Development of Experimental Method to Simulate the Corrosion Products in the Primary System of Nuclear Power Plant

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1. Introduction

Corrosion products are recognized as one of the major sources of occupational radiation exposure for nuclear power plant workers [1]. Also, deposited corrosion products (crud) on the surface of fuel cladding result in axial offset anomaly (AOA) [2]. Numerous studies have been conducted on the primary water chemistry to reduce the amount of crud in the primary circuit to avoid the radioactivity build-up in the plant. However, experiments with crud are restricted in laboratory because the crud is highly radioactive material. The objective of this study is to develop the test method for simulating the deposition of corrosion product in nuclear power plant.

2. Tests and Results

2.1 Simulation of corrosion products in high temperature water by using tube test section

High temperature – high pressure apparatus was developed to simulate nickel ferrite corrosion products which were main compositions of the radioactive crud in the nuclear power plant. Corrosion product similar to the crud was obtained by a tube accumulator system. Nickel alloy and carbon steel were corroded at 270℃ in the corrosion product generator. Ni ions and Fe ions dissolved by corrosion reaction were able to be transported to the accumulator through a stainless steel pipe because the crud generation mechanism was the solubility change with temperature. Figure 1 shows the schematic diagram of tube accumulator system. Stainless steel tube was installed replacing autoclave accumulator for a repetitive test.

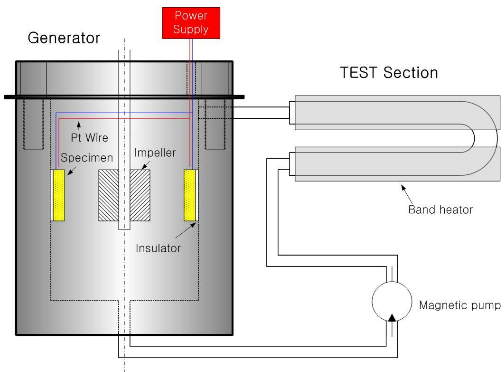

Figure 1. Schematic diagram of high temperature – high pressure crud generator.

To evaluate the properties of simulated corrosion products, scanning electron microscopy and EDAX analysis were performed. The electron microscopy of corrosion product showed the needlelike or crystal structure of oxide depending on precipitating location. The Fe: Ni: Cr atomic ratio of crystal oxide shown in figure 2 was 61.29: 10.88: 17.55. Average bulk formula of crystal oxide was $Ni_{0.53}Fe_{2.47}O_4$, and it was similar to the crud on nuclear fuel cladding [3].

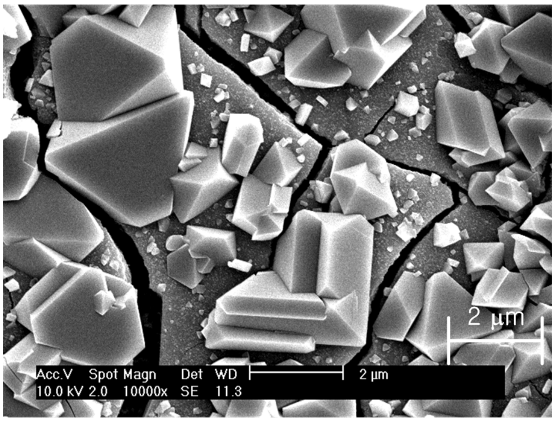

Figure 2. SEM image of corrosion products that have been generated at $pH_{300℃}$ 6.9 solution using the crud generator.

2.2 Simulation of sub-cooled nucleate boiling on the surface of nuclear fuel cladding (on going process)

The cause of AOA is not exactly determined, but it believed to contribute to AOA that deposition of impurities in the coolant on the surface of the fuel cladding. Sub-cooled nucleate boiling occurs at the cladding surface in central areas of core, and this SNB phenomena is considered to better enable the deposition of impurities on the surface of the cladding [4].

To replicate the condition in the primary coolant of a PWR, and the typical heat flux of the cladding, we are manufacturing the wire heating test facility as shown in figure 3.

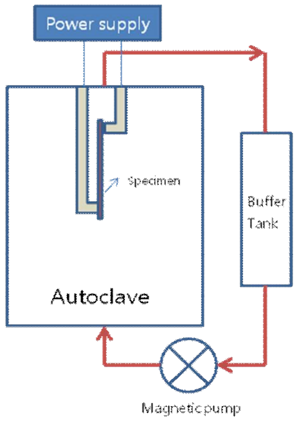

Figure 3. Schematic diagram of wire heating test facility.

There are two electrodes that hold the Zircaloy wire specimen and apply a high current to maintain the surface heat flux on the wire surface. Test parameters are heat flux, temperature, pH, Fe/Ni chemical composition, and flow rate. After the test, we will analyze the deposited corrosion products on the specimen surface to determine microstructure, chemical composition, deposition rate and porosity of crud layer.

3. Summary

High temperature – high pressure apparatus was developed to simulate nickel ferrite corrosion product. Average bulk formula of corrosion product was $Ni_{0.53}Fe_{2.47}O_4$ and it was similar to the crud on nuclear fuel cladding.

We are developing the wire heating test facility to simulate the sub-cooled nucleate boiling. By using this facility, we will determine the crud deposition mechanism and develop the modified primary water chemistry condition.

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