PROGRESS ON THE DEVELOPMENT OF THE ANALYSIS AND RESEARCH LABORATORY FOR DECOMMISSIONING OF FUKUSHIMA DAIICHI NUCLEAR POWER STATION

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ABSTRACT

The Japan Atomic Energy Agency is currently developing an Analysis and Research Laboratory Campus to be built near the Tokyo Electric Power Company Holdings (TEPCO) Fukushima Daiichi Nuclear Power Station (1F). The Analysis and Research Laboratory Campus consists of three buildings: the administrative building, Laboratory-1 and Laboratory-2. The administrative building provides office space and meeting rooms for researchers, apparatus mock-up. Laboratory-1 is for radioactive analysis of low and medium level radioactive rubbles and secondary wastes. Laboratory-2 is planned for radioactive analysis and mechanical and chemical characterization; of fuel debris and high level radioactive rubbles and secondary wastes. Construction of the administrative building will start in mid-2016. Detail design of Laboratory-1 was started in 2015 and construction will be started in early 2017. The specification of Laboratory-2 is being developed; detail design will start in mid-2016.

Radioactive analysis in Laboratory-1 will provide the data needed to establish the strategy and methodology for treatment and disposal of low and medium level radioactive rubbles and secondary wastes from the 1F site. The number of samples required for this analysis has been estimated by TEPCO to be about 190 per year for the time being. The design, including laboratory equipment is optimized based on the number of samples and how many different radionuclides are of interest. It is estimated that four iron cells, ten glove boxes and fifty draft chambers are required for this laboratory.

The analysis and characterization of the fuel debris from reactor units 1, 2, and 3 of 1F are required for purposes including long-term storage, fuel debris retrieval, and severe accident analysis. Laboratory-2 is designed to meet these purposes and the current plan is for 20 to 30 concrete and iron cells.

1. Introduction

The Tohoku Earthquake and the tsunami that followed occurred in March 2011. The surge from the tsunami caused a loss of power and complete loss of cooling in Tokyo Electric Power Company Holdings (TEPCO), Fukushima Daiichi Nuclear Power Station (1F), Units 1-4. The loss of cooling allowed the fuel in reactors 1-3 to heat up and at least partially meltdown. The high temperatures during the loss of cooling provided the conditions for a reaction between the zirconium fuel cladding and steam to split the steam into oxygen and hydrogen. The hydrogen built up and reactors 1, 3, and 4 exploded. The hydrogen explosions generated a large amount of rubble. The large amount of radioactive material released into the environment by these events, contaminated a vast area.

Decommissioning of 1F is generating a variety of radioactive wastes. Fuel debris will be recovered from the 1F pressure vessels and primary containment vessels. Secondary wastes are generated by the KURION, SARRY and ALPS water processing systems used to remove radioactive nuclides from used reactor cooling water and purified ground water that becomes contaminated. Treatment and disposal methods for the variety of waste needs to be determined. It is very important to solve these issues soon in order to progress decommissioning of 1F smoothly.

In March 2013, the Japanese government provided 85 billion yen of funding to JAEA for the construction of research and analysis facilities in order to develop decommissioning technologies. Then in June of 2013 the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station" (the road map) was revised by the "Nuclear Emergency

Response Headquarters Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" [1] [2]. The roadmap assigned to JAEA the responsibility to determine the locations and designs of the required facilities. The final decision for the location of the Okuma Analysis and Research Center was reported in June 2014, and was finalized by the decommissioning and contaminated water management team. The selected location which is next to the 1F site is shown in Figure 1 [3] [4].

The land area of the center will be around 7 ha. The Okuma Analysis and Research Center consists of an administrative building, Laboratory-1 and Laboratory-2. Low and medium level radioactive waste, such as rubbles and many secondary wastes, will be analyzed at Laboratory-1. In the meantime, high level radioactive waste, fuel debris, and water processing media will be analyzed at Laboratory-2. The administrative building provides offices and a mock-up test area for development of the processes to be used in Laboratory-1 and Laboratory-2. The obligated peripheral monitoring area of the 1F site is expanded to enclose Laboratories 1 and 2, which facilities sample transportation from the 1F site to the Laboratories.

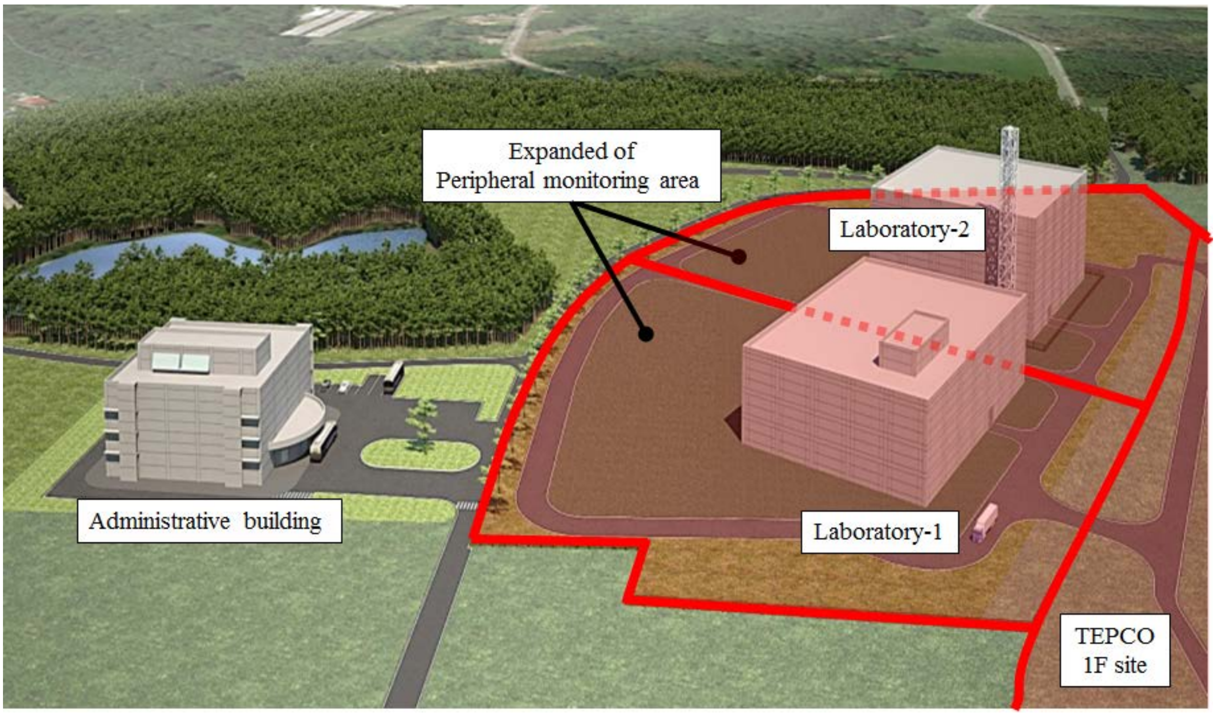

Fig. 1. Okuma Analysis and Research Center (image)

2. Construction and Operation Schedule

Table 1 shows the construction and operation schedule of the Okuma Analysis and Research Center. Detail design of the administrative building began in March 2015, and construction started in August 2016. Detail design of Laboratory-1 also began in March 2015. Start of the construction of Laboratory-1 is scheduled for the beginning of 2017. Conceptual design of Laboratory-2 is complete and detail design of Laboratory-2 will begin in late 2016. Operation of Laboratory-2 will begin in the 3rd or 4th quarter of 2021 with the receipt of the first fuel debris recovered from a 1F reactor [5].

Table 1. Construction and operation schedule of Okuma Analysis and Research Center

Facility \ FY	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Administrative building	Conceptual design etc.		Detail design	Construction				Operation			
Laboratory-1	Conceptual design etc.		Detail design		Construction				Operation		
Laboratory-2	Conceptual design etc.			Detail design			Construction			Operation	

3. Administrative Building

The four story administrative building is not used to handle radioactive materials. The main room on the first floor is a workshop for process development, mock-up testing for Laboratory-1 and Laboratory-2. The second, third, and fourth floors, are office space and meeting rooms for about 400 people. The workshop is equipped with a draft chamber, a glove box and a cell for mock-up and training of analytical procedure. Once the construction site is decontaminated, construction will start in mid-2016. The administrative building is scheduled to begin operations in the fiscal year of 2017.

4. Laboratory-1

Laboratory-1 will be used to analyze low level samples (< 1 mSv/h) and medium level samples (< 1 Sv/h)[*1].

The number of samples is expected to be a maximum of 200 samples/year. There will be 120 samples/year of concrete, metal and secondary waste with medium level contamination [6]. The maximum size of medium level sample is less than 2kg because of handling by manipulator. The maximum size of low level sample is less than 300kg. If additional analysis equipment is purchased and additional technicians are hired, the lab capability can be expanded to process up to 800 samples/year. Also, space is reserved to add 2 iron cells and 50 draft chambers.

Figure 2 shows the schematic layout of Laboratory-1. Laboratory-1 will be three stories. On the first floor is ventilation equipment, emergency generators, truck area room; and temporary storage of radioactive solid and liquid wastes. On the second floor is access control equipment for analysts, a sealed room, 4 iron cells, 10 glove boxes, and 50 draft chambers. On the third floor, there is a test room, the facility control room and an emergency room.

Low level samples are coarsely crushed in the sealed room, then the samples are divided/measured and distributed to glove boxes and draft chambers. At each glove box or draft chamber, low level samples are pretreated using processes like milling, acid treatment, or alkaline melting and extraction.

After analysis the samples are returned to the 1F site. Temporary, secure radioactive waste storage for solid waste will be in $1m^3$ square containers, and in tanks of about $90m^3$ for liquid waste.

[*1] The definitions of low and medium levels are internal to this site only and are not in agreement with international or Japanese accepted definitions of waste levels.

The use of Laboratory-1 is mainly to acquire nuclide concentration data to create guidelines for treatment and disposal of the radioactive solid wastes from 1F, as well as physical/chemical characterization. Table 2 lists the analysis equipment to be used in Laboratory-1. There are a large variety of nuclides, and in many cases the nuclides to be analyzed are unevenly distributed in the samples. The variety and distribution of nuclides could require an enormous amount of samples to accurately describe the strategy and methods for 1F waste treatment and disposal. Sample analysis procedures must be accurate and fast. To meet these requirements, high sensitivity, accurate, state-of-the-art analysis equipment that is capable of high throughput was selected. Laboratory analysts will be trained in the proper use of the equipment and for maximum efficiency.

It was determined that for safe disposal of 1F wastes that 38 nuclides should be assessed. The relationship between target 38 nuclides and equipment is shown in Figure 3. In order to minimize separations, multiple nuclides will be measured at a time, by using inductively coupled plasma mass spectrometer (ICP-MS). This makes it possible to streamline the pretreatment process.

To minimize cost and shorten construction time, Laboratory-1 will be constructed using precast concrete. This method uses concrete components that are cast in a dedicated factory. The cast components are transported to the construction site and assembled.

All radiation controlled areas, the iron cells, glove boxes, draft chambers and the sealed room are kept at negative pressure to confine the radioactive sample materials and prevent the materials from contaminating clean areas. The area around the facility is contaminated with radioactive material from the 1F accident. To prevent flow of this contamination into the facility from the outside the facility, the outer wall of the facility is a double structure with positive pressure between the external walls.

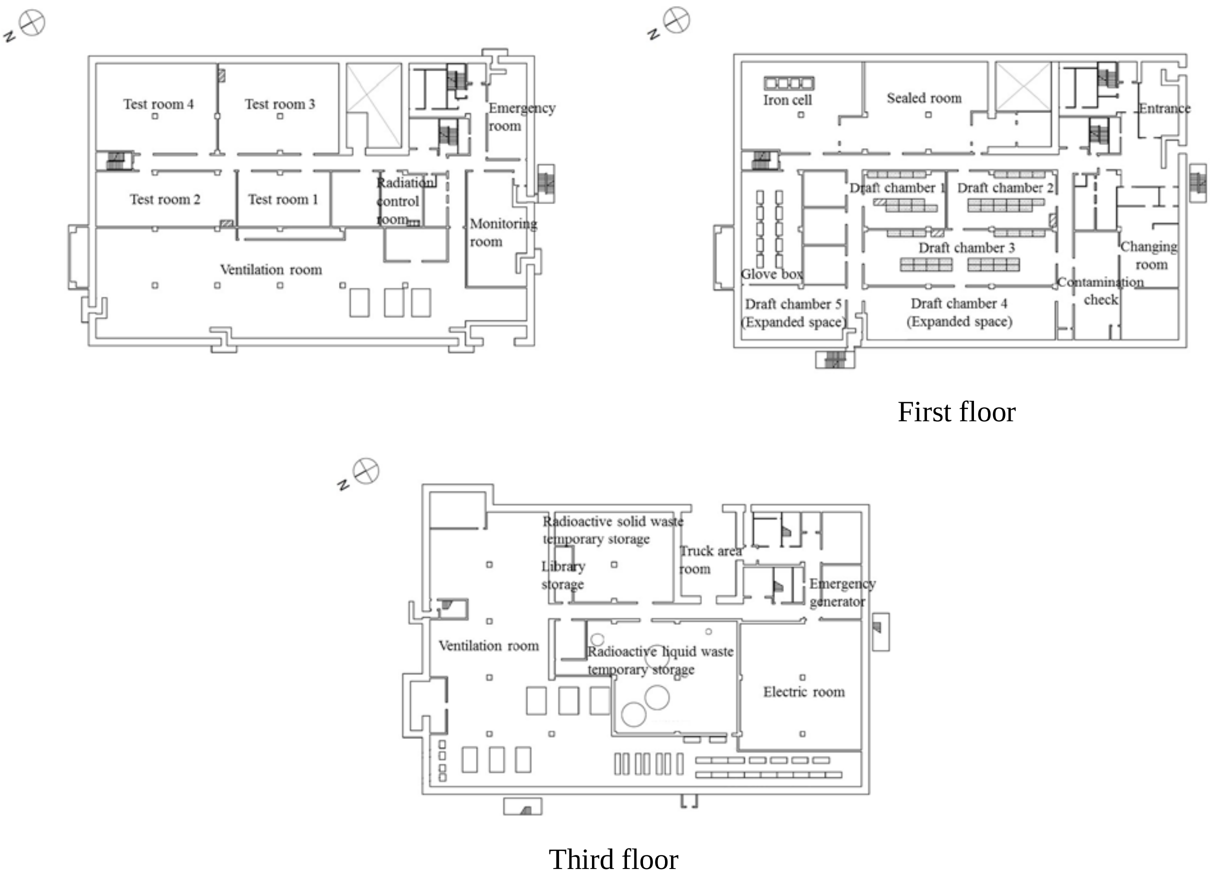

Fig. 2. Schematic layout of Laboratory-1

Table 2. Analysis equipment to be installed in Laboratory-1

Analysis items	Equipment	Data to be acquired (Target nuclide)
Radioactivity	Liquid scintillation counter	Low-energy β-emitter radioactivity (H-3, C-14, Ni-63, Se-79, Sr-90, Zr-93, Mo-93, Tc-99, Pd-107, Sn-126, Sm-151)
	γ-ray spectrometer (HPGe detector)	γ-emitter radioactivity (Co-60, Nb-94, Cs-137, Eu-152,154)
	γ-ray spectrometer (Ge-LEPS detector)	Low-energy γ-emitter radioactivity (Ni-59)
	γ-ray measuring device (NaI (Tl) scintillation counter)	Separation confirmation
	α-ray spectrometer	α-emitter radioactivity (U-233,234, Pu-238,239,240,242, Am-241,243, Cm-244)
	Gas-flow counter	β-emitter radioactivity (Cl-36, Ca-41)
Elemental analysis	Inductively coupled plasma atomic emission spectrometer (ICP-AES)	Trace metal elements concentrations
	Inductively coupled plasma mass spectrometer (ICP-MS)	Actinide nuclide concentration (I-129, Cs-135, U-235,236,238, Np-237, Pu-241, Am-242m, Cm-245,246)
	Atomic absorption spectrometer	Trace metal element concentration
Salinity	Ion chromatograph	Chlorine concentration
Organic matter	Total organic carbon analyzer	Organic matter concentration
Surface	Scanning electron microscope / energy dispersive X-ray spectroscopy (SEM-EDX)	Surface chemical composition
	Digital microscope	Surface condition
Chemical analysis	Ultraviolet-visible spectroscope	Toxic element concentration
Hydrogen gas	Gas chromatograph	Hydrogen gas concentration
Mechanical characteristics	Tensile and compression test equipment	Stress of structural materials
Specific surface area / Particle size distribution	Surface area analyzer	Specific surface area of pulverized sample
	Particle size distribution measuring device	Particle size distribution of pulverized sample

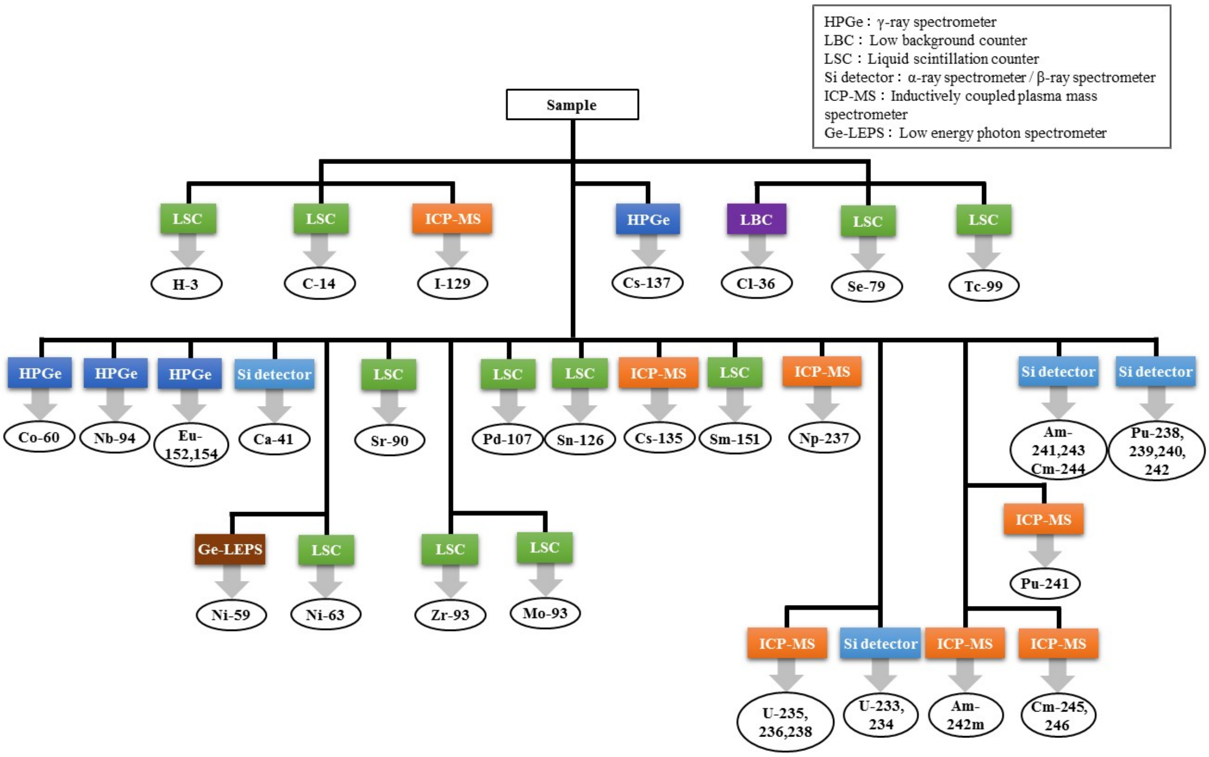

Fig. 3. Relationship between target 38 nuclides and equipment (under consideration)

5. Laboratory-2

Laboratory-2 is expected to handle samples of fuel debris, rubbles and secondary wastes with high level dose rates (=> 1 Sv/h)*2.

Sample size of filter media from adsorption towers from KURION, SURRY and ALPS is not yet determined. Fuel debris samples will be about 5kg (fist-sized) and there will be up to 12 samples/year.

Analysis samples of structural material, fuel debris and reactants from different regions within the primary control vessel such as pressure vessel top, core unit and pressure vessel bottom are necessary. Fuel debris analysis will use the same types of equipment that is used in Laboratory-1.

Laboratory-2 is three floors including a basement. About 20 groups of concrete cells and iron cells in total, a truck air lock, glove boxes and draft chambers will be installed on the first (ground) floor. The entrance to the 1F site, the controlled area entrance and the doorway leading to the outside, each has an air lock in order to maintain the negative pressure in the facility. To enhance the functionality of the facility, special cells are included that can be used for multiple purposes such as decontamination, dismantling and testing.

Transportation casks containing fuel debris, high dose rate rubbles and secondary wastes are inserted into the Laboratory-2 hot area through a dedicated port in the top of the hot cell. A cask containing fuel debris is then transported to a concrete cell and the cask is opened to remove the sample. Fuel debris samples are analyzed using non-destructive methods such as X-ray computed tomography (CT) (Fig.4) and a γ-ray measuring device that have been proven in the Fuels Monitoring Facility of JAEA [7].

The sample preparation system should consider the differences between the fuel debris and normal irradiated fuel. Fuel debris is an inhomogeneous and indeterminate material compared to normal irradiated fuel. Fuel debris is harder and more brittle than normal irradiated fuel. Therefore, strong acid, alkali melting and a large cutting system should be considered for sample preparation.

The analysis equipment to be installed includes electron probe micro analyzers and X-ray diffractometers. The inside of analysis equipment should be shielded to reduce the influence of fuel debris radiation on the analysis data and detectors. The laboratory will use inductively coupled plasma atomic emission spectrometer (ICP-AES) and inductively coupled plasma mass spectrometer (ICP-MS) for the chemical analysis. These types of equipment are useful to understand the phase state change of

*2 The definitions of high level is internal to this site only and is not in agreement with international or Japanese accepted definitions of waste levels.

the sample, the residual state of the fission product and the chemical form. Furthermore, Laboratory-2 will also have reserve space for equipment for future research.

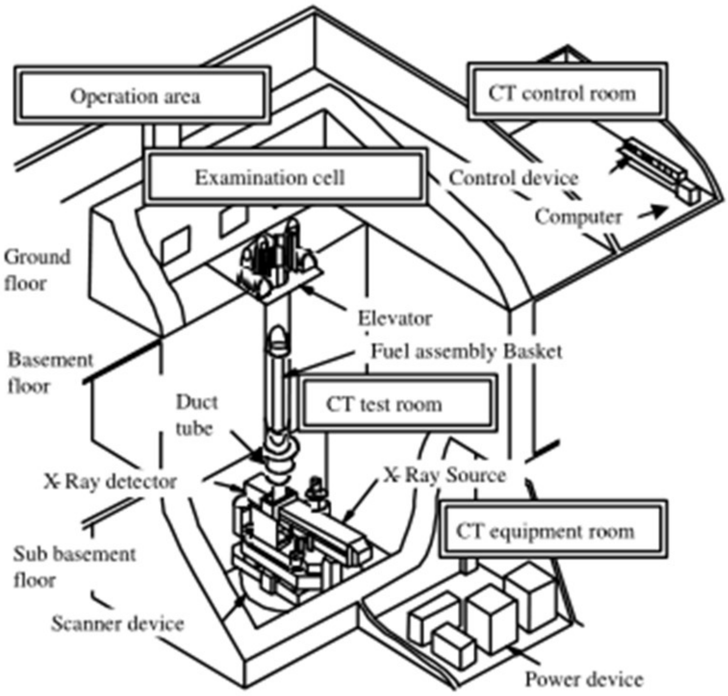

Fig. 4. X-ray CT apparatus (image)

6. Future Tasks

The Okuma Laboratory-1 is expected to require 100-200 analysis technicians. It is necessary to provide technician training until the end of fiscal year 2018 to be ready for the start of operation.

References

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