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Status of Fukushima Daiichi Decommissioning and Decontamination Project

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ABSTRACT

The Fukushima Daiichi nuclear plant accident occurred in March 2011 as a result of a major earthquake and tsunami. It is probably the second worst commercial nuclear plant accident in terms of on-site damage and off-site release; Chernobyl was the world's worst. Japan has begun a huge, complex and expensive effort to recover from the accident at the site, prevent and reduce further off-site damage and health effects, and decommission all the plants on the Fukushima Daiichi site. A major plan and roadmap has been developed and is being pursued. The plan and roadmap are also continually reviewed, and are changed and modified as the actual accident conditions are discovered, and the detailed technical efforts and equipment to achieve success must be dealt with.

An overall project organization has been set up in Japan for the decommissioning. It involves several portions of the Japanese government such as METI and NRA. It also includes TEPCO, IRID and many other Japanese and International companies, R&D organizations, universities, laboratories, local governments, etc. The Japanese have also sought out and set up work with a small International Expert Group, the IEG. These six individuals have extensive knowledge and experience in dealing with the sort of problems and issues that must be faced at Fukushima. Much of this experience comes from dealing with nuclear plant accidents and problems, including severe core damage, at locations outside Japan. The author is a member of this group.

The paper provides an overall summary of the current status and organization of the Fukushima Decommissioning Project, and identifies several of the key organizations and their roles. The paper discusses technical issues and problems currently being pursued on the site, e.g., spent fuel removal, fuel debris removal, monitoring and controlling radiation dose on the site, and collecting, processing, storing and releasing water from the site.

Significant progress has been made. The wide range of Japanese and International organizations are energetically and effectively participating in the needed activities. Safety is improving and doses for off-site public and site workers continue to reduce. Damaged buildings and systems are being repaired, spent fuel removal progresses and radwaste cleanup and storage is underway. Successful pursuit and completion of tasks to date has provided important new information, resulted in better performance of many systems on site, and freed up resources to address important additional tasks. Significant R&D is underway, and is helping identify and produce new hardware and techniques to support needed tasks.

The Japanese estimate the Fukushima decontamination and decommissioning task will require 30-40 more years. Based on the data in hand, the author considers that this estimated duration is uncertain, but seems to be a reasonable estimate. The Japanese are strongly committed and dedicated to this effort being safely achieved, despite the high cost and major needed effort, and the author agrees this should be the expected and anticipated result.

KEYWORDS

Project organization, roadmap, key participants, current status, spent fuel removal, fuel debris removal, radiation dose control, site water handling

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1. Introduction

The Fukushima Daiichi nuclear plant accident occurred in March 2011 as result of amajor earthquake and tsunami. Most major damage came from the tsunami. Fukushima Daiichi is probably the world's second worst nuclear plant accident in terms of on-site damage and off-site release; Chernobyl was the worst.

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Japan has begun a huge, complex and expensive effort to recover from the accident at the site. This effort will likely take many decades. There are three major steps for the recovery to be completed safely:

- Recover from the accident at the plants. As of today, a lot of work in this step has been completed but additional work needs to be done.
- Prevent and reduce further off-site damage and health effects. This step is in progress.
- Decontaminate and decommission all the plants at the site; this step is underway but an enormous effort remains to complete it

2. Decontamination and Decommissioning Program Phases

Fukushima recovery has many activities. The program is currently planned on the basis of four major phases:

- Achieve stable conditions and adequately suppress on-site and off-site radiation emissions and dose.
- Maintain and improve stable reactor cooling and water processing; begin removal of spent fuel. Begin processing of radwaste.
- Complete spent fuel removal from all units and complete processing of accumulated waste water. Begin fuel debris removal. Continue radioactive waste processing and disposal. Commence nuclear facilities decommissioning.
- Complete fuel debris removal. Complete decommissioning of facilities. Complete radioactive waste storage and disposal.

3. Project Roadmap

The recovery program has many ongoing activities that proceed in parallel and fit into various stepsin the plan and the phases of the overall effort. In order to have a general understanding bythe Japanese government, as well as all the participating organizations and participants and interested parties, a major plan and roadmap is needed. A roadmap has been developed and it outlines what is being pursued. As the work progresses, many things change. The plan and roadmap are also periodically reviewed, changed and modified as progress is made, delays occur and new conditions are discovered.So, the roadmap provides guidance regarding schedule, technical efforts and equipment needed to achieve success. Currently, in late 2014 and early 2015, the roadmap is undergoing extensive revision yet again. So, it is not practical to include a Figure illustrating the roadmap.

The Fukushima Roadmap recognizes that such documents have been successfully used in other projects regarding major accidents and key nuclear technology activities. As a result, inputs from other accidents (TMI-2, Chernobyl, PAKs, Sellafield) and from processing facilities such as La Hague, provided suggestions regarding roadmap content, structure and use.

4. Decontamination and Decommissioning Program Organization

A large, complex overall project organization has been set up in Japan for the Decommissioning and Decontamination project. The organization has been adjusted and modified based on experience and the most recent set of changes were made in 2014. The organization involves several portions of the Japanese government and local governments close to the Fukushima site. It addresses stakeholders' needs and issues, e.g., Fisherman organizations and citizen groups. It creates collaboration among numerous Japanese and International companies, R&D Organizations, Universities, Laboratories, Local Governments, etc.

The Japanese organization also sought out and set up work with a small International Expert Group, the IEG. These six individuals have extensive knowledge and experience in dealing with the sort of problems and issues that must be faced at Fukushima. Much of this experience comes from dealing with nuclear plant accidents and problems, including severe core damage, at locations outside Japan. The author is a Chairman of the IEG.

The Fukushima Decontamination and Decommissioning organization has a number of objectives:

- Identify and successfully pursue critical activities
- Set-up decommissioning technology organizations, committees, key members, and workforce needed
- Plan, evaluate progress, and accomplish required R&D by public and private sectors in Japan and abroad
- Support management and achievement of outstanding critical objectives
- Enhance international and domestic alliance, e.g., integrate and disseminate information and research results acquired from decommissioning activities

The organizational structure is very complicated. Figure 1 shows an overall picture. Some of the key participants in this structure are briefly described below.

The national government participants are the Japanese Government, e.g., Ministry of Economy, Trade and industry (METI), and the national government develops policy objectives and directives. The Nuclear Regulatory Agency (NRA) is not explicitly shown in Figure 1 but monitors and reviews, assures compliance to regulatory requirements, and establishes new and modified requirements when needed. Local governments monitor and review plans and work progress, approve particular areas and activities where they have specific responsibility and control, e.g., off-site radwaste storage, and new off-site industrial and training facilities. Key government personnel also follow and interact actively in ongoing meetings and activities by participating organizations.

In summer 2014, TEPCO Fukushima Daiichi Decontamination and Decommissioning Engineering Company (FDEC) was set up and assigned the primary responsibility and authority for site activities and progress. This is a new, large TEPCO subsidiary created solely of this role. The president is Naohiro Masuda. The management includes four highly experienced nuclear industry individuals as Vice Presidents overseeing key areas. TEPCO nuclear Energy Department provides support and services to FDEC at the Fukushima site. FDEC contracts with the International Experts Group (IEG) to obtain advice and consultation.

The International Research Institute for Nuclear Decommissioning (IRID) was created for the Fukushima project in 2013. It is responsible for managing and implementing R&D activities. It establishes cooperative Japanese and overseas research activities. It specifically seeks domestic and international proposals for needed tasks; evaluates, selects, and funds winners; and interacts and oversees work as it progresses. IRID also works to strengthen needed technological developments.

There are many Japanese and international organizations that take partin the organization structure. There are many Japanese vendors and major suppliers: ten Japanese Utilities; several Japanese Technology Specialty Companies , e.g., robotics, instrumentation, water treatment, construction; Japanese R&D Institutes, Laboratories and Universities. There are also many international equipment suppliers, Laboratories, Research Institutes, and Nuclear Technology Firms.

The International Expert Group has been set up to support FDEC since mid-2013. It has two roles:

- Contribute to the safe and efficient implementation of the Decommissioning and Decontamination Activity, including R&D
- Provide objective advice based on the collective view of the IEG, reflecting the differing international experience and expertise of each member of the IEG

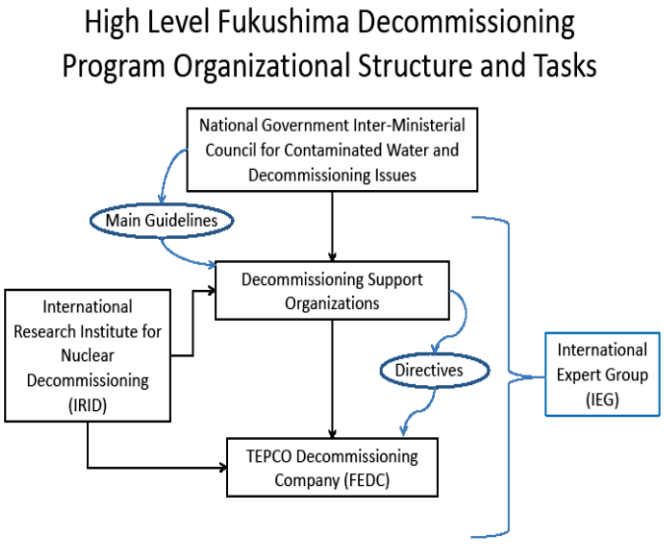

Fig. 1. High Level Fukushima Decommissioning Program Organizational Structure and Tasks

The six IEG members are from five countries (US (2), UK. France, Ukraine, and Russia) and have extensive knowledge and experience in dealing with nuclear accidents, radwaste cleanup and handling, e.g., TMI-2, Chernobyl, PAK, Sellafield and La Hague. The IEG interacts with the Japanese Organizations via periodic meetings of the IEG Team all together, and via working group meetings of portions of the IEG on specific topics. The meetings are effective and the Japanese listen and respond. It is important to understand that the IEG is only empowered to provide advice and suggestions. The Japanese Organizations are responsible for the Fukushima Daiichi D&D and R&D tasks and they are also responsible for the tasks under consideration with the IEG.

5. Current High Priority Activities

There are many high priority activities in progress. Four examples of high priority items are discussed below as significant progress has been made on each and work actively continues.

a. Spent Fuel Removal

Spent fuel removal is planned from all three damaged units and eventually spent fuel will be removed from Units 5 and 6 which are undamaged, but are not likely to be restarted. With regard to the damaged units:

- Unit 4 spent fuel removal began in September 2013 after extensive repairs to the building. About 1350 spent fuel assembles had been removed at the time the paper was presented. All Unit 4 spent fuel as well as used fuel removal was completed on December 20, 2014.
- In Unit 3 extensive building repair and fuel handling system work is in progress. The original fuel removal equipment will be removed and a remotely actuated spent fuel removal system will be used. This design and fabrication has been completed and testing, along with operator training, will begin off-site in a test facility in November 2014. Additional work on the building to complete repairs and reduce doses is underway and spent fuel assembly removal will likely begin in late 2015, and completed in 2016.

- Units 1 and 2 plans and dates for spent fuel removal in these two units awaits a detailed assessment of the buildings, spent fuel conditions and the fuel handling equipment.

b. Monitoring and Controlling Radiation Dose on Site

The TEPCO team and contractors have achieved major success in worker safety and reducing dose and contamination, Examples:

- Well-defined conditions and rules are used in all work zones
- Highly skilled specialists and specialized equipment assure radiation monitoring and protection of workers
- Strong oversight of work conditions indentifies and forecasts changes; adjusts techniques and procedures to increase personnel protection
- Determining and implementing on-site wastes management /storage sites; interacting with Japanese and local governments on waste storage locations

  Future difficult activities such as fuel debris removal and damaged reactor building cleanup and repairs are being worked now to assure needed techniques and processes to reduce dose and assure worker safety.

c. Fuel Debris Removal

Prior fuel debris removal efforts, e.g., TMI-2, PAKs, Chernobyl, and Sellafield all indicate fuel debris and building conditions are crucial and must be well understood. They markedly affect the work effort and duration, and are critical to achieving regulatory agreement. So the Japanese team has begun major efforts in this regard. However, the status of the Units 1-3 buildings and the fuel conditions are highly uncertain. As a result, fuel debris removal will not begin for several years; the actual schedule can be determined once fuel and plant conditions and the results of the R&D program are available.

TEPCO, in cooperation with IRID,is pursuing the actions to identify fuel debris removal conditions and develop tools and procedures. For example:

- Decontamination and other measures to reduce dose
- Identification and inspection of Primary Containment Vessel and Reactor Vessel leaks, and assessing and testing repair techniques; these leaks strongly affect whether wet or dry fuel debris removal techniques can be used
- Development of evaluation and detection techniques regarding nuclear criticality
- R&D program on fuel debris removal techniques plus design, manufacturing, testing, etc, of equipment and processes
- Establish stable storage, processing and disposal of fuel debris after removal

d. Controlling, Processing, Storing, Decontaminating and Releasing Fukushima Site Accumulated Water

The situation on the site is large and complex. Buildings and reactors are damaged; site groundwater leaks into buildings, mixes with contaminated water leaking from the reactors and PCVs; this results in large contaminated water flows out of the buildings to be processed and stored. To deal with this, TEPCO has put a large, complex site water system in place Figure 2, and works steadily to increase its capacity and performance.

Major capabilities that are being implemented include:

- Remove contamination in water: e.g., expand and improve multi-nuclide removal systems. Final discharge of cleaned water to the environment will regain final determination regarding allowable tritium content. Discussions among the stakeholders and the government regarding release of low levels of tritium are

underway.

- Isolate groundwater from contamination; pump up groundwater flowing into site, assure its cleanliness. Bypass clean groundwater to the ocean; install an ice-wall on the ground side of buildings to inhibit groundwater flow and reduce groundwater level adjacent to the buildings
- Prevent leakage of contaminated water off site: inject material to improve site soil condition; prevent leakage to ocean by creating sea-side impenetrable wall; greatly increase capacity and performance of water storage tanks; process tank contents to remove radio-nuclides and reduce risks.

6. Conclusion

Overall, significant progress on Fukushima Decommissioning and Decontamination has been made. A wide variety of Japanese and International organizations are energetically and effectively participating in the work ranging over site work, R&D, engineering testing and processes. Safety has increased substantially and risk has been reduced.A number of very difficult activities have been carried out successfully. The level of effort and cost has been high; the current general estimate is that probably an additional 30-40 years of effort and high expenditures will be required.Based on the data in hand, this estimate is uncertain, but seems a reasonable. No doubt, there is a lot of time-consuming and difficult work yet to be done, e.g., access to heavily damaged reactors and buildings, removing fuel debris, etc. In addition, some of these tasks will require:

- Establishing and complying with new regulatory requirements
- Obtaining local stakeholder acceptance and agreement
- Defining and agreeing on a Japan-wide acceptance and agreement on radioactive waste storage and disposal.

It is the author's view that the long duration Fukushima Daiichi Decommissioning and Decontamination effort can be safely completed.

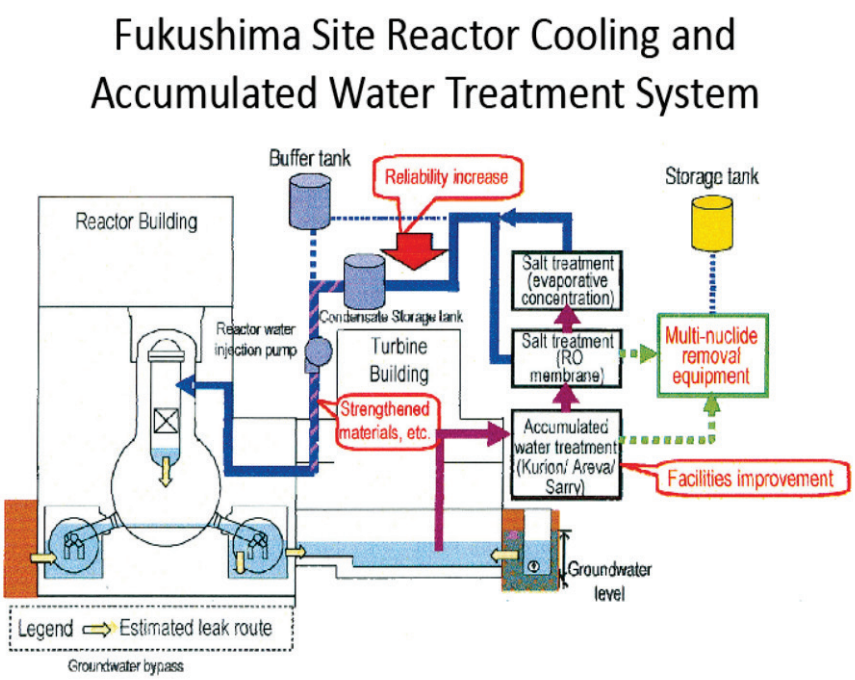

Fig. 2. Fukushima Site Reactor Cooling and Accumulated Water Treatment System