Analysis of fuel debris sampled from Unit 2 on a trial basis

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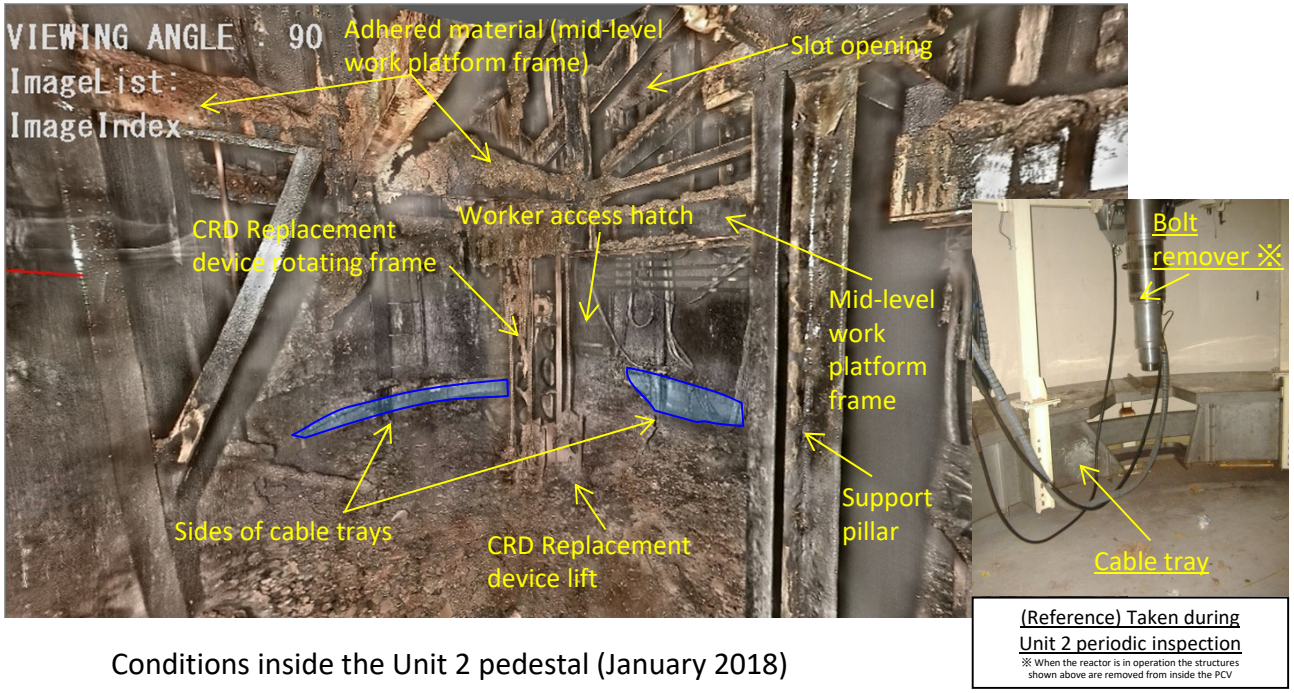
Tokyo Electric Power Company Holdings, Inc.

1. Summary

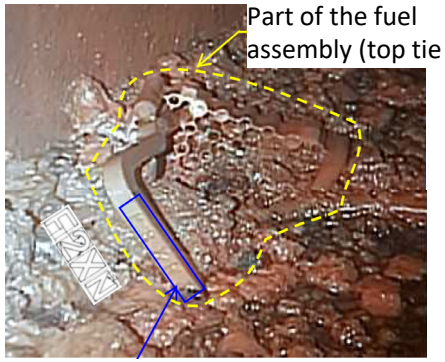
- We are currently performing the trial retrieval of fuel debris from Unit 2 with using the telescopic device, and plan to retrieve a small amount of fuel debris from the surface of the floor inside the pedestal.
- From the results of primary containment vessel internal investigations, we have deduced that the accumulated debris on the surface of the floor inside the pedestal is solidified molten material that consists of fuel elements and also may contain a lot of metal (structural material elements).
- Considering the fact that sampling location is limited and the amount of debris sampled will be very small, the analyses will focus on the three following objectives:
  - Directly ascertain the attributes of fuel debris from the sampling location
  - Examine the process by which the fuel debris was generated (origin, temperature, atmosphere, etc.) to deduce information about the area in the vicinity of the sampling location and the areas (routes) that the fuel debris passed through when it was formed.
  - Continue to analyze fuel debris retrieved in the future in order to better understand the attributes over a wide area and efficiently ascertain the attributes of all fuel debris.
- During the trial retrieval, analysis will focus mainly on the composition of fuel debris and the results will be leveraged to deliberate subcriticality and exposure, etc. during the later phase of the retrieval process.
- The fuel debris will be analyzed at off-site analysis centers (Japan Atomic Energy Agency (JAEA) Oarai Research and Development Institute, Nuclear Science Research Institute, Nippon Nuclear Fuel Development Co., Ltd., (NFD), MHI Nuclear Development Corporation (NDC)).
- The results from overall analysis performed at the JAEA Oarai Research and Development Institute (fuel debris surface element distribution, etc.) should be compiled in several months, and the results of analyses performed at other facilities should be compiled in approximately one year. The time required for analysis may vary depending on work conditions and analysis results.
- Furthermore, the mass of the sampled fuel debris and the amount of hydrogen being generated will be measured when the sample is in the glove box at the Fukushima Daiichi Nuclear Power Station in order to verify safety for the transport of fuel debris.

2. Deductions made about the deposits on the floor of the pedestal based on the results of primary containment vessel internal investigations

- There appear to be pebble-like and clay-like deposits on the floor inside the pedestal.
- There is no significant deformation or damage to structures such as the rotating frame of the CRD replacement device or cable trays, etc.
  - The deposits appear to be molten material that has solidified, but no deformation of the stainless steel cable trays has been found, so it is assumed that not enough heat was generated to cause the structures to deform. Therefore, it is assumed that the fuel debris contains a lot of metal elements (structural material elements).
- Part of the fuel assemblies (top tie plate) was found on the floor of the primary containment vessel.
  - It is assumed that a hole large enough to allow the top tie plate to fall through was formed at the bottom of the reactor pressure vessel, and that the deposits on the floor of the pedestal, including those in the vicinity of the location where the tie plate landed, contain fuel elements.



Conditions inside the Unit 2 pedestal (January 2018)



Top tie plate (January 2018)

3. Information to be gradually obtained during the course of fuel debris retrieval

- Fuel debris retrieval will be carried out in a step-by-step fashion based on internal investigation results.
- The scale of retrieval will be gradually enlarged step-by-step while leveraging existing safety equipment and confirming that safety is being ensured.
- The knowledge we obtain during each step will be reflected in later steps as we acquire new information.
- The main purpose of trial fuel debris retrieval is to obtain information on the composition of fuel debris
- We also aim to accumulated experience with fuel debris analysis that will help us to improve the accuracy of analysis/assessment.

Steps

Scale		Sampled amount	Summary	Storage	Information to be used during later steps
Contact investigation		–	Confirm that the debris can be moved. No sampling	–	Maneuverability
Trial retrieval		Small	Sample fuel debris to analyze the composition and confirm subcriticality	※Stored at 1F after analysis	Subcriticality/exposure (composition)
Gradually enlarge the scale (small-scale)	Grasp/ Vacuum		Confirm the feasibility of the encapsulation, transportation and storage process	Primary storage facility	Subcriticality/exposure (composition, increase in the number of samples) Cutting method (mechanical attributes)
	Cutting	Large	Sample debris by cutting it away and confirm that the same cutting method can be consistently used. Gradually increase the size of the retrieved samples and confirm that large-scale retrieval is possible		Exposure (rise in dose levels during cutting)

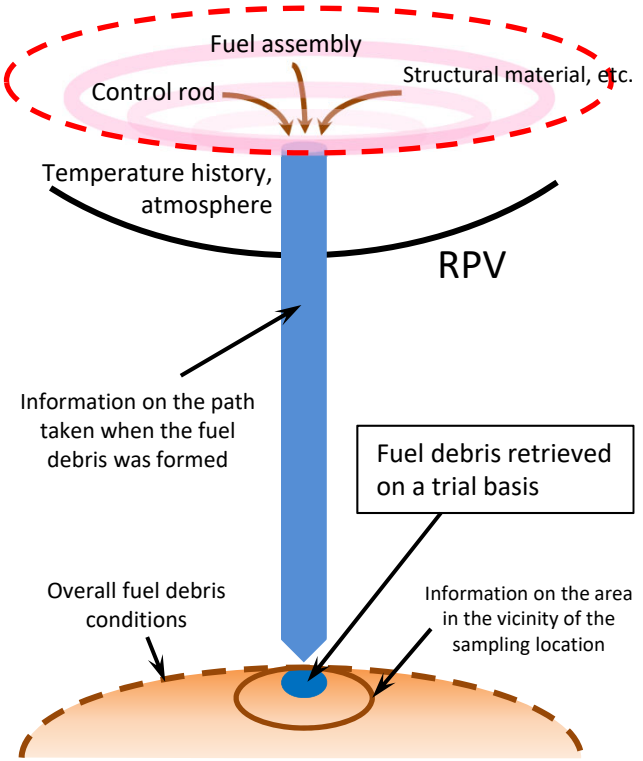
4. Analyze fuel debris attributes and analyze attributes pertaining to the origin of fuel debris

- By analyzing the attributes of the sampled fuel debris we will directly ascertain information such as the composition of debris at the sampling location and radioactivity density, etc.
- Analysis is performed to examine attributes pertaining to the origin of sampled fuel debris (formation process). The results obtained will be used to deduce information on conditions inside the reactor in areas that the fuel debris passed through when it formed (origin, temperature, atmosphere) that will be used to deduce information about the area in the vicinity of the sampling location and other related areas.
- We will continue to analyze fuel debris retrieved in the future in order to better understand the attributes over a wide area and efficiently ascertain the attributes of all fuel debris.

Primary analysis items

Objective	Analysis item	Analysis method (example)
Attributes of sampled fuel debris	External appearance/dimension/mass	External appearance, mass measurements
	Composition/isotope ratio	ICP-AES, ICP-MS, TIMS
	Radioactivity density	α, γ Ray spectrometry
	Phase (density) distribution	X-ray CT
	Element distribution	SEM-EDX, SEM-WDX
	Chemical form	SEM-EDX+TEM-EDX
Origin-related attributes	Local structure	SEM-EDX, SEM-WDX, TEM-EDX
	Local composition/element distribution	TEM-EDX
	Local isotope ratio	SIMS
	Local crystalline structure	TEM-EDX, TEM-Electron diffraction, Raman spectroscopy

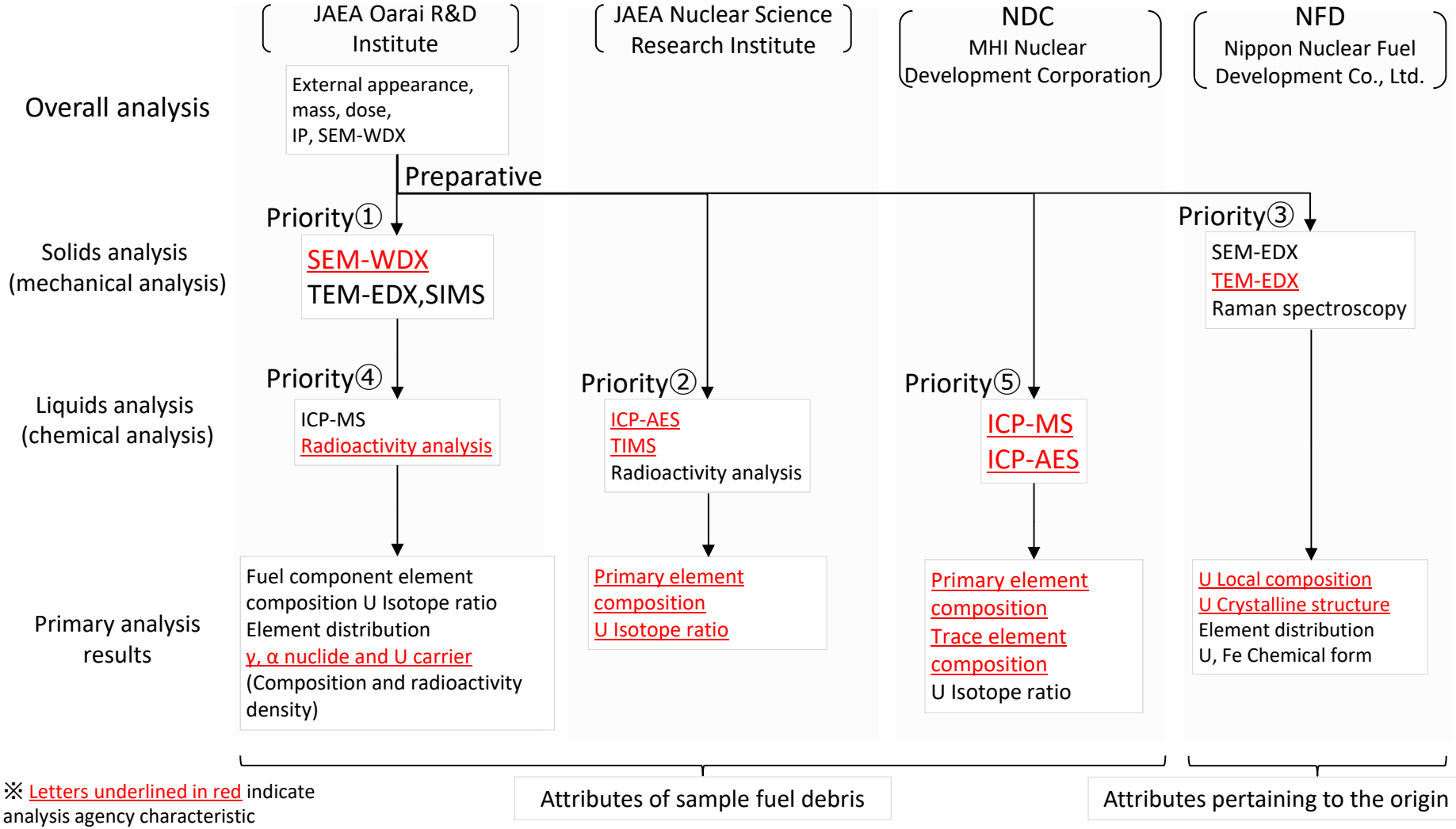
※ Analysis items depend on sample size/condition



Information obtained through fuel debris analysis

5. Overall analysis flow

- The roles of each analysis facility will be divided depending on their characteristics (shown in red)
- Redundant analysis items will be used to examine the equivalence of the preparative fuel debris
- Approximately 0.2g of debris is needed for primary analyses. Analysis priorities shall be set depending on the amount of fuel debris sampled.



※ Letters underlined in red indicate analysis agency characteristic

[Reference] Analysis method and acronym and summary

Analysis method acronym	Analysis method name	Analysis method summary
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy	A nebulized sample is introduced to a high temperature plasma to excite the atoms and ions, causing them to emit electromagnetic radiation at specific wavelengths that is used to identify the elements and perform qualitative analysis of those elements.
ICP-MS	Inductively Coupled Plasma Mass Spectrometry	A sample solution is nebulized and introduced into a high temperature plasma, thereby ionizing the elements in the sample. The ions are brought into a mass spectrometer, where they are separated by their mass-to-charge ratio (m/z) and measured by a detector thereby enabling measurement of the concentration of the elements and isotopes.
TIMS	Thermal Ionization Mass Spectrometry	A chemically purified liquid sample is placed on a metal filament which is then heated to evaporate the solvent thereby ionizing the atoms. The number of ions is measured by measuring the mass-to-charge ratio (m/z) through mass analysis thereby enabling measurement of the concentration of the elements and isotopes
SEM	Scanning Electron Microscope	A device used to observe the surface of the sample by scanning it with electron beams. Analysis of the elements contained in the sample is possible when used in conjunction with an X-ray analysis device.
EDX	Energy-Dispersive X-ray Spectroscopy	An electron beam excites a sample causing it to releasing energy as unique X-rays. The energy and intensity of the unique X-rays are measured to determine the material's elemental composition
WDX	Wavelength-Dispersive X-ray Spectroscopy	An electron beam excites a sample causing it to releasing energy as unique X-rays. The material's elemental composition can be determined by spectroscopy of the unique X-ray’s wavelength.
TEM	Transmission Electron Microscope	A beam of electrons is passed through a thin specimen and a highly magnified image is formed by the interaction of the electrons with the sample. Analysis of the elements contained in the sample is possible when used in conjunction with an X-ray analysis device. The crystalline structure can also be obtained from the diffraction image
SIMS	Secondary Ion Mass Spectrometry	A focused beam of ions applied to the sample's surface generates secondary ion particles after which a mass spectrometer us used to measure the mass-to-charge ratio of these secondary particles to measure the concentration of the elements and isotopes contained in the sample.
Raman spectroscopy	Micro Raman spectroscopy	Light is focused on the surface of a specimen and the Raman scattering is measured through spectroscopy to identify physical attributes such as the molecular composition, temperature, stress, electrical attributes, and orientation/crystalline structure, etc. By combining conventional optical microscopes with Raman spectroscopy, information pertaining to the chemical form on a micrometer level can be obtained.
X-ray CT	X-ray Computed Tomography	A sample is irradiated with X-rays and the intensity of the X-rays that pass through it is analyzed by computer to produce a three-dimensional scan thereby providing information on the internal density distribution of the sample. Differing density phase distributions can be obtained.