

# Corrosion Behavior of Structural Materials in The Closed Cooling Water System of a Nuclear Power Plant

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## 1. Introduction

The Closed Cooling Water (CCW) piping consists of carbon steel in many CCW systems. Carbon steel is subject to corrosion unless protected. CCW can have a falling-off in quality of the system by corrosion, microbial growth, fouling. To prevent corrosion, we must accurately evaluate influence of an inhibitor in CCW system. In the case of CCW of some domestic nuclear power plants, during overhaul period, saturation of ion exchange resin caused by an inhibitor which has high conductivity for an increase in radiation exposure and radioactive waste. In most cases, carbon steel corrosion control in CCW systems is achieved by adding corrosion inhibitor chemicals. In nuclear plants, these inhibitors have included chromates, nitrites, molybdates, hydrazine, and silicate.

The objective of this study is to evaluate the corrosion behavior of structural materials according to corrosion inhibitor.

## 2. Experimental Method

### 2.1 Materials and inhibitor

The test materials were carbon steel (SA106 Gr. B), Ti alloy (SB338 Gr.B) used to CCW pipe Material and carbon steel (SA516-70) used to shell side of heat exchanger [1]. Chemical compositions of test materials are shown in Table 1 and 2.

Table 1. Chemical compositions of Ti alloy (wt %)

Alloy	Ti	Al	Zr	V	Fe	O	H	N	C	Others
SB338 Gr.B	Bal.	-	-		≤0.30	≤0.25	≤0.015	≤0.03	≤0.10	≤0.4

Table 2. Chemical compositions of carbon steel (wt %)

Alloy	Mo	Ni	P	Si	Cr	S	Mn	C	Al	Cu	Nb	V
SA106 Gr. B	0.15	0.4	0.035	0.1	0.4	0.035	0.29/1.06	0.3	-	0.4	-	0.08
SA516-70	0.08	0.3	0.03	0.6	0.3	0.03	1.0/1.7	0.1/0.22	0.02	0.3	0.01	0.02

In order to analyze the corrosion behavior with environment, the Inhibitor used nitrite, hydrazine, polysilicate and molybdate [2]. Table 3 shows the detail of the test conditions.

Table 3. Water chemistry conditions

Inhibitor	Temperature	pH	Dissolved Oxygen
Nitrite (800ppm)	30, 60, 90	9.3±0.5	deaerated, air-saturated
Hydrazine (25ppm)	30, 60, 90	9.3±0.5	deaerated
Polysilicate	30, 60, 90	9.3±0.5	deaerated, air-saturated
Molybdate	30, 60, 90	9.3±0.5	deaerated, air-saturated

### 2.2 Immersion test

The specimen processes wire cutting from the base metal. It was polished by #2000 emery paper, and finally polished with 0.3 μm alumina pastes. The polished specimens have been washed in acetone at ultrasonic cleaning, and weighed on an electric balance with a sensitivity of within 0.1 mg. The total surface area measured with 256.28 mm<sup>2</sup>.

After the test we extracted specimens from the reaction cell and cleansed it in acetone which is used the in ultrasonic cleaning process. In order to measure the corrosion rate, we measured the weight of specimens on an electric balance with a sensitivity of within 0.1 mg. Also we took a photograph of specimens to observe the change of the surface feature each of specimen.

### 2.3 Potentiodynamic polarization test

The specimens was polished with #2000 emery paper, and finally polished by 0.3 μm alumina paste. The polished specimen was washed in the acetone at ultrasonic cleaning.

We used the commercial potentiostat system. That being, nitrogen gas purging for the removing dissolved oxygen were performed over 1 hour. Cathodic charging caught with -1000 mV during 10 min. Scan rate was 0.5 mV/s, and scan range was -1000~1000 mV. The sample area is 2.031 mm<sup>2</sup>.

After the test Was completed, in order to analyze the condition of the solution, we measured the pH of the aqueous solution after being cooled.

## 3. Results and Discussion

### 3.1 Immersion test

When there were corrosion inhibitors in the solution, weight of specimen had not changed after initially decrement of weight. However, the corrosion rate of the carbon steel in the de-mineralized water which has a high (~8 ppm) concentration of dissolved oxygen have been increased by increasing the contact time as shown in figure 1. Figure 2 shows the corroded surfaces of the test specimens.

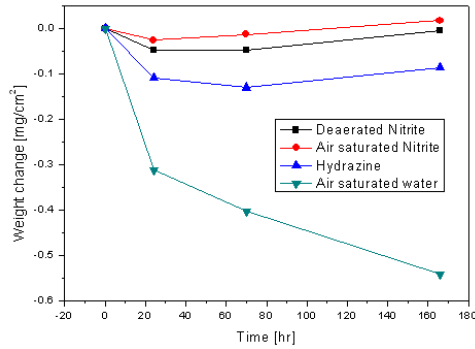


Figure 1. Weight change versus test time in various water chemistry conditions.

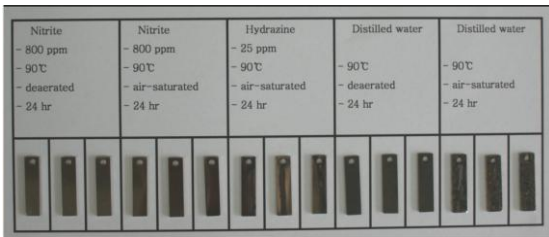


Figure 2. Photo of typical corroded surface after 1 day test.

### 3.2 Potentiodynamic polarization Test

The corrosion rate increases according to the oxidizing power, then decreases suddenly, and the corrosion rate does not change. When the electric potential difference of the solution happens with the destruction of the ostensible oxide film, again, the corrosion increased [3]. In the case of hydrazine, there is no passive region in the polarization curve. In the case of nitrite solution, however, there is distinct passive region after an active region. Therefore, nitrite maintained low current density in a higher oxidizing condition has better inhibitory property.

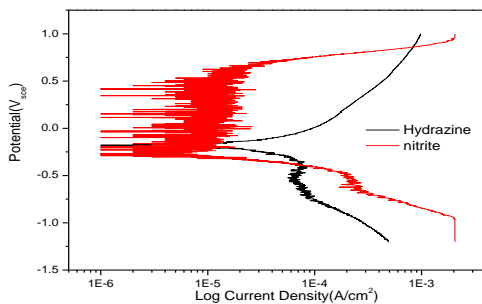


Figure 3. Polarization curves of SA106 Gr.B in 800 ppm sodium nitrite solution at 0 and in 25 ppm hydrazine solution at 90°C.

## 4. Summary

The immersion test and The potentiodynamic polarization test were performed to evaluate the effect of inhibitors on the corrosion of structural materials.

The immersion test determined that both nitrite and hydrazine are good corrosion inhibitors. However, the potentiodynamic polarization test found that the specimen in nitrite solution showed a lower current density than that in hydrazine.

To determine the effective CCW water chemistry condition, we are examining the corrosive properties of various materials with various corrosion inhibitors.

## Acknowledgment

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