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Crud specimens were intensively analyzed using Shielded-EPMA

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1. Introduction

Crud (Chalk River Unidentified Deposit), radioactive corrosion products formed inside nuclear reactors, is a major problem in commercial power-producing nuclear reactors. It can be transported onto the reactor core by cooling water, where it can be deposits on the outside of the fuel pins to form crud. If these radioactive deposited break loose and circulate through a plant, they can cause safety hazards for plant workers [1][2].

Nuclear reactor water chemistry has evolved during the last decades with the introduction of new processes such as Zn injection, higher pH operation, and use of EBA (enriched boric acid) [3]. Adding zinc to the reactor coolant system of a PWR is performed to reduce ex-core radiation fields and to mitigate primary stress corrosion cracking (PWSCC).

Crud specimens, which were scraped from twice-burned fuel cladding in a Korean PWR, were intensively analyzed using Shielded-EPMA.

2. Samples and Results

2.1 Samples

A crud scraper is a tool that samples crud using a suction pump and filter. It is used by scrapping the crud adhered to a fuel rod with scraper and is made of Al_2O_3. The scraper of the blade type is used to scrape crud from the fuel rod, and the separated crud is transported by a Peristaltic suction pump with a capacity of 0.3hp through a hole at the bottom space, and collected at a filter with a pore size of 8 ㎛. The scraper structure is as shown in Figure 1. In addition, scrapers of Φ 9.5 ~ Φ 10.0mm were made with each of Al_2O_3 material and aluminum material, and their scarping efficiencies were measured, As a result, the Al_2O_3 scraper Φ 9.6 in size was found to have the best scraping efficiency, and this scraper was applied to the Ulchin 1 crud sampling campaign.

To prepare the EPMA and SEM specimens, the area found by HIROX was cut by scissors, attached to carbon tape with good adhesion, and deposited using a carbon evaporator.

2.2 Results

Crud flakes were scraped from the twice-burned fuel cladding in a Korean PWR. The specimen was prepared by cutting a filter with scissors after identifying each area of the filter by HIROX to identify the presence of the specimen.

As shown in Fig. 2. crud was shaped as W/L/t ≒ 50/120/12 ㎛, and the boiling chimney hole size was observed to be: ≒ 6 ㎛. As for the surface shape of the area contacting the coolant, crud materials dissolved in the coolant were shown to be deposited in a precipitated form. Precipitation growth is made as very small particles gradually grow, rather than being deposited as a big flake. Other crud flakes are considered to be crud in areas that have contacted the cladding as the surface is flat as it contacts the cladding, and the boiling chimney hole is not clear. As for the shape of this mass, precipitations that reached a relatively consistent size were observed. In the x-ray map analyzed by WDS of this mass, the upper part of the mass has more deposits than the lower part, and iron shows a relatively even distribution, while O is higher at the upper part than at the lower.

As shown in figure 3 for the shape of this mass precipitations that reached a relatively consistent size were observed. While the x-ray map of iron and nickel analyzed by WDS of this mass shows a generally even distribution, and distribution of oxygen concentration does not shown.

The results of quantitative analysis of analysis range at 5,000X, 8,000X and 10,000X magnifications are shown in table 00. In the results of the analysis, the ratio was Fe/Ni/O = 39/57/2.5. This shows a great difference from the composition ratio of $NiFe_2O_4$, the representative composition of crud, and the analysis confirmed the presence of crud which is not and oxide.

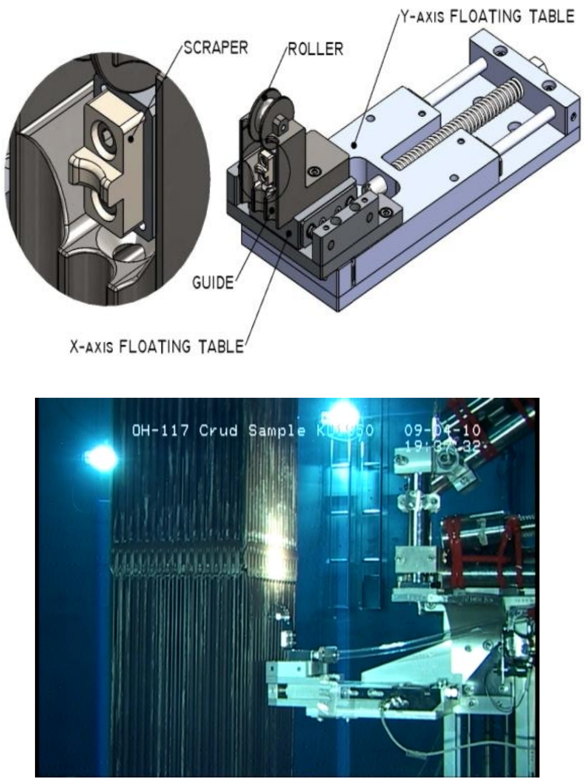


Fig.1. Crud scraping system.

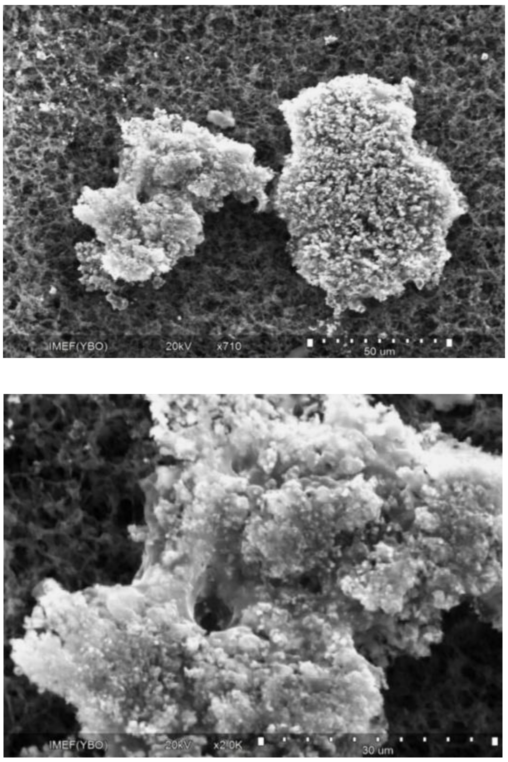
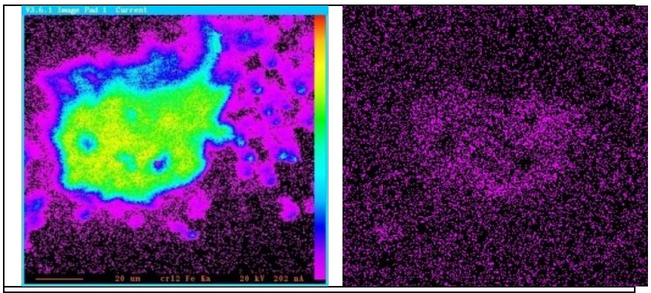


Fig.2. SEM of crud flake and boiling chimney hole.



	Fe	Ni	Zn	Cr	O
wt %	21.32	32.94	0.3	0.78	0.32
At %	39.21	57.25	0.20	0.83	2.51

Fig.3. Chemical composition and X-ray map of Fe Ka, O Ka on the crud flake

3. Conclusion

Fuel crud scraped from the twice-burned fuel cladding in Korean PWRs by EPMA. Crud was shaped as W/L/t ≒ 50/120/12 ㎛ and the crud flake thickness was observed to be ≒ 4~25 ㎛, We also observed the boiling chimney hole size as ≒ 4~6 ㎛. A predominance of nickel-rich needle-like crystals was not observed at Ulchin unit 1.

Crud with a high fraction of nickel-rich needles has been measured in other cores that have experienced AOA. These deposits contained needles of Bonaccordite (Ni_2FeBO_3) in two cores, as well as nickel oxide needles.

Zinc was not detected in the crud by ICP. However, WDS indicated Zn levels ranging from 0.1~to 0.8 at%(oxygen not included) by EPMA.

In addition, the ICP-Ms analysis gave an overall zinc content of 5.3%. However, the in case of Ulchin unit 1 after cycle 17 was twice burned, it was impossible to find any zinc content by ICP-AES. It is difficult to compare the zinc content from other EPRI-sponsored campaigns.

References

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