PCV and RPV needs to be filled with water. However, the area around the PCV is subject to high-dose radiation and is extremely narrow in some places, and the lower part of the PCV (pressure control room, etc.) is flooded. Technologies for repairing damage areas in this type of environment have yet to be established. For this reason, it is necessary to develop inspection methods and devices that could be applied to high-dose areas, narrow spaces, and underwater environments.

Specific actions

1. Examination of repair methods and designing of devices (for the lower part of the PCV)
   - Methods for repairing leak areas in the lower part of the PCV and reactor building will be examined, and the necessary devices will be developed (by incorporating the results of leak detection investigations).

2. Construction and improvement of repair devices (for the lower part of the PCV)
   - Devices for repairing leak areas in the lower part of the PCV and reactor building will be constructed, and improvement will be made as necessary upon evaluating the applicability of the devices (field test).

3. Examination of repair methods and development of devices (for the upper part of the PCV)
   - Methods for repairing leak areas in the upper part of the PCV will be examined, and the necessary devices will be developed (by incorporating the results of leak detection investigations).

4. Construction and improvement of repair devices (for the upper part of the PCV)
   - Devices for repairing leak areas in the upper part of the PCV will be constructed, and improvement will be made as necessary upon evaluating the applicability of the devices (field test).

5. Examination of alternative methods
   - Alternative methods will be examined aside from the method of removing the reactor fuel by filling the PCV with water.

Examples of prospective technologies

Elemental technology	Application example
Repair (sealing) materials Repair (sealing) devices	Sealing materials Grout materials
Hole drilling methods for injection of repair (sealing) material Methods for injecting repair (sealing) material	Void filling, Submerged structures
Robots for remote repair of the PCV	Crawler vehicles

Implementation schedule

Item/Year	Phase 1			Phase 2			
	2011	2012	2013	2014 (beginning) (mid)	2015	2016	2017
1. Examination of repair methods and designing of devices (for the lower part)							
2. Construction and improvement of repair devices (for the lower part)							
3. Examination of repair methods and development of devices (for the upper part)							
4. Construction and improvement of repair devices (for the upper part)							
5. Examination of alternative methods							

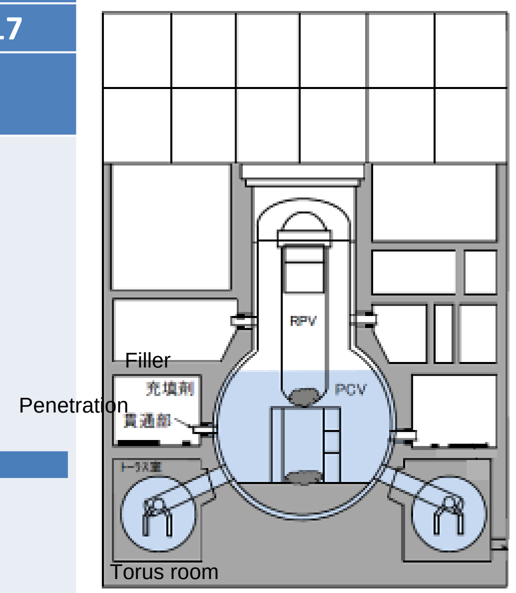


Image of filling the lower part of the PCV with water

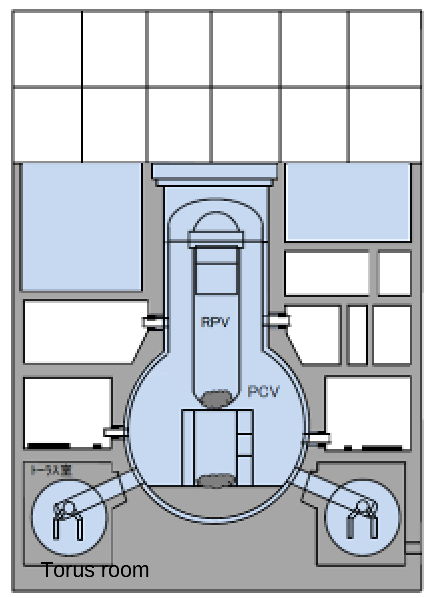


Image of filling the upper part of the PCV with water

(2-(1)-4) Development of Technologies for Investigation of the PCV Interior

Necessity

The state of fuel debris is presently unknown, so in order to remove them, it is necessary to investigate the position and condition of the debris inside the primary containment vessel (PCV), and to also confirm the condition of the pedestal supporting the reactor pressure vessel (RPV). Such investigations need to be performed using remotely operated devices, as the PCV interior is subject to a severe environment of high temperatures, high humidity, and high-dose radiation. Furthermore, a system needs to be developed to prevent the dispersal of radioactive materials when opening the boundary of the PCV to place remote devices inside the vessel.

Specific actions

Methods and devices for investigating the PCV interior will be studied and developed, in order to grasp the condition inside the PCV, conduct a leak detection investigation in the PCV, and examine methods for removing fuel debris. R&D will be performed as follows, based on a plan aimed at investigating the PCV interior by introducing workers or devices up to the exterior of the PCV and injecting the remote inspection device into the vessel from the penetration or other access means.

(1) Study of existing technologies based on an estimation of the internal conditions of the reactor

The conditions inside the PCV and RPV (position and behavior of fuel debris, structural integrity, damage conditions, etc.) will be estimated through plant parameter measurements and simulations to formulate an appropriate survey plan (examination of methodical principles), and existing technologies will be studied in terms of their applicability in severe environments.

(2) Development of access methods and devices (tools)

- Examination of methods for the preliminary investigation of the PCV
- Examination of methods for the full-scale investigation of the PCV interior
- Development of access devices for the full-scale investigation of the PCV interior

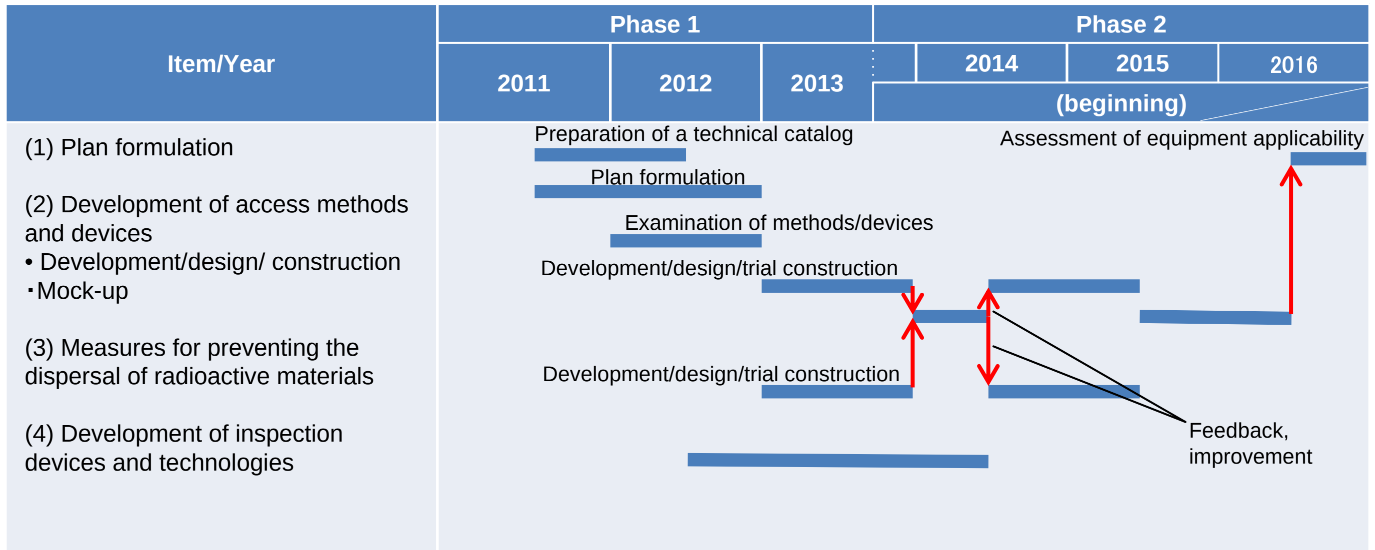
(3) Countermeasures for radioactive materials inside the PCV

As a measure against radiation exposure to workers and the public caused by the dispersal of radioactive materials from inside the PCV either before or after the investigations, considerations will be given to using a dispersal prevention cover and to establishing a remote operation for opening/closing the access holes in the PCV and installing/removing survey devices from holes inside the cover.

(4) Development of inspection devices and technologies

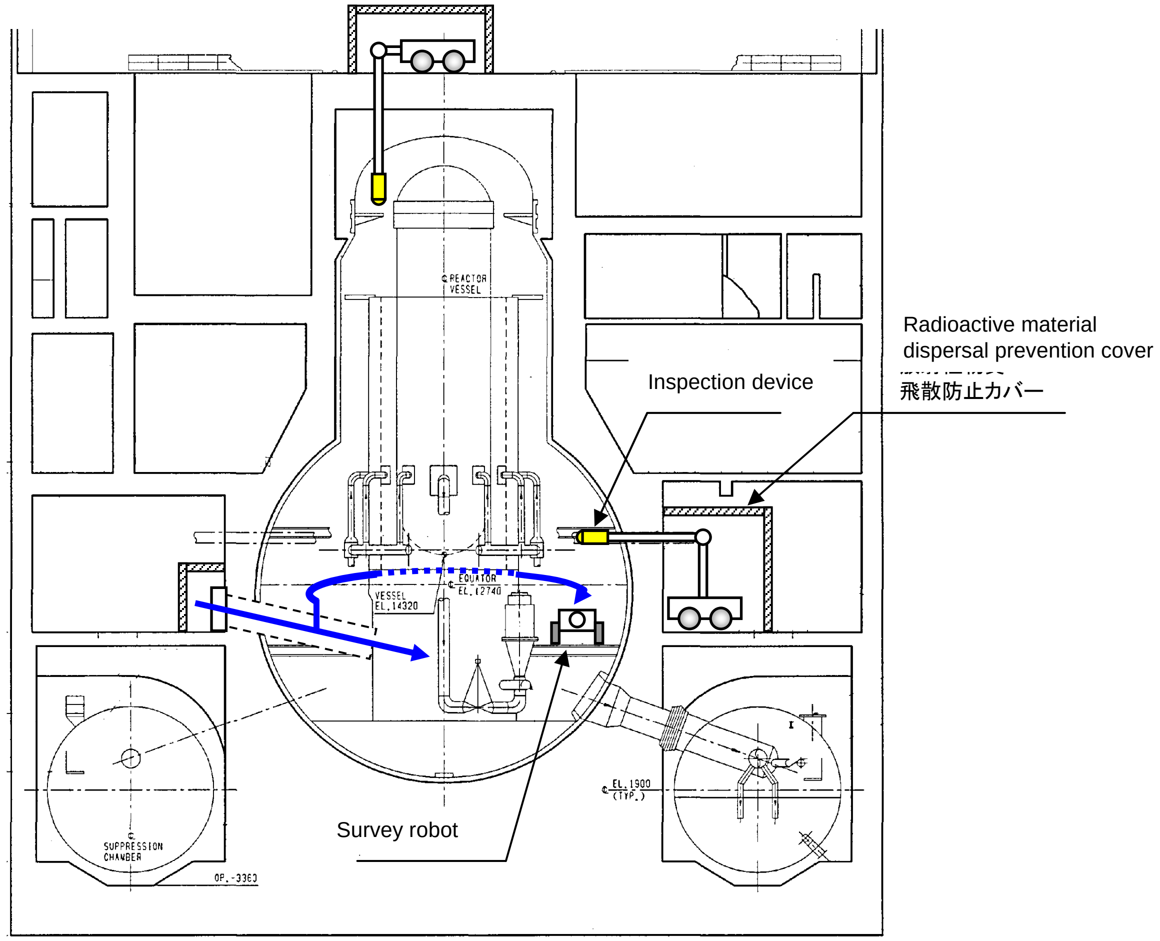
Inspection devices and technologies will be developed to allow inspection of parts by methods and in environments (radiation, temperatures, etc.) that go beyond the scope of conventional inspections, and methods for decontaminating and treating contaminated devices will be examined.

Implementation schedule



Examples of prospective technologies

Elemental technology	Application example
Robots for investigating the PCV interior (remote, unmanned operation under severe environments)	Disaster prevention robots
Robots for performing various tasks inside the PCV	Disaster prevention robots
Measures for preventing the dispersal of radioactive materials	—
Inspection devices and technologies	TMI experience



(2-(1)-5) Development of Technologies for Investigation of the RPV Interior

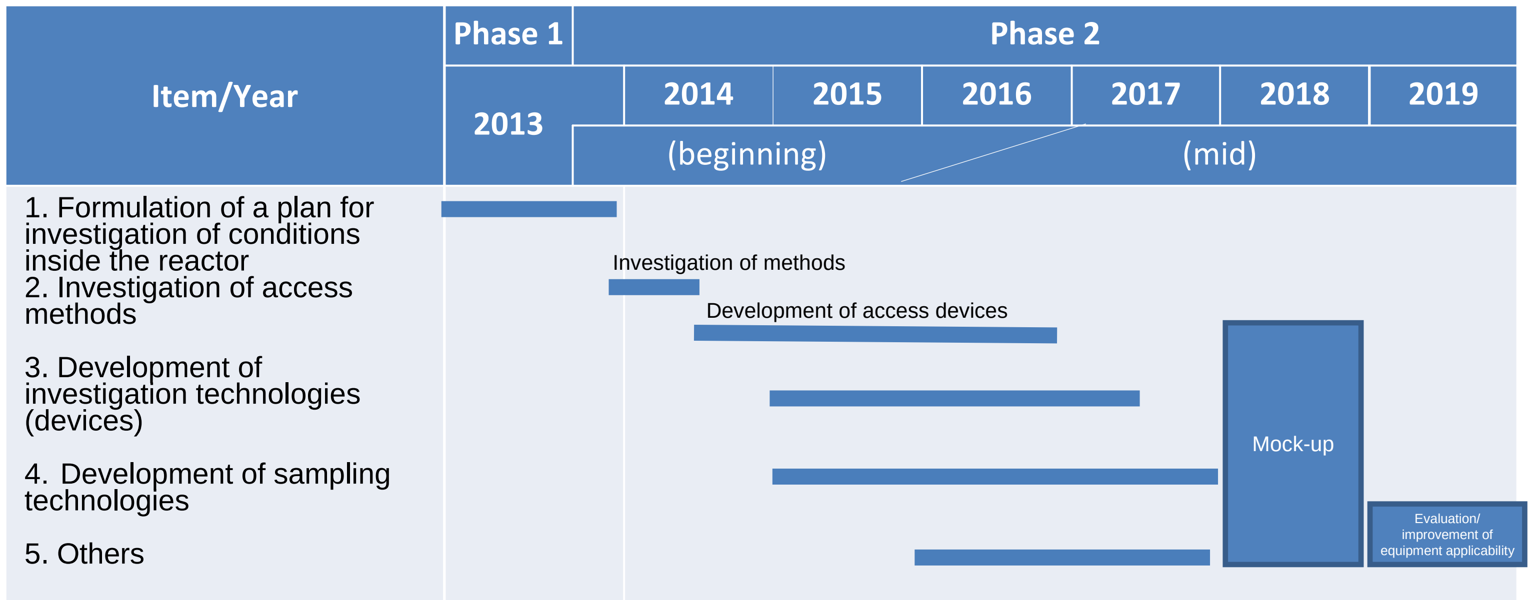
Necessity

Before dismantling the nuclear power plant where a core meltdown has occurred, all fuel debris must be removed and stored in a safe place. In order to do so, it is necessary to develop investigation technologies that would help ascertain the conditions (fuel debris, damage inside the reactor, the conditions of contaminated equipment) inside the reactor pressure vessel (RPV).

Specific actions

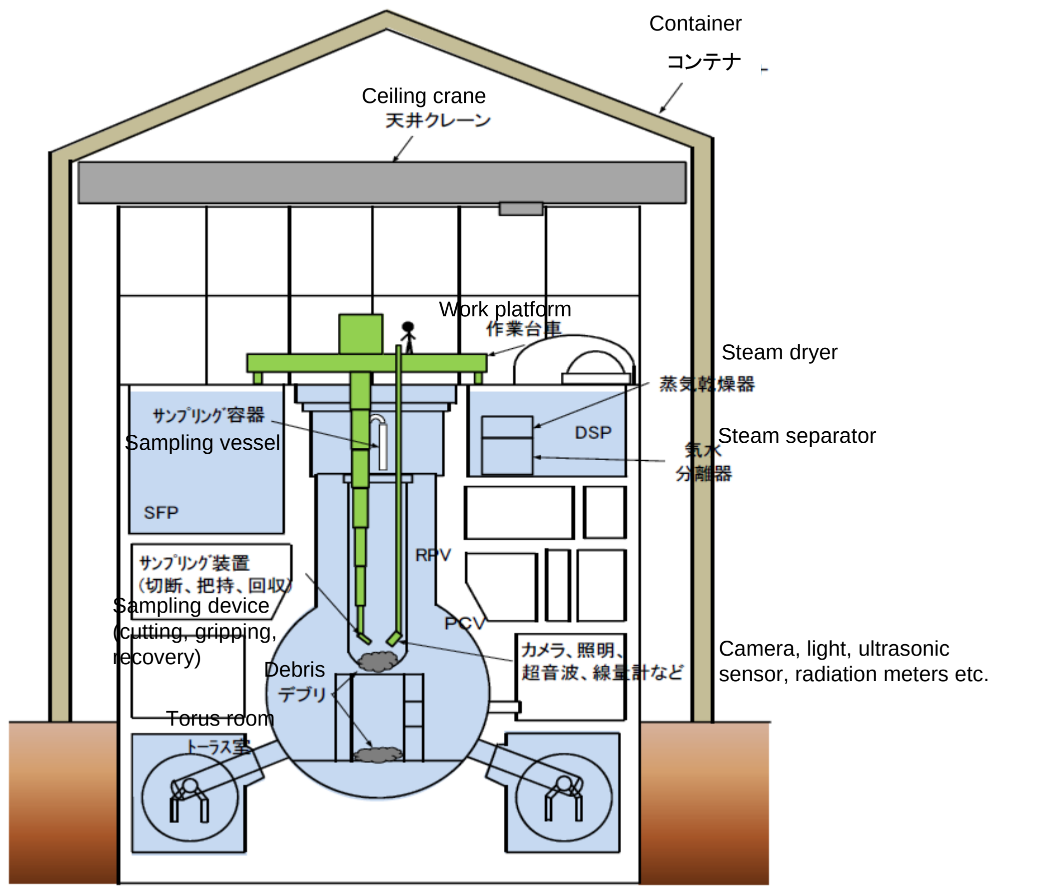
1. Formulation of an investigation plan based on the estimated results of investigations and analyses of the PCV interior and exterior
   - The condition of the PCV/RPV (fuel debris distribution, structural conditions, etc.) will be estimated based on results of investigations and simulations of the PCV interior/exterior, and an investigation plan will be formulated.
   - Existing technologies will be studied to secure elemental technologies and remote operation technologies that are needed for the inspection of target areas under their respective environments (high-dose radiation, narrow spaces, submerged environment, etc.).
   - Onsite investigations will be conducted to acquire information that would be useful in developing inspection methods and devices.
   - An optimum inspection method will be developed based on the above.
2. Investigation of access methods for the investigation of the RPV interior
   - Methods for accessing the inside of the RPV will be investigated in consideration of radiation levels, the feasibility of installing a shield, and the potential of survey devices to access and observe the RPV interior.
3. Development of investigation technologies for high-dose environments
   - A device will be developed to allow observation of the RPV interior under high-dose environments.
   - Remote inspection technologies (robots) will be developed and a mock-up will be implemented.
4. Development/production of technologies for sampling fuel debris
   - Development of sampling devices and tools, and development of methods for the removal of samples from the reactor.
5. Others
   - Development of technologies to prevent the dispersion of radioactive materials during and after investigations
   - Waste treatment technologies for contaminated survey devices

Implementation schedule



Examples of prospective technologies

Elemental technology	Application example
Image observation, ultrasonic radiation measurement under high-dose radiation	TMI experience
Remote robotic technologies (technologies for accessing the RPV interior, sampling technologies, etc.)	Core interior repair devices
Technology for removing samples from the vessel to outside the reactor	Cask
Technologies for treatment of contaminated equipment	Shroud replacement



Conceptual diagram of investigations and sampling inside the reactor (RPV)

(2-(1)-6) Development of Methods and Devices for the Removal of Debris and Internal Structures in the Reactor

Necessity

The TMI-2 case provides a reference for fuel debris removal, but because Fukushima Daiichi Nuclear Power Station is a boiling-water reactor that has many structures inside the reactor pressure vessel (RPV), and also because part of the fuel debris is assumed to have leaked into the primary containment vessel (PCV), new technologies for fuel debris removal need to be developed.

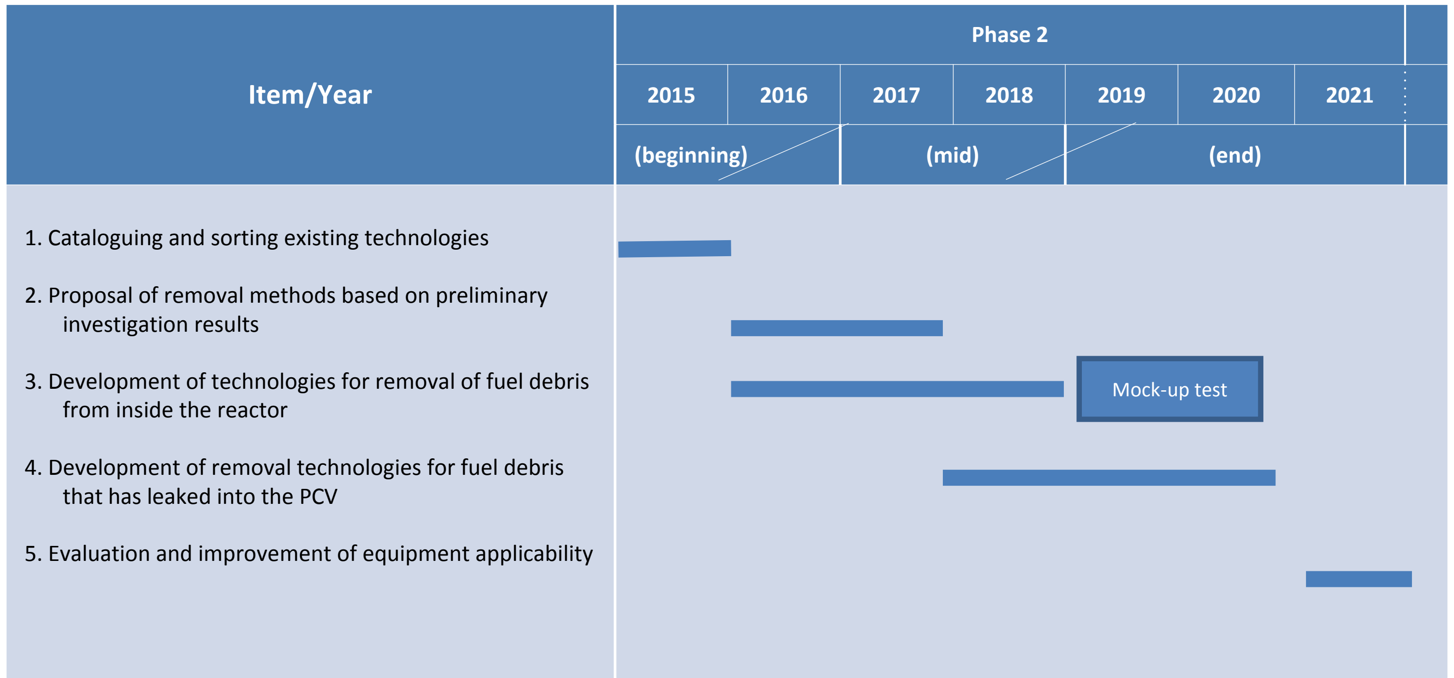
Specific actions

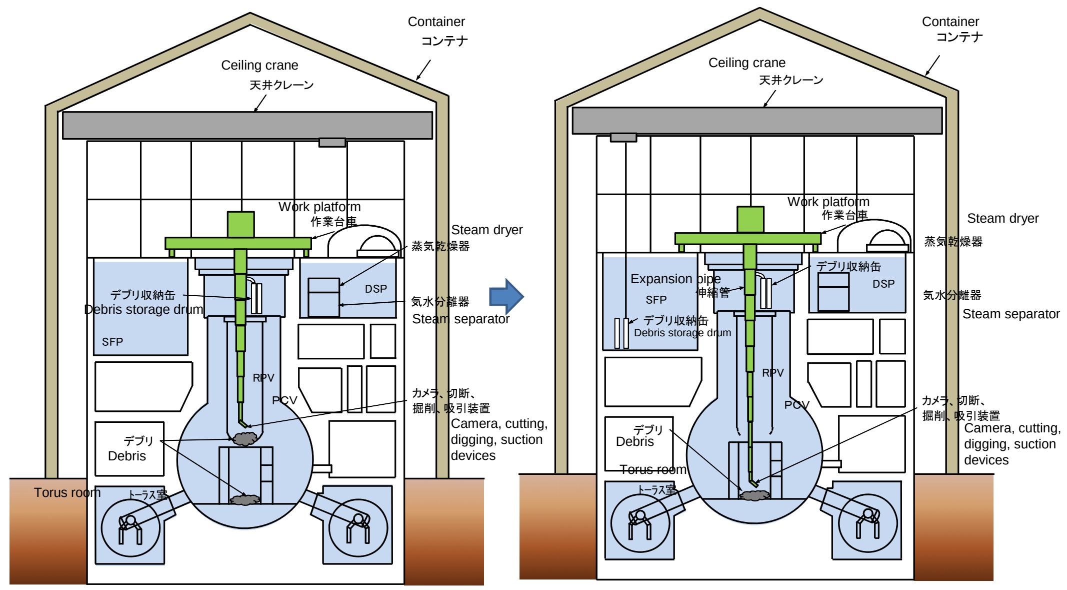
1. Cataloguing and sorting existing technologies (including confirmation of proven devices used in the TMI-2 case)
   Existing technologies that are required for cutting, grabbing, pulverizing, excavating, and recovering fuel debris (internal structures, damaged fuel) will be catalogued and sorted.
2. Proposal of removal methods based on preliminary investigation results
   Based on the results of investigations of the PCV interior/exterior, methods for removing fuel debris and internal structures will be proposed in consideration of fuel debris distribution and the extent of damage to the internal structures.
3. Development of technologies for removal of fuel debris from inside the reactor
   Proven devices used in the TMI-2 case will be improved and tested. Removal devices will also be developed specifically in response to the situation at Fukushima Daiichi Nuclear Power Station.
4. Development of removal technologies for fuel debris that has leaked into the PCV
   A method for removing fuel debris that has leaked into the PCV will be proposed, followed by the development of related technologies, construction of devices, and implementation of a mock-up test.

Examples of prospective technologies

Elemental technology	Application examples
Water-jet cutting, laser cutting, plasma cutting, and other mechanical cutting technologies	Shroud replacement, etc. Cutting processes in the reactor
Technologies for efficient recovery of dust, gas, etc. generated during cutting processes	Shroud replacement, etc. Cutting processes in the reactor
Remote operation technologies (cutting, debris recovery)	Shroud replacement, Cutting processes in the reactor
Recovery of debris fuel from inside the PCV	—

Implementation schedule





Conceptual diagram of the removal of fuel debris from the RPV/PCV

(2-(1)-7) Development of Technologies for the Containment, Transport and Storage of Reactor Fuel Debris

Necessity

The TMI-2 case provides a reference for the basic concept of a fuel debris containment drum, but in consideration of the advancement of corrosion due to the injection of seawater and fuel burn up, it is necessary to develop technologies for the fuel debris drum upon proper assessment of conditions inside the reactor, particularly since radiation dose and heat generation are estimated to be higher at Fukushima Daiichi Nuclear Power Station.

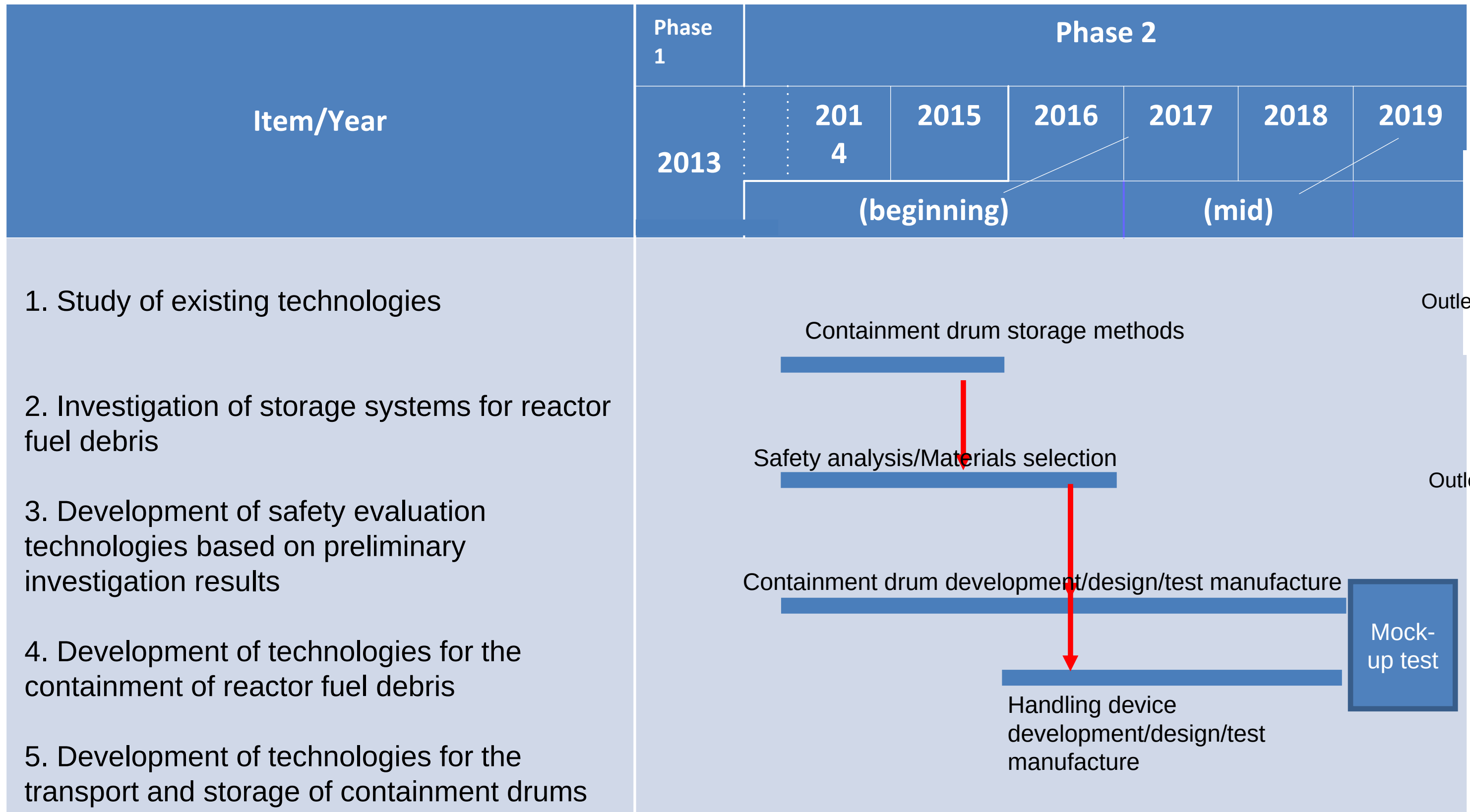
Specific actions

1. Study of existing technologies
  Existing technologies will be reviewed to secure the necessary technologies for development of a drum for containment, transport, and storage of fuel debris.
2. Investigation of a storage system for reactor fuel debris
  Wet storage and dry storage systems (metal cask, concrete cask, etc.) for reactor fuel debris will be examined in consideration of the specific state of Fukushima Daiichi Nuclear Power Station.
3. Development of safety evaluation technologies based on preliminary investigation results
  Methods will be developed for evaluating the containment drum for reactor fuel debris in terms of criticality, shielding, heat removal, sealing, and structure, and a material will be selected in reference to the impact of seawater, microorganisms, sandy liquid, etc. on the material.
4. Development of technologies for the containment of reactor fuel debris
  A containment method will be proposed in accordance with fuel debris shapes and the meltdown status, followed by technical development, manufacturing of the relevant device, and a mock-up test.
5. Development of technologies for the transport and storage of containment drums
  Remote/automatic operation and sealing technologies will be developed for efficient transport and storage of containment drums, followed by the manufacturing of relevant devices and a mock-up test.

Examples of prospective technologies

Elemental technology	Application example
Criticality, shielding, heat removal, sealing, and structural evaluation technologies	TMI experience
Selection of materials in consideration of the impacts of seawater, microorganisms, standby liquid, etc.	TMI experience
Development of technologies for the containment of fuel debris in accordance with fuel debris shapes and the meltdown status	TMI experience
Development of efficient transfer and storage technologies (remote/automatic operation and sealing technologies)	—

Implementation schedule



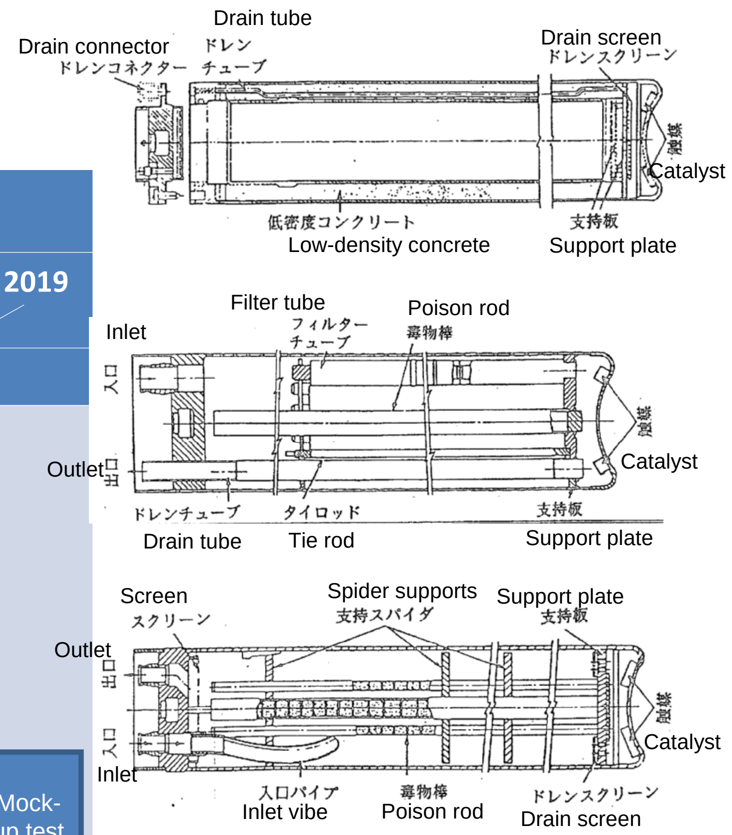


Fig.: Reactor debris containment drum (TMI example)

Fuel debris containment
- Containment method based on fuel debris shapes
- Remote handling

Heat removal and prevention of re-criticality
- Heat transfer structure based on fuel debris properties (decay heat)
- Containment location, materials, and structure for prevention of re-criticality

Shielding
- Shielding materials and structure based on fuel debris inventory (radiation dose)

Sealing
- Evaluation of seal materials based on fuel debris shapes
- Method of confirming sealing soundness

Materials
- Strong, corrosion resistant, and heat resistant materials that correspond to fuel debris shapes and properties

Structure (shape, size)
- Structure that corresponding to fuel debris shapes
- Structure based on containment performance

A multiple number of containment drums are used according to the shapes of the fuel and fuel debris, but their external dimensions are the same, and they use the same transport vessel for containment

(2-(1)-8) Development of Technologies for Assessment of RPV/PCV Integrity

Necessity

The reactor pressure vessel (RPV) and primary containment vessel (PCV) are expected to be continuously exposed to a diluted seawater environment over a long term. Therefore, in order to secure equipment integrity until the time when the fuel could be extracted, the necessary corrosion data will be acquired for proper assessment and prediction of the advancement of corrosion deterioration. Additionally, anti-corrosion measures that are applicable to the actual equipment will be established and their effectiveness confirmed.

Specific actions

There are concerns about the corrosion of RPV and PCV structural materials, because they have been exposed to seawater at high temperatures. The deterioration of the reinforced-concrete RPV pedestal is also a concern for the same reason. Therefore, quantitative data relating to the exposure of each material to seawater will be acquired to provide reference for future structural integrity assessment. Furthermore, a verification test will be performed regarding measures for preventing the corrosion of the structural materials of the PCV/RPV and RPV pedestal by seawater.

(1) Corrosion test on the structural materials of the RPV/PCV
- A corrosion test will be performed on steel materials that have been exposed to high-temperature seawater or diluted seawater, to acquire data on the corrosion speed of structural materials. High-temperature strength data will also be acquired to contribute to remaining lifetime assessment.

(2) Degradation on the reinforced concrete of the RPV pedestal
- A test will be performed on the penetration of chloride ions in the concrete of the RPV pedestal. A corrosion test will also be performed on the reinforcement embedded in the concrete.

(3) Verification test on anti-corrosion measures for the RPV/PCV and RPV pedestal
- A verification test will be performed regarding the anti-corrosion measure that is to be applied to the RPV/PCV structural materials and the RPV pedestal, to confirm its effectiveness in preventing corrosion.

(4) Remaining life assessment and life extension assessment of the RPV/PCV and RPV pedestal
- Based on conventional knowledge and the above database, an assessment of residual lifetime extension will be conducted on the structural materials of the RPV/PCV and RPV pedestal.

(5) Development of an anti-corrosion system and evaluation of equipment applicability
- An anti-corrosion system applicable to the actual equipment will be developed, and based on the above results, the anti-corrosion measure judged to have a life-extending effect will be applied to the PCV on a test basis. The anti-corrosion effect on the structural material of the actual PCV will be confirmed by applying a corrosion monitoring test piece to the retained water processing loop.

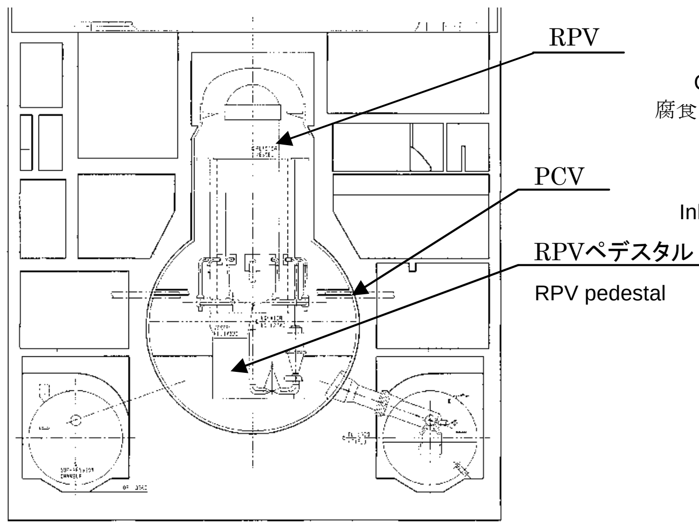
(6) Basic tests related to the integrity assessment of the structural materials of the reactor
- Basic tests will be conducted in consideration of the radioactive environment required for the above integrity assessment, to acquire relevant data.

Examples of prospective technologies

Elemental technology	Application example
RPV/PCV corrosion test and evaluation (evaluation simulating high-temperature conditions)	None for high-temperature seawater countermeasures, diluted seawater countermeasures, standby liquid countermeasures
RPV pedestal corrosion test and evaluation (evaluation simulating an earthquake damage such as the state of cracks, the state of cracks caused by high temperatures, and high-temperature conditions; evaluation of the effect of dilution by switching from seawater injection to freshwater injection)	None for high-temperature seawater countermeasures, diluted seawater countermeasures, standby liquid countermeasures
Verification test of anti-corrosion measures for the RPV, PCV, and RPV pedestal (verification of the effect of anti-corrosion measures on the structural materials of the RPV, PCV and RPV pedestal, assessment of the impact of anti-corrosion measures on water quality in radioactive environments)	None for high-temperature seawater countermeasures, diluted seawater countermeasures, standby liquid countermeasures There are examples of anti-corrosion measures, but they have not been applied to actual equipment, and their concrete penetration effect is unknown
Remaining life assessment technologies and life extension assessment technologies for RPV, PCV, and RPV pedestal structures	None for high-temperature seawater countermeasures, diluted seawater countermeasures, standby liquid countermeasures

Implementation schedule

Item/Year	Phase 1			Phase 2		
	2011	2012	2013	2014 (beginning)	2015	2016
Development of RPV/PCV integrity assessment technologies						
(a) Investigation of test conditions based on an analysis of the accident history						
(b) Corrosion test on the structural materials of the RPV/PCV						
(c) Deterioration test on the reinforced concrete of the RPV pedestal						
(d) Verification test on the anti-corrosion measure for the RPV/PCV and RPV pedestal				Judgment on the applicability of anti-corrosion measures to the RPV/PCV		
(e) Remaining life assessment and life extension assessment of the RPV/PCV and RPV pedestal structure						
(f) Development of an anti-corrosion system						
(g) Evaluation of equipment applicability						
(h) Basic tests related to integrity assessment						



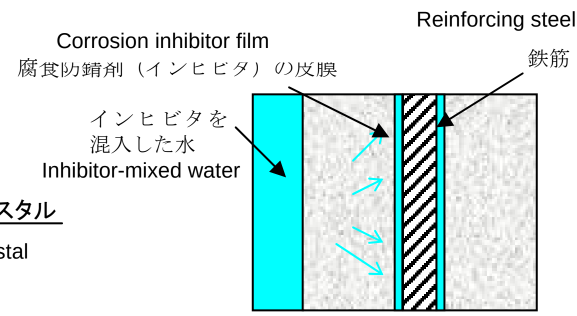


Image of the application of a corrosion inhibitor to the reinforcing steel in the RPV pedestal

(2-(1)-9) Development of Technologies for Controlling Debris Criticality

Necessity

To prevent recriticality in the future even if debris shapes and water volume change accompanying fuel removal and other work, subcritical assessment and monitoring technologies need to be developed.

Specific actions

1. Criticality assessment

An analysis will be conducted based on estimated fuel debris and plant conditions after a severe accident to examine the scenario of criticality. Information regarding fuel debris will also be acquired from a separately planned simulated fuel debris test to increase the precision of analysis of fuel debris removal in stages. Furthermore, an analytical evaluation will be made of neutron response and fissile material volume under estimated criticality conditions to formulate exposure mitigation measures in the case of criticality.

2. Waste liquid treatment technologies and technologies for subcritical management of cooling facilities

Subcritical monitoring is necessary, because there is the possibility of a criticality occurring as a result of fuel debris escaping and accumulating in the waste liquid treatment facility and cooling facilities. A system will be developed for estimating subcriticality by measuring the neutrons generated from the fuel debris and processing neutron signals so that changes in neutron source strength and changes in subcriticality can be distinguished.

3. Technologies for detection of recriticality in the reactor

Neutron detection methods and methods for measuring short-life fissile materials will be examined.

(1) A predictive evaluation will be conducted through an analysis of the distribution of neutron doses inside and outside the PCV. Additionally, neutron detection areas will be surveyed based on the results of a separately planned investigation of the PCV interior and exterior, to develop an appropriate neutron detection system.

(2) γ rays emitted from fissile materials will be analyzed by spectral analysis, and their short-lived nuclides will be measured. As nuclide analysis is difficult under the present state of high γ background, a detection system will be developed that reduces the γ background to increase the detection precision of short-lived fissile nuclides and allows constant monitoring.

4. Criticality prevention technology

To prevent recriticality during fuel removal, transport and storage, a neutron absorbing material and a work method that uses the material will be developed. Additionally, a criticality test will be conducted to confirm the effectiveness of the new neutron absorbing material.

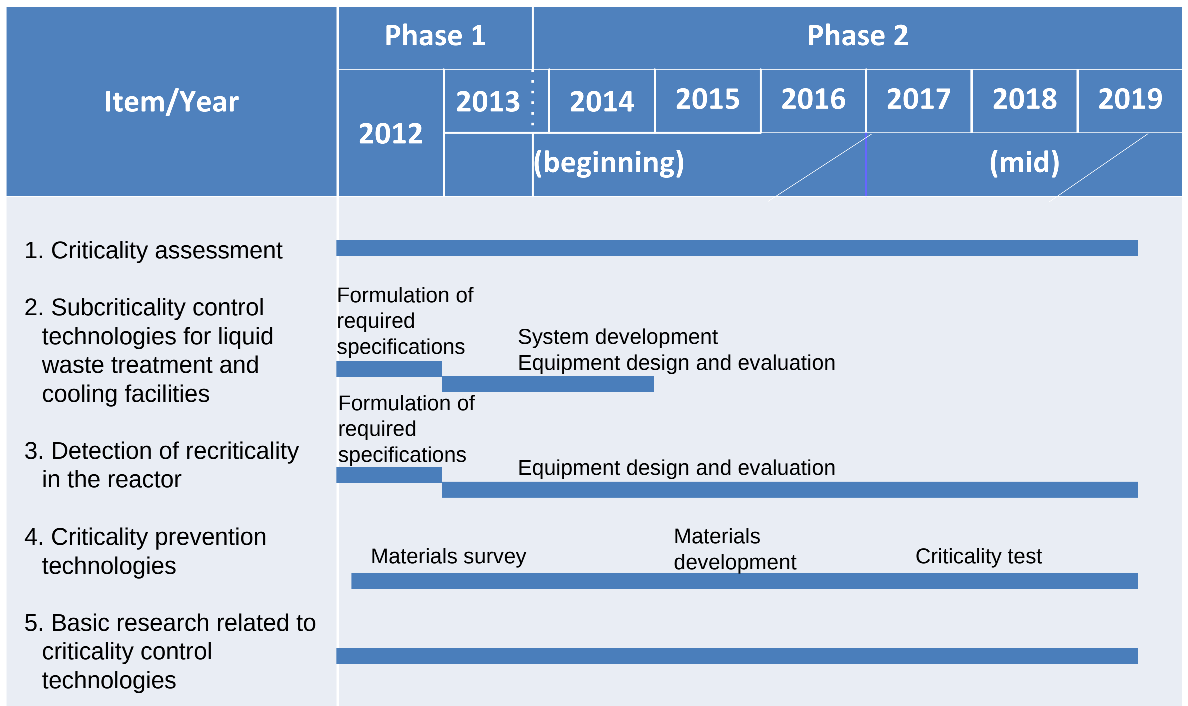
5. Basic research related to criticality control technologies

Based on information on fuel debris properties acquired from the simulated fuel debris test and others, criticality analysis codes will be improved and developed for use in criticality assessment, and evaluations and tests will be conducted to increase the precision of nuclear data.

Examples of prospective technologies

Elemental technology	Application example
Criticality assessment	Power plants
Subcriticality control	Reprocessing facilities
Criticality detection	Power plants
Criticality prevention	-

Implementation schedule



[Provisional Translation]

(2-(2)-1) Further Advancement of Technologies for Analysis of Accident Progression to enable Understanding of Status of Reactor Interiors

Necessity

At present, the damaged fuel is in a stable cold state, but it is necessary to ascertain the actual status of damage to the reactor cores in order to provide a reference for the formulation of medium- to long-term initiatives and safety measures. However, the highly radioactive conditions make direct observation of the damage to the reactor cores difficult, and current numerical simulations involve a great deal of uncertainty. Given this, it will be essential to push ahead with continuous research and development towards the realization of increased estimative accuracy in numerical simulations.

Specific actions

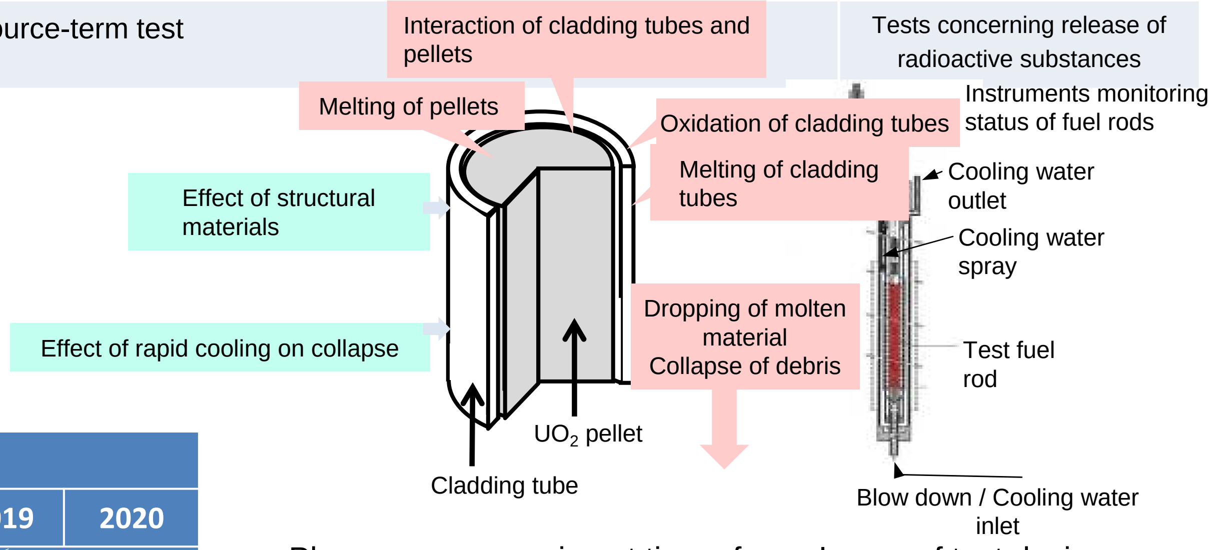
1. Analysis of behavior of plant at time of accident
・Seeking to understand the sequence of events from loss of power to core melt and the occurrence of hydrogen explosions, we will analyze the behavior of the plant based on data including plant operating data and measurement data from actual equipment at the time of the accident, compiling the data necessary for an analysis of the sequence of events during the accident.

2. Advancement of severe accident analysis codes
・In addition to organizing relevant information regarding the specifics of the existing severe accident analysis codes (MAAP, MELCOR, THALES, SAMPSON, etc.), we will evaluate and organize data concerning their applicability in achieving an understanding of the status of the reactor interiors.
・Based on the results of studies including analyses of plant behavior at the time of the accident, evaluations (mock-up tests, etc.), and surveys of the reactor interiors, we will attempt to increase the sophistication of the severe accident analysis codes (through the addition of models of the migration of fuel debris that take the structure of the lower sections of the reactors into consideration, etc.).

3. Mock-up tests, etc. that will contribute to the detailed analysis of the progression of events in severe accidents
・We will conduct tests including tests on the characteristics of high-temperature materials and tests on structures in order to study the responses of structures to the migration and accumulation of fuel debris following the core meltdowns.
・We will conduct tests including mock-up tests of loss of cooling water using irradiated fuel, mock-up fuel, mock-up pressure vessels, etc., in addition to fuel melting tests.
・We will study behavior related to the release of radioactive substances originating in fuel at the time of the accident.

Examples of prospective technologies

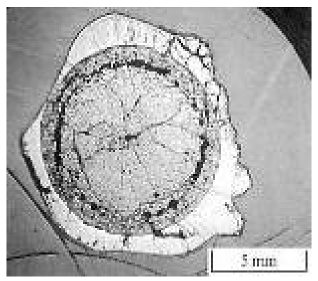
Elemental technologies	Application example
Severe accident analysis codes (MAAP, MELCOR, THALES, SAMPSON, etc.)	Accident management evaluation
Tests of soundness of pressure vessels, etc. (Tests of characteristics of high-temperature materials, structural analyses, etc.)	Evaluation of fracture toughness of pressure vessels Analysis of thermal shock Seismic response analysis
Tests for evaluation of progression of melting of fuel (Mock-up tests of loss of cooling water, fuel melting tests, etc.)	Mock-up tests of loss of cooling materials in Halden Reactor
Source-term test	Tests concerning release of radioactive substances



Phenomena occurring at time of loss of cooling water and contributing factors

Image of test devices inside reactor

Enables data to be obtained on the change in shape, melting and collapse of the fuel rods, the relocation of the pellets, etc. when cooling water is lost



Implementation schedule

Item/Year	Phase 1			Phase 2						
	2011	2012	2013	2014 (beginning)	2015	2016	2017 (mid)	2018	2019	2020 (end)
1. Analysis of behavior of plant at time of accident	Analysis of plant behavior									
2. Advancement of severe accident analysis codes	Evaluation of applicability									
	Advancement of analysis codes									
3. Evaluations using mock-up tests, etc.		Soundness tests/Tests for evaluation of progression of melting of fuel/Source-term tests								

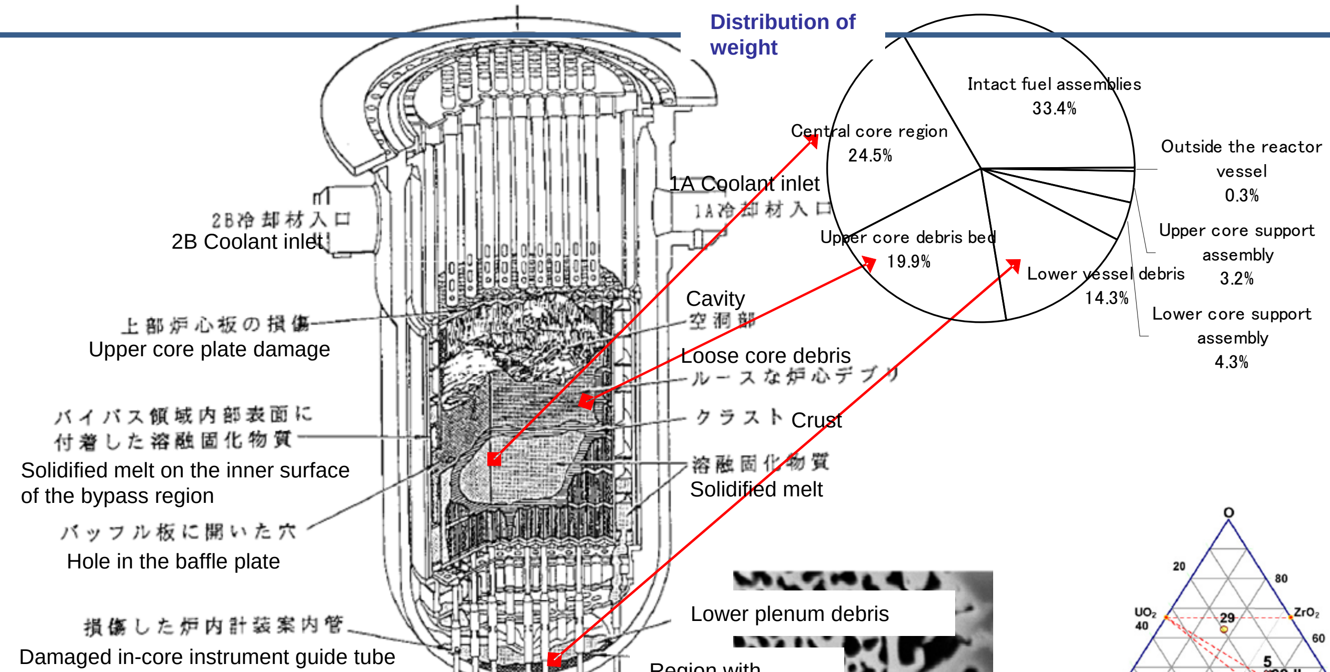
(2-(3)-1, 2, 3) Study of Characteristics using Simulated Fuel Debris, Analysis of Properties of Actual Debris, and Development of Technologies for Processing of Debris

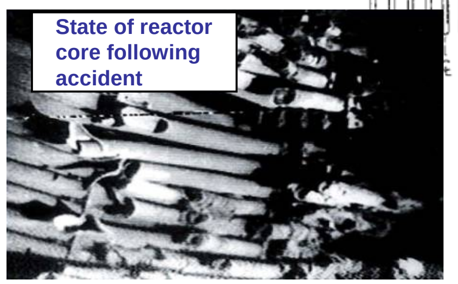
Necessity

Because factors such as the period of continuous core melt, the configuration of the reactor cores, and the injection of seawater into the reactors differ in the case of the accident at the Fukushima Daiichi Nuclear Power Station as compared to the TMI-2 accident, it is predicted that the fuel debris produced in the reactor cores will also be different. Given this, when we come to remove the fuel debris, it will be essential to understand the characteristics of the debris and ensure its stability, and to prepare the appropriate equipment for removal based on those characteristics. Further, when considering the processing and disposal of the fuel debris following removal, in addition to possessing an understanding of its chemical properties (solubility, chemical stability, etc.), it will be necessary to conduct tests concerning processing and disposal using both simulated and actual debris, and to obtain a firm outlook regarding the long-term storage and processing/disposal of the debris following its removal from the reactors.

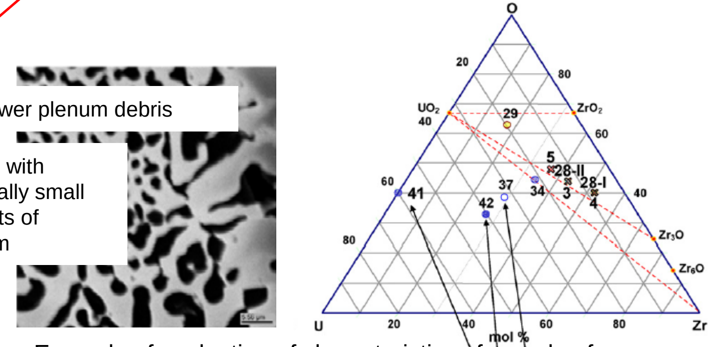
Specific actions

1. Manufacture of simulated debris
・ We will manufacture simulated debris (studies will include evaluations using simulations), taking into consideration factors including the length of time that the core melts continued, the structure of the cores, and the injection of seawater at the Fukushima Daiichi Nuclear Power Plant.
2. Evaluation of properties of simulated debris
・ Using the simulated debris, we will conduct measurements and evaluations of fundamental properties, test and evaluate chemical properties, and test and evaluate physical properties.
3. Comparison with TMI-2 debris
・ We will compare the properties of Fukushima Daiichi debris with those of debris from TMI-2 in order to identify factors that should be reflected in the procedures used for fuel removal.
4. Analysis of properties of actual debris
・ We will analyze the properties of actual debris collected in advance of removal work in order to contribute to the development of debris recovery technologies and the study of processing technologies for the fuel that is removed.
5. Development of processing technologies for debris
・ We will study the potential for application of existing processing technologies (wet methods, dry methods, etc.) for debris containing melted fuel and reactor structures in addition to a high salt content.
・ We will conduct studies concerning the applicability of disposal methods, including the manufacture of waste blocks from waste produced by processing and direct disposal of debris.





Reactor core following TMI accident



Example of evaluation of characteristics of sample of simulated debris

Left: External appearance of simulated debris; Right: U, Zr, and O composition

Source: Nuclear Engineering and Design, 238, 2761, (2008).

Implementation schedule

Item/Year	Phase 1			Phase 2						
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
				(beginning)			(mid)			(end)
1. Manufacture of simulated debris	━	━	━							
2. Evaluation of characteristics of simulated debris		━	━	━	━					
3. Comparison with TMI debris				━	━					
4. Analysis of properties of actual debris					━	━	━	━	━	━
5. Development of processing technologies for debris	━	━	━	━	━	━	━	━	━	━

Examples of prospective technologies

Elemental technology	Application example
Study of conditions for manufacture of simulated debris (including evaluations using simulations)	Experience of TMI
Manufacture of simulated debris	Experience of TMI
Evaluation of characteristics of simulated debris	Experience of TMI
Comparison with TMI debris	Experience of TMI
Analysis of properties of actual debris	Experience of TMI
Study of potential for application of debris processing technologies	–
Study of applicability of debris disposal technologies	Tokai Reprocessing Plant Rokkasho Reprocessing Plant

[Provisional Translation]

(2-(3)-4) Establishment of a new accountancy method for fuel debris

Background

Because fuel assemblies in Units 1-3 cores were melted partially or wholly, the standard nuclear material (NM) accountancy method of treating one assembly as one unit may not be applied. The development of a new nuclear accountancy method to allow effective and efficient nuclear accountancy is thus required in order to ensure transparency until the commencement of removal (defueling) and storage of the fuel.

Specific actions

1. Literature review and study of past accidents
   Investigate the accountancy method and safeguards measurement implemented in the TMI-2 and Chernobyl cases and compare with Fukushima Daiichi case.

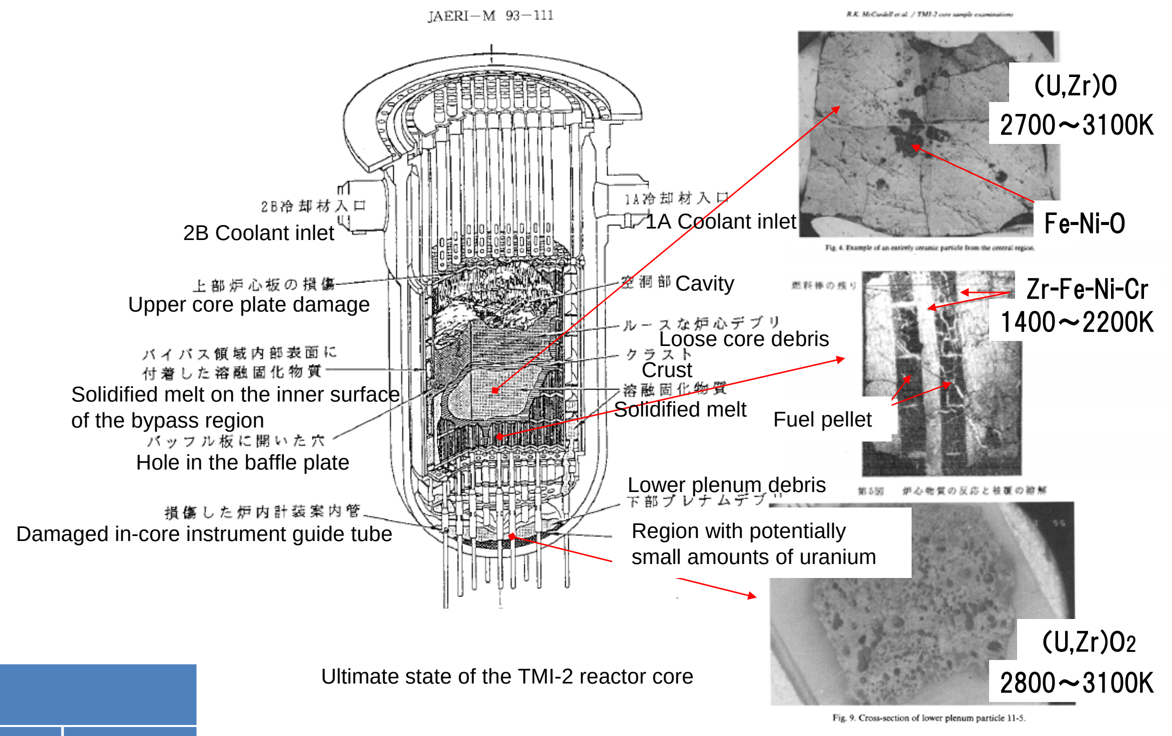
2. Evaluation of NM distribution
   Evaluate NM distribution based on (1) calculated data of NM at the time of the earthquake and (2) the results of sampling studies and in-core surveys.
   *The results of other R&D projects (2-1, 2-3, etc.) will be referred.

3. Establishment of a new accountancy method for fuel debris

- Evaluate the amount of total U/ fissile U / total Pu / fissile Pu per effective accounting unit for defueling and storage process.
- Develop an effective and efficient NM measurement technology and its accountancy method with minimum impact on defueling process.
- These developments will be closely communicated with the IAEA and relevant organizations for exchanging relevant information and technologies.

Example of technology

Item	Example
Technology for measurement of NM	Experience of TMI-2; IAEA' technology etc.



Fuel debris (Example from TMI)

Implementation schedule

Fiscal year	First period: 2011	2012	2013	2014	Second period: 2015 (beginning)	2016	2017 (mid)	2018	2019	2020 (end)
1. Literature review and study of past accident	Study of TMI-2 etc.									
2. Evaluation of NM distribution	Estimate NM distribution in/out of the core									
3. Establishment of a new accountancy method for fuel debris	Study of applicability of measurement technology			Development of measurement technologies				Evaluation of optical measurement technologies / Verification of applicability		
				Development of new NM accountancy method						

(3-1) Development of Technologies for Processing and Disposal of Secondary Waste produced by the treatment of Contaminated Water

[Provisional Translation]

Necessity

The removal of radionuclides including cesium from the large amounts of contaminated water generated at the Fukushima Daiichi Nuclear Power Station is a significant issue. The system employed for treatment of contaminated water combines sorption of cesium using zeolite with coagulation-sedimentation and demineralization. This results in the production of secondary waste including zeolite, sludge and concentrated liquid waste. To enable the sequence of operations from processing, through intermediate storage, to disposal as waste package to be conducted stably and in a rational manner, it will be necessary to conduct research and development programs including studies of the properties and stability of the secondary waste, the conditioning, and the optimization of disposal.

Specific actions

1. Study of properties of waste zeolite, sludge, etc.
・We will conduct studies including analyses of the concentration of radioactivity in order to gain a knowledge of the properties of the target waste essential to the examination of measures enabling long-term storage and the development of processing and disposal technologies.

2. Study of long-term storage evaluation
・Because it will be necessary to stably store the secondary waste produced by the treatment of contaminated water until the development of technologies for its processing and disposal, we will conduct studies of factors including hydrogen generation, heat generation, and corrosion, looking towards long-term storage of the waste.

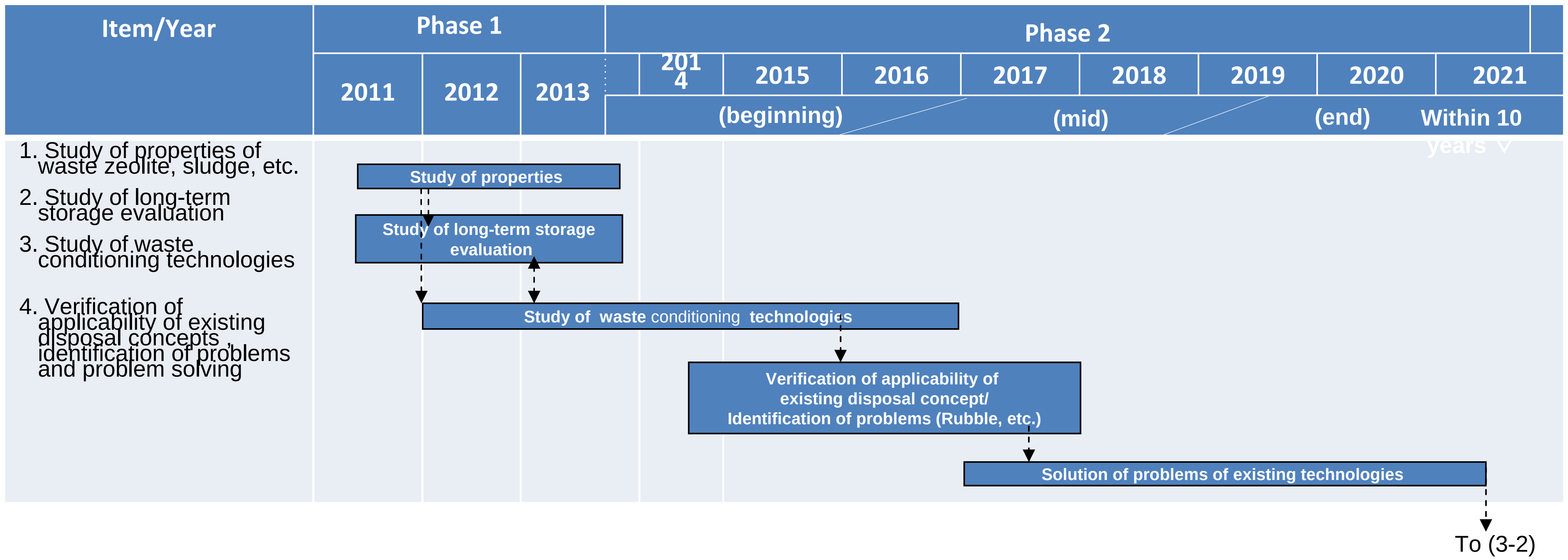
3. Study of waste conditioning technologies
・In addition to developing technologies essential to the waste conditioning (solidification technologies, etc.) based on existing technologies, we will also conduct studies of the performance of solidified wastes.

4. Verification of applicability of existing disposal concepts, identification of problems and problem solving
・Based on the findings concerning the performance of the solidified wastes obtained as a result of the item 3 above, we will verify the applicability of existing disposal concepts, identify the fundamental problems in relation to processing and disposal, and resolve those problems.
・We will develop new technologies for the treatment and disposal of waste for which it is difficult to apply existing disposal concepts (see 3-2).

Examples of perspective technologies

Elemental technology	Application example
Waste conditioning technology (Cement solidification)	Low-level radioactive waste
Waste conditioning technology (Vitrification)	Returned vitrified waste
Container technologies for disposal (Drums)	Low-level radioactive waste
Container technologies for disposal (Others)	Low-level radioactive waste
Disposal concepts (Trench Disposal, Pit Disposal)	—
Disposal concepts (Disposal in shallow pits)	Low-level radioactive waste (Rokkasho Reprocessing Plant)
Disposal concepts (Yoyusindo disposal)	—
Disposal concepts (Geological disposal)	—

Implementation schedule



(3-2) Development of Technologies for Processing and Disposal of Radioactive Waste

Necessity

Radioactive waste other than the secondary waste products generated by the treatment of contaminated water will include rubble and effluent from decontamination procedures. As in the case of the secondary waste products, it is predicted that the characteristics of these wastes will also differ from those of the radioactive waste produced normally by nuclear reactors. Because of this, it is essential to study characteristics of these wastes and to develop technologies for disposal, which defines the condition for completion of decommissioning.

Details

1. Study of characteristics of rubble, etc.
- We will conduct studies of the characteristics of rubble, harvested timber, soil, etc. (status of adherence of radioactive substances, etc.) necessary for the development of processing and disposal technologies.

2. Study of characteristics of wastes from decontamination, decommissioning, etc. and development of technologies for waste conditioning.
- We will conduct studies of the characteristics of effluent produced during the decontamination of and waste produced by decommissioning.
- In addition to the above, we will develop technologies for the waste conditioning based on existing technologies, and evaluate the performance of the waste package.

3. Verification of applicability of existing disposal concepts and identification of problems
- Based on the outcomes of 1. and 2., we will verify the applicability of existing disposal concepts, and then identify and resolve problems regarding processing and disposal.

4. Development of technologies for the processing and disposal of waste for which it is difficult to apply existing disposal concepts
- We will develop new technologies for processing and disposal for the radioactive waste (including secondary waste products generated by the processing of contaminated water) for which it is difficult to apply existing disposal concepts .

Examples of perspective technologies

Elemental technology	Application example
Waste conditioning technology (Cement solidification)	Low-level radioactive waste
Waste conditioning technology (Vitrification)	Returned vitrified waste
Container technologies for disposal (Drums)	Low-level radioactive waste
Container technologies for disposal (Others)	Low-level radioactive waste
Disposal concepts (Disposal in shallow trenches)	–
Disposal concepts (Disposal in shallow pits)	Low-level radioactive waste (Rokkasho Reprocessing Plant)
Disposal concepts (Yoyusindo disposal)	–
Disposal concepts (Geological disposal)	–

Implementation schedule