The Analysis for Corrosion Products in Primary Circuit Structures to Increase FSD (Full System Decontamination) Efficiency

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1. Introduction

During the operation of nuclear power plant, lots of corrosion products are produced in primary circuit structures, especially, inner surface of reactor pressure vessel and head, inside wall of steam generator tube, and primary piping, etc. They are usually activated products and fuel clad corrosion ones (CRUD. Chalk River Unidentified Deposits). Some are ionic, some are particle and others are soluble. Therefore, to increase primary circuit full system decontamination efficiency, the exact analysis for corrosion products are necessary and to find out the best way to remove them efficiently.

In this paper, various sources of corrosion products in the primary coolant are explained with formation mechanism and deposition behavior.

2. Analysis for Corrosion Product Source

2.1 Activated Producst

Activated O^{16} included in primary coolant is changed to N^{16} through the (n,p) reaction, which emits high energy γ-rays of 6.1 MeV and 7.1 MeV. So, it becomes the main radioactive source with the short half-life of 7 seconds. Ar^{41} which also emits γ-ray is produced with the reaction of neutron capture (n,γ) by Ar^{40} soluble in primary coolant. Ag^{110m} released from the position of fuel clad crack is the important radioactive source in steam generator, especially, deposited nearby the inlet nozzle. Sb^{124} is also the important source in the reactor coolant pump and it is produced caused by the corrosion of neutron source clad which includes Sb-Be.

2.2 Fuel Clad Corrosion Products (CRUD)

CRUD, Ni-Fe series corrosion product, is deposited on the surface of high temperature fuel clad. Its thermal conductivity is lower than the one of zirconium clad and it includes Lithium and Boron. Even though the stream of porosity in CRUD is slow, it helps to develop the nickel ferrite oxidization ($NiFe^2O^4$).

Usually, in pressurized water reactor, the CRUD thickness is about 100 um, Fig. 1 depicts the SEM for CRUD formation in reactor pressure vessel and Fig. 2 for CRUD cross section image.

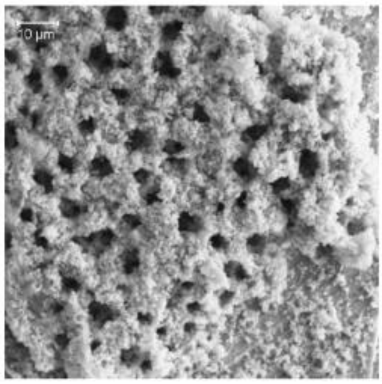

Fig. 1. CRUD Formation [1].

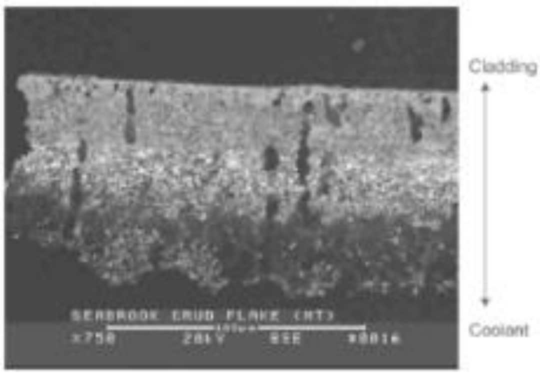

Fig. 2. CRUD Formation (Cross Section) [1].

As the CRUD formation is proceeded continuously, the inner corrosion of clad is increased and eventually, damaged clad will be incurred (CILC. CRUD Induced Localized Corrosion).

2.3 Activities in Corrosion Products

Corrosion and erosion are the main mechanisms to produce the corrosion products. They are transported as being soluble in coolant, the type of colloid or particle and deposited on the surface of oxidized layer in structures and finally activated. It is easier for particles to be deposited on the area of low fluid velocity or horizontality [4]. They will become the major radioactive sources around the lower part of reactor pressure vessel and on the steam generator tubes.

In case of PWR nuclear power plant, long half-life nuclides – Cr^{51}, Co^{58} and Co^{60} – which are included in corrosion products caused by activation of stainless steel structures are the main radioactive sources. Among the isotopes of Cobalt, Co^{58} is produced by the activation of Ni^{58} which are produced in Ni alloy or steam generator tubes. Co^{59} is produced from Co^{58} and Co^{60} is produced from Co^{59} with the reaction of neutron capture.

Table 1 describes the results of measured specific activity for each nuclide for the condition of normal operation and shutdown with proceeding oxidation. In case of normal operation, the main nuclides are Co^{58} and Co^{60}, however, after shutdown, Co^{58} is the main one and Sb^{124} and Ab^{110m} are the minor radioactive sources with decreasing nuclide of Co^{60}.

Table 1. Measured Specific Activity in Primary Circuit [3]

Specific Activity	Co^{58}	Co^{60}	Sb^{124}	Ag^{110m}
Normal (MBq/t)	10~100	1~10	-	-
Shutdown (MBq/t)	100,000	3,000	10,000	2,000

3. Conclusion

The main radioactive sources inside structures in primary circuit are Cobalt series nuclides of corrosion products with about scores of um thickness which emit γ-rays. CRUD is deposited on the surface of clad and it is composed of Ni-Fe based material. To perform full system decontamination efficiently, analysis for corrosion product producing mechanism is very important, because various kinds of corrosion products are deposited on the surface of complex structures with various thicknesses. And it is necessary to make optimized decontamination process, design facilities and prepare reagents to remove them and to increase decontamination factor up to the target based on the corrosion product analysis.

Acknowledgement

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REFERENCES

[1] J. Deshon et al., "Pressurized Water Reactor Fuel Crud and Corrosion Modeling", Journal of Materials, 63(8), 64-72 (2010).

[2] IAEA, Modeling of Transport of Radioactive Substances in the Primary Circuit of Water-Cooled Reactors, IAEA TECDOC-1672, 2012.

[3] H. Provens, Primary Circuit Contamination in Nuclear Power Plants: Contribution to Occupational Exposure

[4] M. Vepsalainen, Deposit Formation in PWR Steam Generators, VTT-R-00135-10, VTT Technical Research Centre of Finland, 2010.