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Characteristics of Cruds Deposited on the Spent Fuel Rods of Youngkwang-Unit 1

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1. Introduction

Crud deposited onto the fuel elements in nuclear power plants was not a big problem until an upper core flux depression was developed at Callaway, USA in 1989.[1] The unexpected flux depression was named as an Axial Offset Anomaly(AOA). Though the mechanism of an AOA is not completely understood, crud is believed to be a key component of it.[2,3] After the corrosion products in the reactor cooling system are deposited onto the fuel clad by a sub-cooled nucleate boiling at the clad surface, boron is adsorbed in the crud.[4] Then a measurable reduction in the neutron flux occurs to cause an AOA problem.

To reduce the AOA phenomena, ultrasonic fuel cleaning technology has been applied to reloading fuels in US[5] and it is scheduled to be applied to the reloading fuels of Gori Unit-3 at the end of this year. However, to minimize the crud deposited onto the fuel assembly, the characteristics of the crud should be known so as to apply adequate primary water chemistry as well as a shut down chemistry. This work was carried out to measure the elemental compositions and particle size distribution of the crud. All the experiments were performed in the Post Irradiation Examination Facility (PIEF) and the Irradiation Material Examination Facility (IMEF) at KAERI.

2. Experimental and Results

Crud samples were taken from two spent fuel rods of Youngkwang Unit-1 cycle 14. Fuel rods were transferred to KAERI for the burn-up measurements. Total burn-ups were 40,531 GWd/tU and 50,111 GWd/tU for the P09-B17 and O59-L14 fuel rod, respectively. Scotch tape and steel knife were used to collect the cruds from the fuel rods.

For the P09-B17 fuel rod, samples were taken with scotch tapes at 3,000mm and 400mm from the bottom of the fuel rod. Cruds taken at 3,000mm(up) produced well crystallized particles while those taken at 400mm(down) produced non-crystalline particles. It indicates that the upper part of the fuel assembly provides a better condition to form a crud deposit due to its higher temperature.

Particle size information is necessary to select an adequate pore size of the filter to collect the cruds released from the fuel assembly by an ultrasonic operation. Thus, a size distribution measurement was carried out with well crystallized samples. Fig. 1 shows the size distribution of the crud particles taken at 3,000mm of the P09B17 fuel rod.

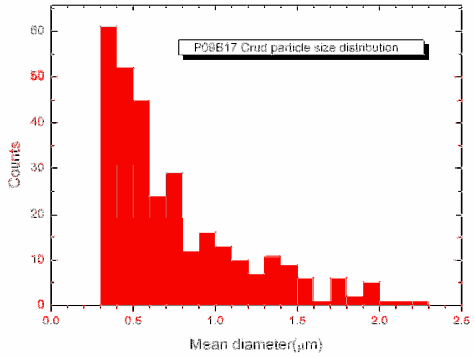

Fig. 1. Particle size distribution of crud sample taken at 3,000 mm of P09B17 fuel rod.

Even though fine particles smaller than 0.5μm were abundant, the total weight was less than 5%. It indicates that more than 95wt% crud particles can be collected by using a 0.5μm filter system. Pore size of the filter affects both the collecting efficiency of the crud and the filtering time. If a smaller pore size of the filter is used, more cruds are able to be removed but the filtering time is increased due to the slow flow rate. By increasing the pore size of the filter, the filtering time is shorten but less crud is collected.

Composition analyses were carried out by using Scanning Electron Microscope-Energy Disperse X-ray Analysis, Electron Probe for Micro Analyzer, and ICP-AES. Fe, Ni, and Cr were found as the main elements in the crud but boron was not found in any of the crud samples. The composition of Fe and Ni in the crud particles varied from particle to particle. In most particles Ni was found more than Fe.

Zn is often added to the reactor coolant for dose rate control or crack mitigation in the US and Europe. In

Korea Zn addition method was not applied to the nuclear power plants. However, Zn was detected by three different analytical methods for fuel rods discharged from Youngkwang Unit-1. By the EPMA measurement, Zn was found as ZnO or $ZnFe_2O_4$. Through the AOA research carried out by Korea Nuclear Fuel Co., Ltd., Youngkwang Units suffered less from the AOA problem while Kori Unit-3 and Uljin Unit 1 and 2 suffered more from it. It is not known how Zn was introduced into the crud samples but Zn might mitigate the AOA in Youngkwang NPPs.

To understand the different behavior of the Youngkwang Unit-1 plant from the Kori and Uljin plants, coolant samples as well as crud samples from other plants have to be taken and analyzed.

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