Evaluation of Specific Activity in the Primary Circuit of SMART-P

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1. Introduction

SMART-P is a soluble boron free reactor, and the ammonia is used as a pH reagent. The titanium alloy, which has a high corrosion resistance, is chosen as a steam generator tube material. Despite these design features to achieve the corrosion reduction, it is expected that SMART-P exhibits a relatively high specific activity in the coolant due to the lack of purification during the power operation.[1,2,3] The main reason for the high specific activity is the activation and transportation of the corrosion products that released from the primary circuit surfaces.

The objective of this work is to analyze the corrosion product activity in the primary circuit of SMART-P using a multi-region model, KORA. This model, which is incorporated with the mass and activity transport between the dissolved corrosion products in the coolant and the surface, describes the specific activity of corrosion products in coolant and on the surfaces according to the operation modes.

2. Multi-Region Model

The KORA program is an engineering tool for analysis of corrosion products activity in primary circuits of the nuclear power plants and it is initially developed by OKBM in Russia. This model is aimed at evaluation the corrosion products concentrations in coolant and on the surface of major equipments in the reactor coolant system. This model includes the mass transfer between the various locations of the plant and also accounts for reactor plant operation modes.[4]

The primary circuit is divided into nine control volumes. Between the control volume and its associated surfaces, the radioactive nuclei are transported by the sedimentation, washing-out, and release of corrosion products. The coolant between the control volumes transports the nuclei, too. Dividing the primary circuit into several regions needs more differential equations to be solved and takes a longer computation time.

During the normal operation, it is assumed that the mass transfer constants are equal for the active and inert corrosion products and that the concentrations of the parent nuclides and activation products in the reactor coolant are in equilibrium. The concentrations are calculated under the consideration of the production rate and removal rate. The parent nuclides are produced by the corrosion of surface materials consisting of primary circuit and are transported by coolant into reactor core region. The parent nuclides are removed by neutron induced activation in reactor core region, by deposition on surface of primary circuit equipments.[4]

3. Results and Discussion

The behavior of the various radioactive corrosion products is simulated for SMART-P. The calculation was done for the one fuel cycle of 15,000 hours but the release of the corrosion products into water was calculated for the time of the metal exposure in water of 24,000 hours. The calculated specific activities of the various species on the surface of core and steam

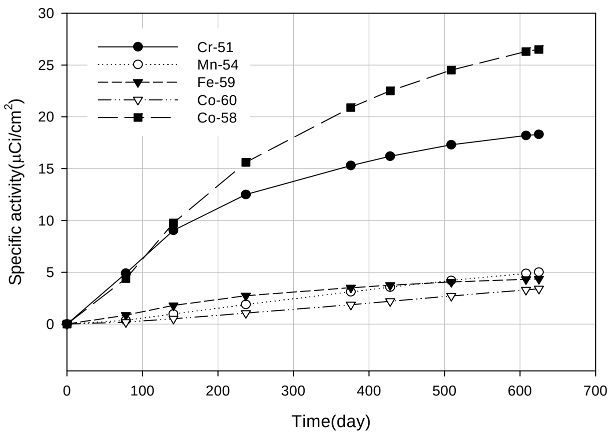

Figure 1. Behavior of specific activity according to time (day) in core surface

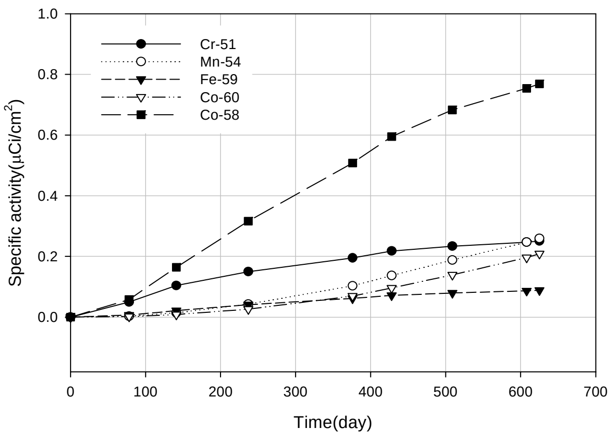

Figure 2. Behavior of specific activity according to time (day) in steam generator surface

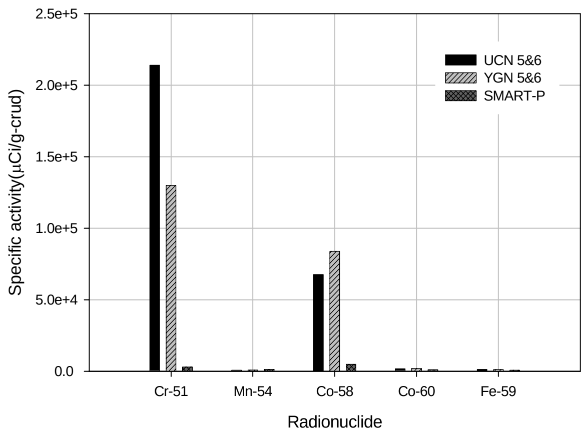

Figure 3. Comparison of crud specific activity between SMART-P, YGN 5&6 and UCN 5&6

generator during the effective full power hours, 15,000 hours, are shown in **Figure 1** and **Figure 2**, respectively. On the reactor core surface, the final specific activities of Cr-51, Mn-54, Fe-59, Co-60 and Co-58 are estimated to be 18.3, 5.01, 4.36, 3.41 and 26.5 $\mu Ci/cm^2$, respectively. On the steam generator surface, the final specific activities are also estimated to be 0.251, 0.259, 0.0882, 0.209 and 0.769 $\mu Ci/cm^2$, respectively. It means that the greater part of the generated corrosion product in the reactor is deposited on core surface.

These values are less than that of KSNP such as Yonggwang Units 5&6, Ulchin Units 5&6 as shown **Figure 3**. These values of these power plants are given in final safety analyst report of the Yonggwang Units 5&6 and Ulchin Units 5&6, respectively.

In **Figure 3**, the biggest difference is shown at Cr-51 and Co-58. The specific activities of Cr-51 of Yonggwang Units 5&6 and Ulchin Units 5&6 are about 2.2×10^5 μCi/g and 1.35×10^5 μCi/g. In SMART-P, it is estimated 4.05×10^3 μCi/g, which is 1/50, 1/30 less than that of Yonggwang Units 5&6 and Ulchin Units 5&6, respectively. In case of Co-58, specific activities in KSNP are 8.38×10^4 μCi/g, 6.76×10^4 μCi/g, respectively. These are 13 and 10 greater than that of SMART-P as 6.39×10^3 μCi/g. The higher values of specific activities of Cr-51 and Co-58 in KSNP as shown **Figure 3** are due to the higher release rate of inconel, which has the high nickel and chromium content. The specific activities of others are shown similarly, but that of SMART-P is the lowest value.

Above the result is explained to the difference of structural materials and the water chemistry between SMART-P and KSPN. In SMART-P, the titanium alloy is applied to the steam generator tube material which is known as a weight gain material while inconel used in KSNP as weight loss material. It is means that a layer of protective titanium oxide formed on the surface would increase to disturb the diffusion of the oxygen ion through the oxide layer, giving a decrease of corrosion rate as the corrosion reaction proceeded.

The water chemistry in KSNP is the H_3BO_3-LiOH chemistry. The lithium hydroxide alkali, which is injected for a reaction control in the primary coolant circuit of KSNP to compensate for the acid properties of boric acid, brings about the stress corrosion cracking of steam generator tube and the corrosion of zirconium alloy for a fuel cladding. Furthermore in SMART-P, hydrogen, which is used to remove the dissolved oxygen in the coolant, is not added to the primary coolant. The hydrogen concentration is maintained by ammonia dosing in the primary coolant where hydrogen and nitrogen are generated by an ammonia subsequent radiolytical and thermal decomposition.[2,3,5,6]

4. Conclusion

In order to evaluate the analysis of corrosion products in SMART-P, a multi-region mass balance model is applied. The specific activities of the various species on the surface of core and steam generator throughout the effective full power hours, 15,000 hours, are simulated for SMART-P.

As a result, the specific activities of corrosion products SMART-P showed very low compared to those of KSNP such as Yonggwang Units 5&6, Ulchin Units 5&6. In SMART-P, a significant reduction of specific activities from the activated corrosion products is obtained due to the introduction of the titanium alloy to the steam generator tube and the avoidance of boric acid induced corrosion. From this result we conclude that the design features of SMART-P can prevent and reduce the generation of corrosion products in the primary circuit.

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