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INFLUENCE OF PLATING BATH COMPOSITION AND STEEL SURFACE TREATMENT ON CORROSION RESISTANCE OF CADMIUM COATINGS

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EXTRACTION METALLURGY DIVISION

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Influence of Plating Bath Composition and Steel Surface Treatment on Corrosion Resistance of Cadmium Coatings

by

A.W. Lui* and G.R. Hoey**

ABSTRACT

The corrosion resistance of cadmium coatings on mild steel prepared from the Mines Branch cyanide plating bath and a commercial bath, was assessed by means of humidified SO_2-air and combined humidified SO_2-air and environmental chamber tests. The mild-steel surfaces had been prepared by three different techniques.

There was no significant difference in corrosion resistance between coatings on surfaces prepared by the same cleaning method but plated from different cyanide baths. However, the corrosion resistance of cadmium coatings on surfaces prepared by a nitric acid-acetic acid-phosphoric acid treatment was higher than those on surfaces prepared by other methods. The corrosion rates in the combined humidified SO_2-air and environmental chamber test were higher than those in the humidified SO_2-air test.

The experimental results indicate that the service life of cadmium coatings of equal thickness is determined by the severity of the environment and the method of surface preparation but not by the type of cyanide plating bath used to plate mild steel.

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Direction des mines

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L'INFLUENCE DE LA COMPOSITION DU BAIN DE PLACAGE ET DU TRAITEMENT DE LA SURFACE D'ACIER SUR LA RÉSISTANCE À LA CORROSION DES DÉPÔTS DE CADMIUM

par

A. W. Lui* et G. R. Hoey**

RÉSUMÉ

Les auteurs ont évalué la résistance à la corrosion du cadmium déposé sur l'acier doux préparé de deux bains de placage de cyanure, un de la Direction des Mines et l'autre de l'industrie par moyen de deux tests: a) l'air - SO_2 humidifié, b) la combinaison de l'air - SO_2 humidifié et de la chambre pour contrôler les conditions de l'environnement. Ils ont préparé les surfaces d'acier doux par trois techniques différentes.

Ils n'ont pas trouvé de différence significative dans la résistance à la corrosion entre les dépôts sur les surfaces préparées par la même méthode de nettoyage mais plaqués des bains de cyanures différents. Cependant, les auteurs ont trouvé que la résistance à la corrosion des dépôts de cadmium sur les surfaces préparées par un traitement d'acide nitrique, acétique et phosphorique était plus élevée que sur les surfaces préparées par d'autres méthodes. Les vitesses de corrosion dans le test de la combinaison de l'air-SO_2 humidifié et de la chambre pour contrôler les conditions de l'environnement étaient plus élevées que celles dans le test de l'air - SO_2 humidifié.

Les résultats expérimentaux ont indiqué que la durée de service des dépôts de cadmium de la même épaisseur est déterminée par la sévérité de l'environnement et par la méthode de préparation de la surface et non pas par le type de bain de placage de cyanure utilisé pour plaquer l'acier doux.

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INTRODUCTION

As a recent invention of Dingley, Bednar and Rogers(1), zinc and cadmium cyanide plating baths and cathodic surface preparation techniques were patented. Some aspects of the invention are greater stability of plating bath, higher cathodic current efficiency, less hydrogen embrittlement of steel, and finer crystalline deposits which can be brightened satisfactorily by dilute acid treatment.

This investigation was undertaken to compare the corrosion resistance of cadmium coatings obtained from the Mines Branch plating bath(1) and from a commercial plating bath and to compare the influence of surface preparation techniques on corrosion resistance of the coatings.

The corrosion resistance of zinc coatings obtained from different cyanide plating baths were compared and reported previously(2).

EXPERIMENTAL

Preparation of Cadmium Coatings

Two cyanide cadmium plating baths (Mines Branch bath and a commercial bath) were used to deposit cadmium on mild steel (AISI 1010). The composition of the baths are shown in Table 1. The plating was performed in a rectangular cell containing 2 litres of plating solution into which the mild steel cathode

TABLE 1

Composition of Cadmium Plating Baths (g/ℓ)

Baths	Cd	NaCN	NaOH
Mines Branch	34.5	98.3	80.3
Commercial	26.5	100.0	-

(1 x 3.5 in.) and cadmium anodes were suspended. The plating conditions were essentially those of Dingley, Bednar and Rogers[1] consisting of plating at a temperature of 25 ± 2°C and a cathodic current density of 38 A/ft^2.

Three different techniques of cathodic surface preparation were employed of which the first two were those used by Dingley et al: (1) degrease with trichlorethylene vapor, treat with N.A.P. solution (23.3% HNO_3, 32.7% CH_3COOH, and 28.3% H_3PO_4, all by weight) for an hour, clean with distilled water under the influence of ultrasonic vibrations, and then rinse with distilled water; (2) degrease with trichlorethylene vapor, sand blast with 220-mesh aluminum oxide, pickle in 18 % HCl for 1 min under the influence of ultrasonic vibrations, and then rinse with distilled water; and (3) degrease with trichlorethylene vapor, sand blast with 220-mesh aluminum oxide, and then clean with air. In all experiments, the thickness of the coatings, as measured by an Accuderm thickness gauge (manufactured by Unit Process Assemblies Inc., Woodside, N.Y.), was between 1.0 and 1.2 mil.

Corrosion Testing Methods

Two accelerated corrosion testing methods, the humidified SO_2-air and the combined humidified SO_2-air and environmental chamber tests, were used to test the corrosion resistance of the cadmium coatings. These testing methods were described fully in a previous communication[2].

RESULTS AND DISCUSSION

Results of corrosion testing of cadmium coatings by the humidified SO_2-air and the combined humidified SO_2-air and environmental chamber testing methods are shown in Tables 2 and 3, respectively. The figures shown are averages for two panels tested under identical conditions. There was no consistent difference in corrosion resistance between the two coatings that had received the same surface preparation. However, both types of coatings (Mines Branch and commercial) on steel surfaces prepared by the N.A.P. treatment resisted corrosion better than coatings on surfaces prepared by other methods.

The corrosion resistance of cadmium coatings has been tested by many investigators. In the galvanic series in sea water, cadmium is active to iron or steel and confers galvanic protection on the underlying ferrous metal[3]. Cadmium is resistant to corrosion in alkaline medium, in wet spray, and intermittent immersion in sea water and sodium chloride solutions[4]. However, it is highly susceptible to corrosion in acidic environments in the presence of oxygen[5].

TABLE 2

Results of Humidified SO_2-Air Testing

Type of Coating	Method of Surface Preparation	Corrosion Rate* (mdd) **
Mines Branch	(1) N.A.P. treatment	181
	(2) Ultrasonic in 18% HCl	200
	(3) Sand blast and air clean	192
Commercial	(1) N.A.P. treatment	167
	(2) Ultrasonic in 18% HCl	192
	(3) Sand blast and air clean	193

*Based on 14 days exposure
**mdd means mg/dm/day

TABLE 3

Results of Combined Humidified SO_2-Air and

Environmental Chamber Testing

Type of Coating	Method of Surface Preparation	Time to First Sign of Rust (hr)	Corrosion Rate* (mdd)**
Mines Branch	(1) N.A.P. treatment	72	264
	(2) Ultrasonic in 18% HCl	60	306
	(3) Sand blast and air clean	48	350
Commercial	(1) N.A.P. treatment	84	284
	(2) Ultrasonic in 18% HCl	48	335
	(3) Sand blast and air clean	48	354

*Based on 75 % of surface corroded
**mdd means mg/dm/day

In outdoor exposure and laboratory accelerated tests, Brum, Strausser and Brenner[4] compared cadmium coatings obtained from cyanide plating baths with and without additions of "gulac" (an organic product of sulfite pulp) and from cyanide plating baths with additions of nickel sulfate. They reported there was a marked difference in appearance and crystal structure among the cadmium coatings, however, there was no consistent difference in protective values among them. The time for substantial rusting increased with thickness of the coatings, but the time was not a linear function of coating thickness; it was greatly influenced by the presence of SO_2 in the corroding atmosphere but not by the brightness of the coatings or the baths from which the coatings were deposited.

In a similar manner, Hudson and Banfield[6] tested the corrosion resistance of cadmium coatings prepared by different methods under identical exposure conditions. Their results showed that the service life of the coatings depended chiefly on their weights and that the method of preparation was not important. Sample, Mendizza, and Teel[7], on the other hand, tested the corrosion resistance of cadmium coatings prepared from identical cyanide plating baths but under different exposure conditions. Their results showed that the length of time a given coating thickness of cadmium provided corrosion protection to steel was dependent upon the environment; the coatings failed more rapidly in industrial atmospheres than in either marine or rural ones.

The results obtained in this study agreed in general with those reported by the above investigators with the notable exception of surface preparation effect. There was no consistent difference in corrosion resistance between coatings obtained from the Mines Branch plating bath and the commercial bath. However, the corrosion resistances of cadmium coatings on steel surfaces prepared by N.A.P. treatment were consistently higher than those on surfaces prepared by other methods.

Under the conditions of humidified SO_2-air and combined humidified SO_2-air and environmental chamber tests, the corrosion rates of cadmium coatings are higher than those of zinc coatings previously reported[2]. The order is in line with the results of industrial environments exposure tests carried out by Sample[7], White[8] and Biestek[9] and agrees with those reported by Carter[10] who concluded that zinc is superior to cadmium in corrosion resistance in industrial areas. The exposure in this study has been similar to industrial environment exposure, and SO_2 has been the chief corrodent in both cases, therefore they are useful in assessing the relative corrosion resistance of cadmium and zinc coatings in industrial environments.

In contrast, salt spray tests are not suitable for the assessment of corrosion resistance of zinc coated and cadmium coated steel in industrial environments. Blum *et al*[4] reported that the life of zinc coated steel was shorter than that of cadmium plated steel when tested in salt spray. LaQue[11] also found that salt spray tests failed to place zinc and cadmium in the same order as in industrial outdoor exposure.

SUMMARY

1. In the humidified SO_2-air and the combined humidified SO_2-air and environmental chamber tests, there was no significant difference in corrosion rates (either mdd or "time to first sign of rust") between cadmium coatings, obtained from the Mines Branch cyanide plating bath and a commercial bath, from 1.0 to 1.2 mil thick.

2. Both types of cadmium coatings deposited on steel surfaces treated by the N.A.P. solution (23.3 % HNO_3, 32.7 % CH_3COOH and 28.3 % H_3PO_4, all by weight) exhibited a higher corrosion resistance than coatings on steel surfaces prepared by other methods.

3. The corrosion rates for both types of cadmium coatings in the combined humidified SO_2-air and environmental chamber test were higher than those in the humidified SO_2-air test.

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