

Evaluation of Material Integrity by AP-OX Oxidation-Reduction Process Environments

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1. Introduction

Nuclear Utilities widely apply chemical decontamination process to remove deposited radioactivity and thereby lower exposure of plant personnel to ionizing radiation. In particular, operational decontamination is important not only to achieve the desired decontamination factor, but also to ensure the integrity of structural materials for future operation[1].

This experiment was conducted to evaluate the material integrity by AP-OX(Alkaline permanganate-Oxalic acid) oxidation-reduction process for the purpose of applying operational decontamination.

2. Experimental Methods

2.1 Experimental Apparatus

In this experiment, ‘Steam Generator Chemical Cleaning Demonstration Equipment (Fig. 1)’ created by KHNP-CRI was used.



Fig. 1. Experimental Apparatus.

2.2 Test Specimens

The main piping material of primary system is stainless steel cladding over carbon steel. The actual piping surface of the system will be covered with metal oxides. However, in this experiment, specimens were tested with bare metal for evaluation in the most aggressive environment.

The test specimens were as follows:

- Stainless steel : SS 304
- Carbon steel : SA 508, SA 516

Table 1. Chemical composition of specimens (from Material Certificate)

Materials	C	Mn	Ni	Cr	Mo	Si
SS 304	0.05	1.74	8.03	18.4	0.37	-
SA 508	0.19	1.35	0.83	0.13	0.49	0.2
SA 516	0.21	1.04	0.07	0.06	0.02	0.19

2.3 Experimental Conditions

In this experiment, the AP-OX process was applied for 1 cycle as shown below.

2.3.1 Oxidation step (AP process).

- Conc. : 1,000 ppm KMnO_4 + 100 ppm NaOH
- Temp. : $95 \pm 2^\circ\text{C}$
- Holding Time : 6 hours

2.3.2 Reduction step (OX process).

- Conc. : 2,000 ppm Oxalic acid
- Temp. : $95 \pm 2^\circ\text{C}$
- Holding Time : 4 hours

2.4 Evaluation Methods

2.4.1 Surface Analysis.

Before and after the

experiment, the surfaces of the specimens were observed using Videoscope and SEM.

2.4.2 Calculation of Corrosion Rate. The weights of the specimens were measured before and after the experiment. Then, each corrosion rate was calculated according to the following equation.

$$C. R = \frac{1,550 \times W}{D \times A \times T} \quad (1)$$







C. R : corrosion rate($\mu\text{m/hr}$), W: mass loss(g),
D : specimen density(g/cm^3), A : surface area(in^2),
T : exposure time(hr)

3. Results and Discussion

3.1 Surface Analysis

In the case of the stainless steel(SS 304) specimens, no corrosion pattern was found. The carbon steel(SA 508, SA 516) specimens were uniformly eroded.

Table 2. Surfaces of specimens before and after experiment

SS 304		SA 508		SA 516	
					
before	after	before	after	before	after

3.2 Corrosion Rate

The corrosion rates calculated according to the above equation was as follows.

Table 3. Corrosion rate

Materials	SS 304	SA 508	SA 516
C. R ($\mu\text{m/hr}$)	< 0.01	0.27	0.27

3.3 Others

During the experiment, dark brown precipitate was formed in large quantities immediately after the injection of oxalic acid. The precipitate was excessively injected and the residual permanganate reacted with oxalic acid to form manganese dioxide($\text{MnO}_{2(s)}$). It was deposited on the bottom of the reactor and adhered to the specimen surface(Fig. 2, left). Further observation using SEM, it is considered that the precipitate did not cause local corrosion(Fig. 2, right).

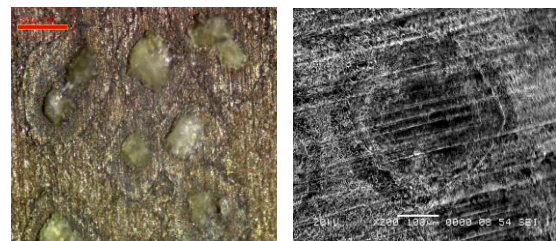


Fig. 2. Carbon Steel Surface. (Videoscope, x300(left) / SEM, x200(right)).

4. Conclusion

As a result of the corrosion test of AP-OX chemical decontamination process, stainless steel(SS 304) specimens showed almost no corrosion and carbon steel(SA 508, SA 516) specimens showed uniform general corrosion.

The piping material in contact with primary system water is stainless steel. Therefore, if this decontamination process is applied, the impact on the material corrosion will be very low.

And when the process is actually applied, it is necessary to review the injection concentration of the oxidizing and reducing agents to minimize the generation of $\text{MnO}_{2(s)}$ precipitates.

REFERENCES

- [1] EPRI, "Decontamination Handbook", TR-112352 (1999).