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Decontamination Performance of Foam Decontaminating Agent

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1. Introduction

Radioactive corrosion oxides in pressurized light water reactors consist of an inner layer formed of crystals of Fe, Ni, and Cr ions formed through the oxidation of a metal element at the interface between the oxide film and metal, and an outer layer formed by being diffused to the boundary between the coolant and oxide film through the pores of the oxide film and precipitated. Because the Cr^{3+} component present in the inner layer of the corrosion oxide film has insoluble characteristics, an oxidizing agent has to be added to oxidize into soluble Cr^{6+} [1].

Four types of chemical decontaminating agents were prepared by varying the concentrations of cerium (IV) and nitric acid, which are the main components of an oxidizing chemical decontamination agent. The decontamination performance of three types of foam decontaminating agents prepared by mixing the foaming agents selected through a preliminary test with each of the chemical decontaminating agents was investigated [2]. The weight loss and SEM & EDX of the $FeCr_2O_4$ oxide specimen were measured before and after decontamination. The decontamination behaviors of these foam decontaminating agents were compared with those of chemical decontaminating agents.

Using the composition of the most effective foam decontaminating agent obtained from the foam decontamination experiment with the simulated oxidation test specimen, a radioactive demonstration test of foam decontamination was performed on the SG plug drawn from the nuclear power plant site.

2. Methods and Results

2.1 Experimental Methods

304 stainless steel specimens (20 mm x 20 mm x 2 mm) were prepared through corrosion for 7 days at 230 °C using 0.05M Na_2H_4 • EDTA and 5 ppm N_2H_4 • H_2O in an autoclave (SUS-316, capacity: 4.5 L, temperature deviation within ± 1 °C). The dissolved oxygen concentration was controlled to 800 ppb by N_2 gas.

Four kinds of foam decontaminating agents were prepared, as shown in Table 1, by fixing the composition of the foaming agent ((1% (v / v) TBS + 1 wt.% M-5 silica)) and varying the concentrations of nitric acid and cerium (IV), which are chemical decontamination agents. To compare the decontamination behavior, a chemical solution decontaminating agent with a composition of 2M HNO_3 / 0.5M Ce (IV) was prepared. 75 mL of four kinds of chemical decontaminating solutions were prepared by mixing appropriate amounts of chemicals in accordance with the concentrations of Ce (IV) and HNO_3. The weight loss of the specimens was measured every 2 h after decontamination. SEM (SNE-4000M, Korea) and EDX (BRUKER, XFLASH DETECTOR, 410-M, Germany) were measured before and after the decontamination experiment).

The specimens used in the radioactive demonstration test of foam decontamination were SG plugs (each 10 cm × 2 cm size) of I-690 material drawn from the Kori Nuclear Power Plant 2. Co-60, Co-58, Mn-54, and Fe-55 were the main radionuclides detected in this specimen. The initial surface dose of specimen for KAERI formulation foam test was 48 μSv/h. The composition of the foaming agent and the chemical decontamination agent used in the radioactive demonstration test were 1%(v/v)TBS / 1wt.% M-5 silica and 2M HNO_3 / 0.5M Ce (IV), respectively. MCA (CANBERRA Model GC1518 / AMOLIFIER 2025) was used to measure the radioactive decontamination behavior. The concentration of radionuclides by MCA was measured for about 10 minutes.

Table 1. Types of chemical decontaminating agents

	Composition of foaming agent	Composition of decontamination chemicals
Solution decon.		2M HNO_3 & 0.5M Ce (Ⅳ)
Foam-1	1%(v/v) TBS & 1wt.% silica	2M HNO_3 & 0.5M Ce (Ⅳ)
Foam-2	1%(v/v) TBS & 1wt.% silica	1M HNO_3 & 0.5M Ce (Ⅳ)
Foam-3	1%(v/v) TBS & 1wt.% silica	2M HNO_3 & 0.2M Ce (Ⅳ)
Foam-4	1%(v/v) TBS & 1wt.% silica	1M HNO_3 & 0.2M Ce (Ⅳ)

2.2 Results & Discussion

From the results of the weight loss analysis of the sample according to the decontamination time shown in

Fig. 1, it can be explained that the Ce (IV) concentration rather than the HNO_3 concentration has a large effect on the foam decontamination behavior and that a Ce (IV) concentration of 0.5 M or more is required.

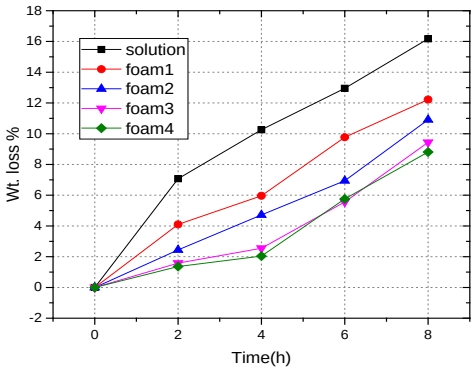

Fig. 1. Weight loss % for the $FeCr_2O_4$ specimen in the solution decontaminating agent and foam decontaminating agents.

Comparing the decontamination behaviors of foam decontamination and solution decontamination using the same chemical decontaminating agent for 8 h decontamination based on the weight loss, the removal rate of the foam decontamination method (Foam-1) is about 75.6% of the solution decontamination method, showing a relatively effective decontamination performance. This decontamination behavior can be clearly confirmed from a photograph of the surface of the specimen .

From the SEM photographs and EDX results before and after the decontamination, both the solution decontamination test specimen and the foam decontamination test specimen showed that after 8 h of decontamination all of the oxide films were removed and a corrosion of the base metal started. This is confirmed from the fact that the EDX results after 8 h for all decontamination specimens are almost identical to the EDX results for the SUS 304 metal materials, irrespective of the type of specimen.

The Co removal behavior of the KAERI foam decontaminating agent over time for the contaminated nuclear specimen was measured using MCA (Fig. 2).

The Co removal % of KAERI foam decontaminating agent appeared to be 50.3% during the first 2 h, and then 59.3% and 64.0% after 4 h and 6 h, respectively. It can be seen that about 80% of the total Co removed is removed during the initial 2 h.

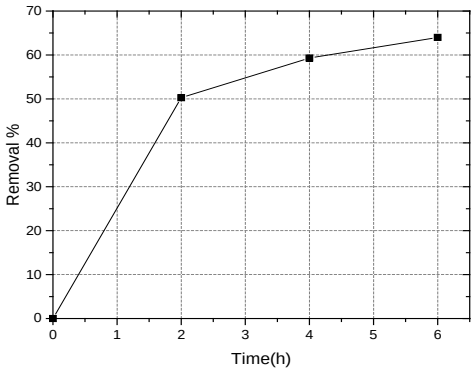

Fig. 2. Comparison of cobalt removal % of KAERI foam decontaminating agent**.**

3. Conclusions

It can be concluded that the Ce (IV) concentration rather than the HNO_3 concentration has a large effect on the foam decontamination behavior, and that a Ce (IV) concentration of 0.5 M or more is required.

Comparing the decontamination behaviors of foam decontamination and solution decontamination using the same chemical decontaminating agent for 8 h decontamination based on the weight loss, the removal rate of the foam decontamination method (Foam-1: 2M HNO_3 / 0.5M Ce (IV) in 1%(v/v) TBS + 1wt.% M-5 silica) is about 75.6% of the solution decontaminating method, showing a relatively effective decontamination performance.

The radioactive decontamination demonstration test performed on the SG plug drawn from the nuclear power plant site revealed that the Co removal % of KAERI foam decontaminating agent showed 50.3% during the first 2 h and then 59.3% and 64.0% after 4 h and 6 h, respectively.

ACKNOWLEDGEMENTS

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[2] C. H. Jung et al., “Dissolution of Chemical Decontaminating Agent for a Foam Decontamination”, Transactions of the Korean Nuclear Society Spring Meeting, May 18-19, 2017, Jeju(2017).