Corrosion Resistibility of Chemical Inhibitors for Carbon Steels in the Closed Cooling Water System of Nuclear Power Plant

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1. Introduction

In the Nuclear Power Plant (NPP), the Closed Cooling Water (CCW) system provides cooling to both safety-related and non-safety-related heat exchange equipment [1]. In general, chemical treatment is used for minimizing corrosion, controlling microbiological growth, and preventing scale in the CCW system. In the NPP, these inhibitors have included chromate, nitrite, molybdate, hydrazine, and polysilicate. In some domestic NPPs in which nitrite inhibitor program was adapted, during overhaul period, saturation of ion exchange resin caused by corrosion inhibitor which has high conductivity is causative for increase in the radiation exposure and the radioactive waste. To prevent corrosion without any disadvantages, we must accurately evaluate influence of inhibitor in the CCW system.

The objective of this study is to evaluate the corrosion behavior of CCW materials with various corrosion inhibitors.

2. Experimental procedures

2.1 Materials and water chemistry conditions

Carbon steels and low alloy steels are widely used in the CCW systems of many industry plants. The test materials were SA106 Gr.B steel used to CCW pipe material and SA516-70 steel used to shell the side of heat exchanger. Chemical compositions of test materials are shown in Table 1.

Table 1. 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 evaluate the corrosion behaviors of test materials according to water chemistry conditions, the nitrite, hydrazine, polysilicate and molybdate were used as corrosion inhibitors. Table 2 and 3 show the detail test conditions. Corrosion resistibility of each inhibitor was analyzed with concentration test, and acceleration tests were performed at 90℃.

Table 2. Water chemistry conditions for concentration test

Inhibitor	Conc. [ppm]	Temp. [℃]	Time [hr]
Nitrite	*200, 400, 800, 1200*	*R.T.*	*168*
Hydrazine	*5, 25, 50, 100*		
Polysilicate	*10, 20, 40, 60*		
Molybdate	*200, 400, 600, 1000*		
None	-		

Table 3. Water chemistry conditions for acceleration test

Inhibitor	Conc. [ppm]	pH @ 25℃	Temp. [℃]
Nitrite	*800*	*9.3±0.5*	*90*
Hydrazine	*25*		
Distilled water	-	*neutral*	

2.2 Immersion test

The specimen processes wire cut from the base metal. Because the cleanliness of the surface presence of foreign matter can exert a very strong influence on the initiation and rate of corrosion [2], specimens were polished by #2000 emery paper, and finally polished with 0.3 ㎛ alumina pastes. The polished specimens were degreased into acetone with ultrasonic cleaning. The total surface area measured as 256.28 mm^2.

In order to measure the corrosion rate of test material, we measured the weight of specimens on an electric balance with a sensitivity of within 0.1 mg before and after the immersion test. Also photographs of specimens were taken to observe the change of the surface feature of the specimens.

3. Results and discussion

Normal operating range for nuclear power plant is 500~1500 ppm as NO_2^- to compensate for potential losses due to leaks, microbiological activity, or oxidation. In this study, 200 ppm nitrite was enough to inhibit corrosion of CCW materials because there was no loss of nitrite. When the chloride concentration is less than 3 x 10^{-4} M, chloride ion doesn't affect the corrosion resistibility of nitrite inhibitor [3]. So, maximum 1.0 ppm chloride concentration can be allowed in the nitrite program. However, Liquid Radwaste disposal System (LRS) of NPP gets heavy load due to high ion concentration of nitrite.

Since molybdate is less effective in deaerated solutions, it is not suitable for CCW of NPP, even though it shown similar inhibition property like nitrite inhibitor.

Concentration effect of silicate on corrosion rate of steel was unintelligible, because highly tenacious polymeric silicate was not easy to dissociate fully in this study.

Hydrazine might be an alternative corrosion inhibitor to nitrite for reduction of LRS load. In this study, more than 50 ppm hydrazine was needed to reduce the corrosion rate of carbon steel to satisfy the CCW operation guidelines. If hydrazine is continuously injected into the CCW system, the critical concentration of hydrazine will be lower. Protective layer of steel in hydrazine solution would be easily broken by chloride ion, thus the critical concentration of hydrazine for preventing corrosion of steel increased with increasing the concentration of chloride ion [4]. So, the maximum concentration of chloride ion would be limited under 150 ppb for the hydrazine program.

Table 4. Proposed water chemistry guidelines for CCW

Parameter	Limit	Remark
pH	9.0~10.0	
Chloride (max.), ppm	≤ 1.0	- for sodium nitrite
	≤ 0.15	- for hydrazine
Corrosion inhibitor	700~1000 as NO_2	- sodium nitrite / borate, ppm
	25~50 as N_2H_4	- hydrazine, ppm
Activity		< Detectable

4. Summary

The corrosion behaviors of CCW materials within various corrosion inhibitors were evaluated by immersion test. An alternative hydrazine water chemistry guideline to nitrite program was proposed for CCW in the nuclear power plant.

Acknowledgment

This work was supported by the Korea Hydro & Nuclear Power (KHNP).

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