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THE EFFECT OF HIGH ALPHA RADIATION ON THE CORROSION OF METALS EXPOSED TO CHLORIDE SOLUTIONS

R. D. Baybarz

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CHEMICAL TECHNOLOGY DIVISION

Chemical Development Section A

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R. D. Baybarz

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ABSTRACT

No direct effects of alpha radiation at a level of 2 watts/liter on corrosion of several alloys and glass were found. Secondary effects were noted for Hastelloys B and C and titanium 45A, these effects being attributed to the presence of H_2O_2 produced by radiolysis of water. Under some conditions the corrosion rates of Hastelloys B and C were increased and of titanium drastically decreased by the alpha radiation. Corrosion rates of glass and tantalum were <1 mpy under all conditions tested and of Zircaloy-2, <10 mpy.

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1.0 INTRODUCTION

Corrosion tests were made on various welded alloys exposed to chloride solutions containing high concentrations of Am-241 to determine the effect of alpha radiation, to be encountered in the Transuranium Facility, on corrosion rates. The tests were made with an alpha activity level of 2 watts/liter, but tentative plans are to make similar tests with Cm-242 at 20 watts/liter to determine the effect of both higher energy alpha particles and higher activity levels.

Previous tests (1) had indicated that Zircaloy-2, tantalum, and glass have acceptable corrosion rates, <1 mpy, under chloride concentrations and temperatures expected in the TRU facility, but in the absence of radiation. Hastelloy B had acceptable corrosion rates at low temperatures or for limited times at higher temperatures, while Hastelloy C rates were acceptable only at low temperatures (45°C). Rates for titanium 45A were acceptable only under oxidizing conditions.

The author gratefully acknowledges the helpful suggestions of J. C. Griess, W. E. Clark, J. L. English who also supplied the corrosion specimens, and to the laboratory work of J. T. Wiggins.

2.0 CORROSION DATA

Tantalum. Tantalum was exceptionally resistant to corrosion under all experimental conditions (Sect. 3.0), with corrosion rates in all cases of <1 mpy and in many cases a slight weight gain from oxide film formation.

Hydrogen embrittlement occurred in the tantalum wire used to hang a titanium specimen in the vapor phase over 6 M HCl at 105°C for 130 hr. The wire crumbled when touched. Bishop and Stern (2) found hydrogen embrittlement of tantalum in a few hours when exposed to HCl at 190°C but no embrittlement when the tantalum was coupled with platinum at an area ratio of 1,000/1. The corrosion rate of both metals was also decreased by the couple.

Hastelloy B and C. Both Hastelloy B and C were corroded more in the Am-241 solution than in the control (Table 1). A loose black oxide film formed on the coupon, more on Hastelloy C than on B, which was readily washed off and could plug small piping. English (1) obtained the same results in the absence of radiation with solutions to which 0.001 M H_2O_2 had been added, indicating that the radiation effects were secondary and produced by the H_2O_2 formed by radiolysis of water.

Titanium 45A. Titanium 45A showed excellent corrosion resistance to chloride solutions in the presence of the alpha radiation. The H_2O_2 produced by the alpha activity from Am-241 completely inhibited corrosion at low temperatures, and vapor phase samples were in excellent condition due to O_3 production. In these tests at

Table 1. Corrosion Results

Solution	Temp, °C	Corrosion Rates, mpy Vapor	Corrosion Rates, mpy Solution	Exposure, hr	Comments
			Hastelloy B		
6 M HCl-20 g/l La	45	9	6	20	Loose black oxide scale on all samples, washed off before weighing
		8	2	163	
	85	29	5	24	
	105		27	22	
6 M HCl-20 g/l Am	45	54	68	22	
		23	31	156	
	85	46	73	19	
	105		53	44	
10 M LiCl-0.5 M HCl-20 g/l La	45	1.2	a	24	Corrosion rates decreased with exposure time
		1.3	None	166	
	110	58	6	41	
		29	2	162	
10 M LiCl-0.5 M HCl-20 g/l Am-241	45	5	7	19	
		2	9	131	
	110	15	39	19	
		11	26	160	
			Hastelloy C		
6 M HCl-20 g/l La	45	26	7	20	
		18	5	163	
	105	680	1080	18	Deep intergranular penetrations in heated area of weld
		263	600	134	
6 M HCl-20 g/l Am-241	45	48	57	22	
		23	24	156	
	105	793	693	20	Test terminated
10 M LiCl-0.5 M HCl-20 g/l La	45	7	a	24	
		9	1	166	
	110	100	94	41	Acid depleted
		27	22	162	
10 M LiCl-0.5 M HCl-20 g/l Am-241	45	7	9	19	
		2	8	131	
	110	11	15	19	Deep pitting on weld and in heated area
		13	15	160	

Table 1 (Cont.)

Solution	Temp, °C	Corrosion Rates, mpy Vapor	Corrosion Rates, mpy Solution	Exposure, hr	Comments
		Titanium 45A			
6 M HCl-20 g/l La	45	143	441	20	Very heavy attack
		91	405	164	
	105	2250	4990	18	Catastrophic
		Dissolved	Dissolved	133	
6 M HCl-20 g/l Am	45	a	3.1	22	No evidence of corrosion
		a	3.5	156	
	105	1430	4870	20	Test terminated
10 M LiCl-0.5 M HCl-20 g/l La	45	63	217	24	Acid depleted
		13	51	166	
	110	900	700	41	Test terminated
10 M LiCl-0.5 M HCl-20 g/l Am	45	a	a	19	No evidence of corrosion
		0.3	1.4	131	
	110	a	1.0	19	
		a	0.9	160	
		Zircaloy-2			
6 M HCl-20 g/l La	45	3	5	20	
		0.3	0.7	163	
	105	1	3	18	
		a	0.7	134	
6 M HCl-20 g/l Am-241	45	6	12	22	
		1	7	156	
	105	0.8	a	20	Golden oxide film
		3	a	138	
10 M LiCl-0.5 M HCl-20 g/l La	45	1	2	24	
		a	0.7	166	
	110	a	7	41	
		a	1	162	
10 M LiCl-0.5 M HCl-20 g/l Am-241	45	a	0	19	
		0.2	0.1	131	
	110	0.5	2	19	
		0.2	2	160	

[a]Slight weight gain.

105°C the 6 M HCl was boiling, but at the 110°C used the salt solution was not boiling. This shows up in the fact that at 110°C in the salt solution corrosion of titanium was inhibited by the alpha radiation, while at 105°C in the acid solution corrosion was severe since H_2O_2 is rapidly removed from solution by boiling. English (1) obtained the same results with titanium in nonradioactive solutions containing H_2O_2.

Zircaloy-2. Zircaloy-2 alloy was corrosion resistant at all temperatures and chloride concentrations tested. Corrosion rates decreased with exposure time, and the presence of radiation had no effect. No evidence of intergranular or pitting corrosion was found on the base metal or on the welded area.

Glass. Pyrex and soft glass coupons showed corrosion rates of <1 mpy as determined by weight loss. The samples were exposed for 600 hr with no noted effects in either the control or the test solutions.

3.0 TEST CONDITIONS

The most corrosive solutions in the transuranium processing will probably be azeotropic boiling HCl and slightly acid solutions of concentrated LiCl with activity levels of ~2 watts/liter. Solutions were made up with 6 M HCl and with 10 M LiCl—0.5 M HCl containing 20 g of Am-241 per liter to yield an activity level of 2 watts/liter (1.44×10^{11} d/m·ml). Corrosion specimens, 1 by 2 cm and varying in thickness from 1/32 to 1/8 in., were placed in a Pyrex glass test tube and covered with 10 ml of solution; others were suspended in the vapor phase by a tantalum wire. Tests were made at 45°C and at near boiling for 7 days with a corrosion rate check after ~24 hr. Samples were weighed before and after exposure on a semi-micro Ainsworth balance, and the corrosion rates in mils per year calculated from the weight loss. Fresh solutions and new specimens were used for each solution and temperature tested. Conditions were identical for the test and control runs except that nonradioactive lanthanum replaced americium in the control solutions.

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