Outline of Japan Atomic Energy Agency's Okuma Analysis and Research Center (3) - Laboratory-2 -

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Abstract

Currently, the Japan Atomic Energy Agency has been constructing the Okuma Analysis and Research Center near Fukushima Daiichi Nuclear Power Station based on the "Mid-and-Long-Term Roadmap". The Okuma Analysis and Research Center consists of three buildings: Administrative building, Laboratory-1 and Laboratory-2.
Laboratory-2 will be used for the technological development of techniques to treat and dispose fuel debris, and high level radioactive rubble and secondary wastes. The specific analytical content and its importance has been discussed by an experts committee in FY 2016. The committee regarded fuel debris retrieval and criticality control related topics as the most important item. As a result, it will be a priority to introduce equipment to perform examination such as shape and size measurement, compositional and nuclide analysis, hardness and toughness test, and radiation dose rate measurement. In addition, since the analysis objects will have high dose rates (=> 1 Sv/h) at the time of reception, concrete cells and steel cells with enough radiation shielding ability will be used. In these hot cells the pre-processing will be performed, such as processing and dissolution of samples. Processed analysis objects will be examined in concrete cells, steel cells, glove boxes and fume hoods.
Detail design of Laboratory-2 started on FY 2017.

1. Introduction

Tokyo Electric Power Company (TEPCO), Fukushima Daiichi Nuclear Power Station (1F) was hit by the 2011 Tohoku Earthquake off the Pacific coast and the tsunami associated with the earthquake. Since the power supply equipment was lost by these natural disasters, cooling function of reactor core was lost [1]. The accident progress after that has been presumed as follows: Firstly, fuel pellets of Units 1-3 melted. Next, the molten fuels fell to the bottom of the reactor pressure vessel while melting all or a part of the reactor core. Finally, these molten materials have been cooled and solidified. These solids are referred to as fuel debris. Units 1, 3 and 4 had explosion caused by generated hydrogen gas. As a result, rubble was scattered around outside of the reactor building. Because of the cooling water injection into the nuclear reactor and the groundwater inflow into the reactor building, contaminated water has been generated day by day. This contaminated water has been treated through water processing systems such as KURION, SARRY and ALPS. Radioactive wastes generated through these systems are referred to as secondary wastes from water processing. To treat and dispose these fuel debris and radioactive wastes they are issued towards decommissioning [2, 3].

In 1F, various efforts have been done towards the decommissioning based on the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (Revised June 12, 2015). The Japan Atomic Energy Agency (JAEA) has been constructing the research and development facility "Okuma Analysis and Research

Center" near 1F as part of the efforts. The Okuma Analysis and Research Center will be used for research and development to ascertain characteristics of radioactive wastes, and technological development to treat and dispose fuel debris.

Figure 1 shows the expected completion drawing of the Okuma Analysis and Research Center [4]. The Okuma Analysis and Research Center consists of an administrative building, Laboratory-1 and Laboratory-2. The administrative building provides researcher's office spaces, meeting rooms and a workshop. The Laboratory-1 will perform radioactive analysis, chemical and mechanical characterization of low and medium level radioactive rubble and secondary wastes. Laboratory-2 will perform radioactive analysis, mechanical and chemical characterization of fuel debris and high level radioactive rubble and secondary wastes.

In this paper are reported the analysis contents of fuel debris, and the building and equipment design concepts of Laboratory-2.

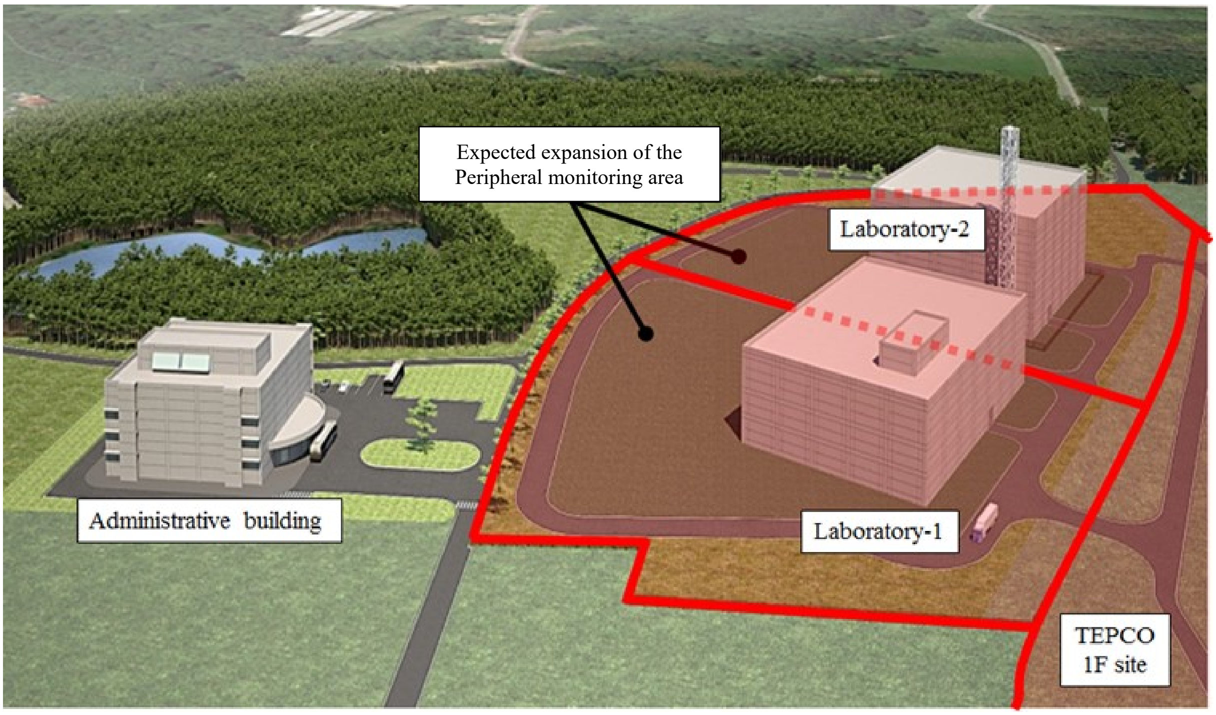

Fig. 1. Okuma Analysis and Research Center (expected completion drawing).

2. Expected samples

Table 1 shows the list of expected objects of analysis for Laboratory-2. The samples for Laboratory-2 are roughly classified into fuel debris, rubble and secondary wastes. Fuel debris is expected to be found in the following forms: (1) Fuel pieces and partial molten fuel. (2) Fuel melded with reactor core materials such as zircaloy, control rod elements (B4C), steel materials and the reactor vessel (stainless steel, etc.). (3) Fuel melded with control rod drive mechanisms. (4) Molten core concrete interaction (MCCI) products.

Reactor core materials and dismantling wastes will be handled as highly contaminated materials at Laboratory-2. Unlike Laboratory-1, currently under construction, this facility will handle fuel debris, and rubble and secondary wastes with alpha-contamination or high dose rate (=> 1 Sv/h).

Figure 2 shows an image of the presumed fuel debris distribution within reactor by the Collaborative Laboratories for Advanced Decommissioning Science (CLADS). According to the CLADS, the characteristics of the fuel debris will be different depending on its position within the reactor, for this purpose the in-reactor area has been classified into eight regions. Similarly, the International Research Institute for Nuclear Decommissioning (IRID), has classified the in-reactor zone into nine regions. TEPCO and the IRID will sample fuel debris from each of these nine regions. Fuel debris will be sampled a total of 240 times including spares from Units 1-3. These samples will be analyzed during a span of 20 years after the start of operation of Laboratory-2. To achieve this, TEPCO and the IRID plan to transport 12 fuel debris samples annually. These analysis objects will be transported mainly from 1F to Laboratory-2 by transportation casks of top or side loading type. The received fuel debris will have a maximum weight of 5 kg. Rubble and secondary wastes will be received with a maximum weight of 5 kg and 2 kg respectively, and from these the laboratory will receive a total of 50 samples/year.

Table 1. Presumed analysis objects list (TBD).

	Major analysis samples		Quantity
Fuel debris and highly contaminated material	Fuel debris	Oxide : $(U,Zr)O_2$-X, $(U,Pu,Zr)O_2$-X Alloy : U-Zr-Fe, U-Pu-Zr-Fe Molten corium MCCI product (Molten Core-Concrete Interaction)	12 samples / year
	Reactor core materials	Metal from reactor pressure vessel (RPV) and primary containment vessel (PCV)	
	Dismantling waste	Concrete and metal from reactor building dismantling	
Secondary wastes	Sludge	Barium sulfate (water decontamination)	50 samples / year
	Absorbent	Zeolite from cesium absorption by KURION equipment	
		Zeolite from cerium absorption by SARRY	
Rubble	Rubble	Concrete, metal	

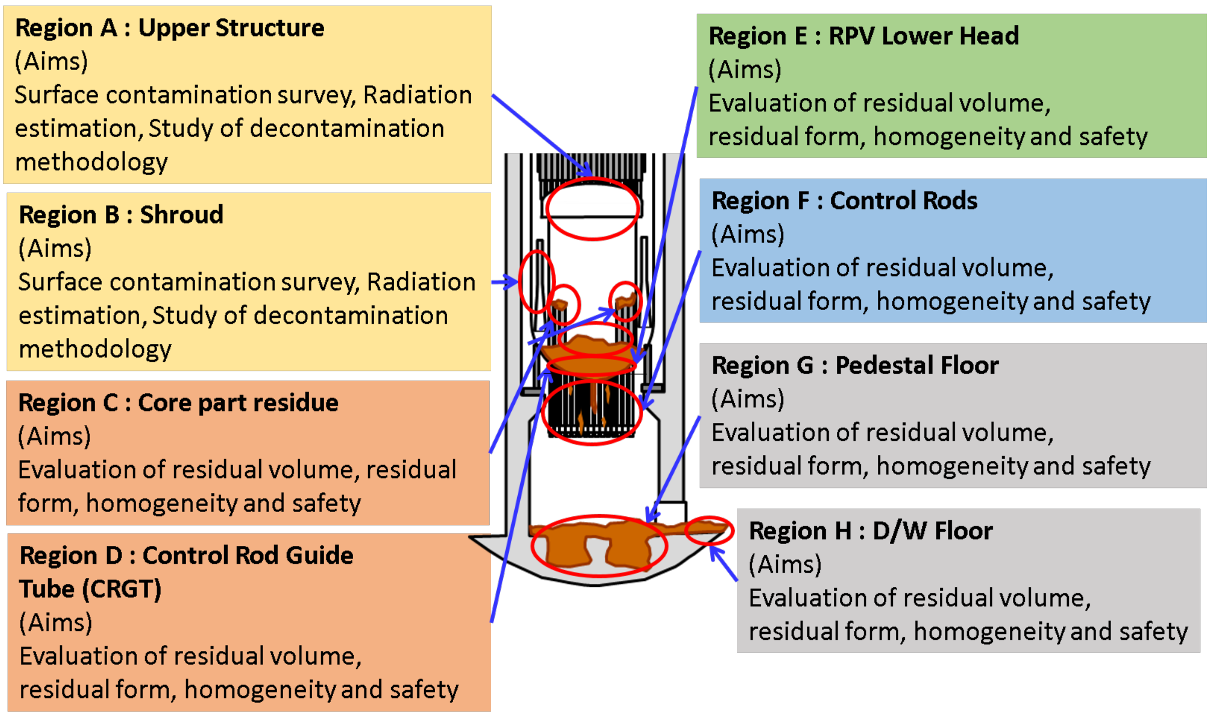

Fig. 2. Image of the expected fuel debris distribution within reactor by the CLADS.

3. Analysis needs and methods

Analysis needs in each step towards a decommissioning have been extensively considered by TEPCO, the IRID, the CLADS, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), other many organizations and so on. Meanwhile, because the situation within reactor hasn't been grasped enough, when the specific examination of Laboratory-2 in FY 2016 was started, these analysis needs couldn't be narrowed down. However, since the decommissioning is based on the Roadmap and must make a steady progress, it was necessary to examine the presented analysis needs minutely and make a decision. From this, it was decided to organize a committee of experts with extensive background and experience, to evaluate the presented analysis needs based on the newest domestic and foreign knowledge.

Table 2 shows the fuel debris analysis importance classification list. TEPCO and IRID divided the analysis needs and contents in six categories: basic property, mechanical property, thermal property, radiological property, other, and test. In the committee, these needs and contents were classified by three grades of A to C. Grade A is highest importance analysis contents. Evaluation criteria are as follows: (Class A) The necessary contents in step of fuel debris retrieval and criticality control. This class was considered urgent and required immediately after the start of operation of Laboratory-2, due to the importance of basic characterization. (Class B) The necessary contents in all step including fuel debris storage and transport, and wastes disposal. In this class, it was considered of importance the items related to safety such as criticality, explosion and thermal effect during fuel debris storage. (Class C) The necessary contents in all step other than Class A and B. Contents of this class have been applied to fuel pellet etc. in other facilities but need to examine its applicability to fuel debris.

Table 2. Fuel debris analysis importance classification list.

Importance	Class	Category	Content
High	A	Basic property	Shape, Size, Particle size, Chemical form, Surface Analysis, Elemental analysis, Compositional analysis Nuclide analysis
		Mechanical property	Hardness, Toughness
		Radiological property	Radioactive dose rate
Middle	B	Basic property	Density, Porosity, Salinity, Organic content, Moisture content Steam (Hydrogen) production
		Thermal property	Thermal behavior, Thermal conductivity Thermal diffusivity
		Radiological property	Calorific value
Low	C	Test	FP gas release behavior

4. Design concepts

Laboratory-2 will be reinforced-concrete-construction with three stories above ground and one story basement. Figure 3 shows a layout plan within Laboratory-2. Equipment within Laboratory-2 are roughly classified into analysis related equipment and utility related equipment. As analysis related equipment, 14 concrete cells, 12 steel cells, 19 glove boxes and 8 fume hoods will be introduced. As utility related equipment, commercial power supply, emergency power supply, air conditioning ventilation, drainage, etc. will be introduced. By these equipment and building, radioactive materials can be confined in the building. In addition, because radioactive materials were released to the surrounding environment with the 1F accident, it is necessary to prevent the invasion of these radioactive materials into the building. Therefore, the outer wall will be constructed with a double positive pressure structure.

Figure 4 shows sample flow in the current design of Laboratory-2. Design concepts of each analysis related equipment will be described in following sections.

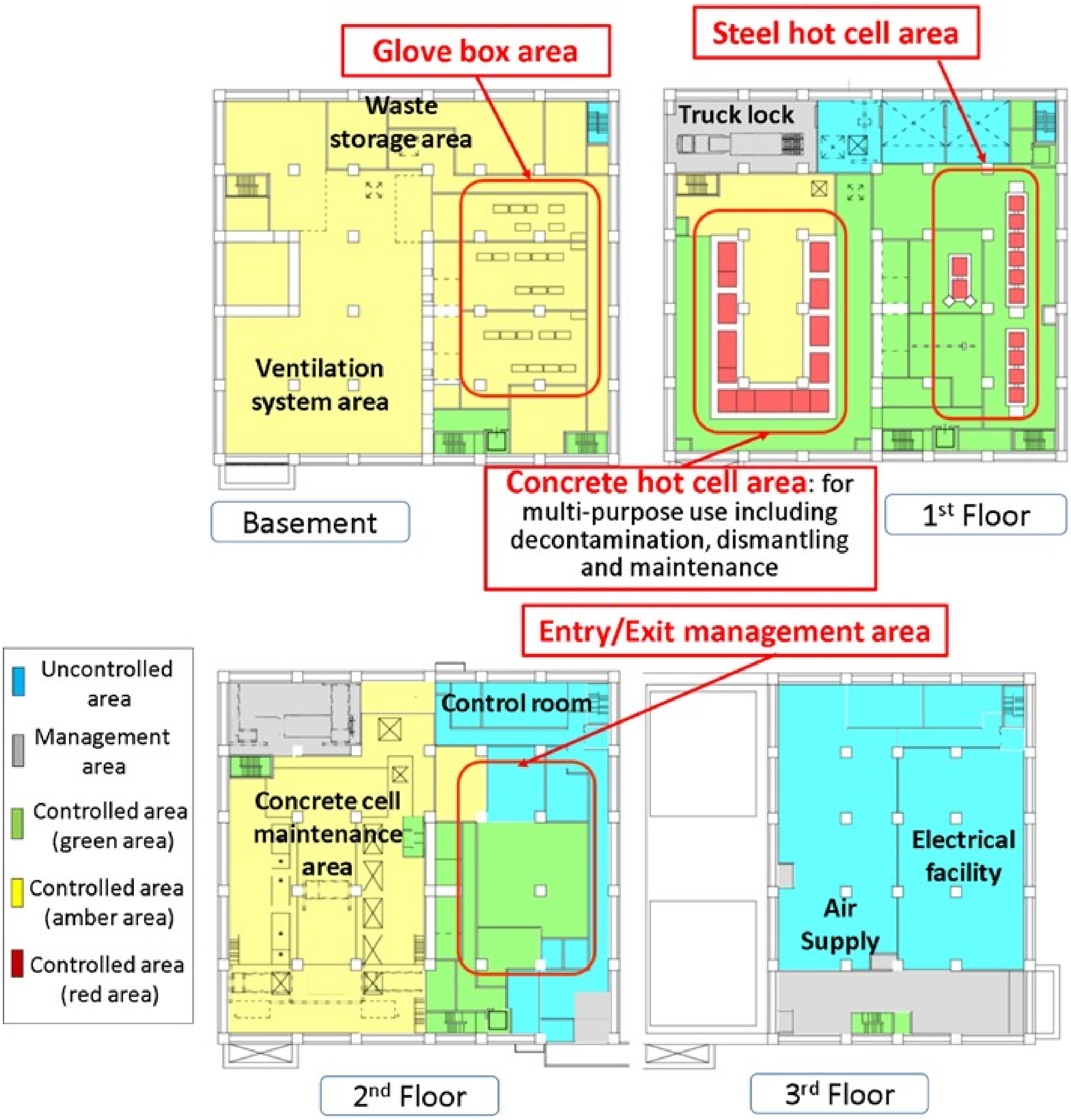

Fig. 3. Conceptual layout.

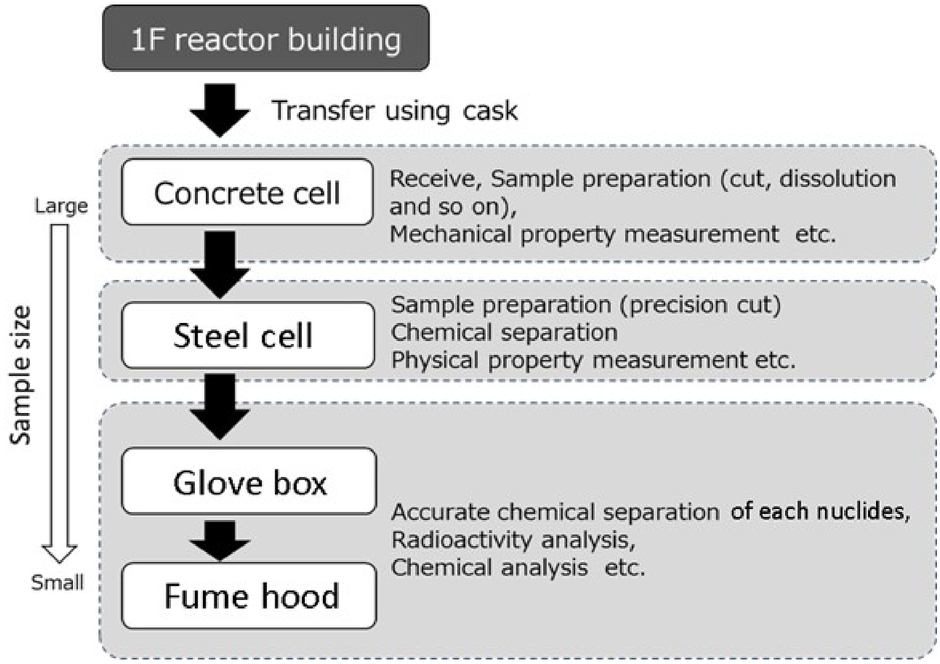

Fig. 4. Sample flow.

4.1. Concrete cell

Concrete cells consist of two lines: one line to handle fuel debris, and the other line to handle high level radioactive rubbles and secondary waste. Each line will be provided with a receiving cell for analysis samples, sample preparation cells for visual and structure observation, a mechanical strength cell to perform mechanical testing such as hardness test, compression test, etc., and a dissolving cell for dissolution. In addition, in the line for fuel debris, X-ray CT will be introduced for grasping the internal structure such as density and porosity of the fuel debris and evaluating the cutting position. Figure 5 shows X-ray CT apparatus scheme [5].

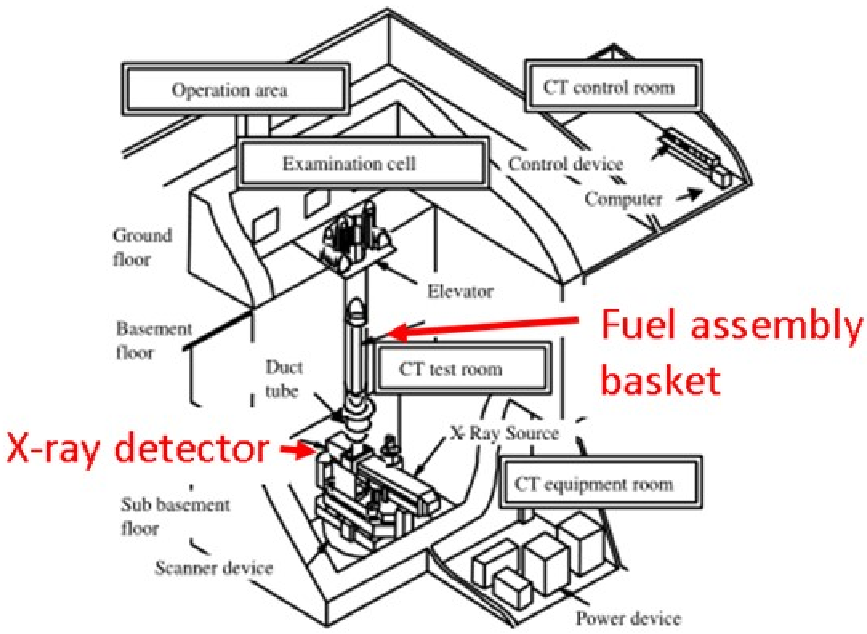

Fig. 5. X-ray CT apparatus scheme.

4.2. Steel cell

The steel cells consist of three lines: one line to handle solid samples such as visual observation, structure observation and physical property measurement, another line to handle liquid samples such as ICP-AES, and the other line to install analysis apparatus such as SEM and EPMA. These steel cells will handle all types of analysis samples. Therefore, measures will be taken to prevent cross contamination.

4.3. Glove box and fume hood

The glove box to preprocess radioactivity analysis consists of three lines: one line to handle fuel debris, another line to handle high level radioactive rubbles and secondary waste, and the other line to install analysis apparatus such as ICP-MS and atomic absorption spectrophotometer. In the fume hood, radioactive measurement will be performed such as alpha spectrometer. In addition, the glove box for sample preparation is designed with the capacity for analysis samples import/export. At the moment, the glove box will be connected to the fume hood, and analysis objects of the glove box will be exported via the fume hood.

5. Summary

In the Japan Atomic Energy Agency, the Okuma Research and Analysis Center has been progressing based on the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station".

Laboratory-2 of the center will handle fuel debris and high level radioactive rubble and secondary wastes.

Related to the analysis contents of fuel debris, examination by experts was performed in FY 2016.

Currently, the examination and design of the building, equipment, analysis apparatus, etc. are progressing based on this results, and Laboratory-2 aims to start operation in 2021.

References

[1] Tokyo Electric Power Company Holding web page. http://www.tepco.co.jp/nu/fukushima-np/outline/2_1-j.html As of June 9, 2017

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