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Behaviour of painted aluminium in Ibero-American atmospheres

M. Morcillo*, J. Simancas*, F. Corvo**, B. Rosales***, F. Fragata****, J. Peña*****, M. Sánchez******, S. Flores*******, E. Almeida********, S. Rivero********* and O.T. de Rincón**********

Abstract

Aluminium generally presents good corrosion resistance to the atmosphere. However, unprotected aluminium and aluminium alloys weather outdoors to an ugly grey colour, which deepens to black in industrial atmospheres, and undergo superficial pitting in marine atmospheres, etc. Finishing technologies are applied for their protection and decoration in a wide range of applications. These technologies basically consist of two protection processes: anodizing and painting; the latter going from conventional solvent base paints to modern water-borne, high solids and powder coatings. This paper considers the weathering performance of three paint systems: alkyd, polyurethane and polyester, after more than three years of exposure in a wide spectra of Ibero-American atmospheric conditions. The information reported includes resistance to undercutting corrosion at the scribe, filiform corrosion, fungal attack and change in the physical-chemical properties of the paint surface (loss of gloss, colour changes, chalking, etc.).

Keywords Atmospheric behaviour. Aluminium. Painting. Lackering. Ibero-America.

Comportamiento del aluminio pintado en las atmósferas de Iberoamérica

Resumen

El aluminio, en general, presenta una buena resistencia a la corrosión en la atmósfera. Sin embargo, el aluminio sin ninguna protección y las aleaciones de aluminio expuestas a la intemperie envejecen mostrando un color gris, negro en el caso de atmósferas industriales, sufren la formación de picaduras en atmósferas marinas, etc. Para su protección, o a efectos decorativos, se le aplican diferentes procesos de acabado en un amplio rango de aplicaciones. Estos procesos de acabado, básicamente consisten en dos métodos de protección: anodizado y pintado; este último abarca desde pinturas convencionales de base disolvente hasta modernos sistemas base agua, de alto contenido en sólidos o pinturas en polvo. Este trabajo considera el comportamiento de tres sistemas de pinturas: alquídico, poliuretano y poliéster, tras más de tres años de exposición en un amplio espectro de condiciones atmosféricas de Iberoamérica. La información presentada incluye la resistencia a la deslaminación en la incisión, corrosión filiforme, ataque por hongos y cambios en las propiedades físico-químicas de la superficie de la pintura (pérdida de brillo, color, entizado, etc.)

Palabras clave Comportamiento en la atmósfera. Aluminio. Pintado. Lacado. Iberoamérica

(*) Department of Materials Engineering. Degradation and Durability. National Metallurgical Research Centre (CENIM-CSIC). Avda. Gregorio del Amo, 8. 28040 Madrid (España).
(**) Centro Nacional de Investigaciones Científicas. Cuba.
(***) CITEFA. DEICOR.
(****) CEPEL. Ilha da Cidade Universitaria-Rio de Janeiro. Brazil.
(*****) Escuela Superior Politécnica del Litoral. Ecuador.
(******) Universidad Tecnológica de Panamá. Panamá.
(*******) Pontificia Universidad Católica del Perú. Perú.
(********) Instituto Nacional de Engenharia e Tecnología Industrial (INETI), Estrada do Paço do Lumiar, 1649-038 Lisboa (Portugal).
(*********) Universidad de la República. Montevideo (Uruguay).
(**********) Facultad de Ingeniería, Universidad del Zulia, Maracaibo, Venezuela.

1. INTRODUCTION

This research forms part of the Ibero-American 'PATINA' project (Anti-Corrosion Protection of Metals in the Atmosphere), which involves the participation of fourteen countries of the Ibero-American region[1]. One of the main tasks of this network is to evaluate the corrosion protection behaviour of a wide range of conventional and advanced coatings in typical atmospheres of the Ibero-American region.

The different coating technologies were distributed between six working groups. Group 5 included protective coatings on aluminium: anodizing[2] and painting[3 and 4].

Aluminium generally presents good corrosion resistance to the atmosphere. However, unprotected aluminium and aluminium alloys weather outdoors to an ugly grey colour, which deepens to black in industrial atmospheres, and undergo superficial pitting in marine atmospheres[5].

This work reports the main results obtained in the project with reference to paint coatings applied on aluminium, after 36-42 months of exposure in different atmospheres of Ibero-America.

2. EXPERIMENTAL

Specimens of 10×15 cm were cut from aluminium plate of 2 mm thickness, L-3350 alloy (UNE 38335), for paints A and B, and L-3140 alloy (UNE 38314) for paint C.

After surface conditioning by means of degreasing, washing and drying, the specimens received the following protection systems:

- Systems A and B. Yellow chromating by means of immersion for 2 minutes in a dissolution of $Na_2Cr_2O_3$ 0.1 N (DIN 50939), followed by washing and drying.
  Paint A: Polyester powder coating. Average dry film thickness of 110 μm.
  Paint B: Polyurethane liquid paint coating. Average dry film thickness of 45 μm.
- System C. Following treatment with a wash-primer of polyvinyl butiral and zinc chromate, catalysed with phosphoric acid, a liquid paint based on an alkyd resin esterified with vegetable oil (long oil) was applied. The average dry film thickness of the coating applied was 130 μm.

Once the paint coatings had cured in the laboratory atmosphere, a scribe of 0.3 mm thickness was made in the lower zone of the specimens, with an angle of attack of 60 ± 15 °, penetrating the paint coating and reaching base aluminium. Another series of specimens was unscribed.

Series of specimens were exposed in a variety of atmospheres of the Ibero-American region representing a broad spectrum of atmospheric corrosivities (Table I). Figure 1 shows a grid corresponding to ISO standard 9223[6], on classification of atmospheric aggressivity according

Table I. Testing stations. Environmental and corrosivity characteristics for aluminium

Tabla I. Estaciones de ensayo. Características ambientales y de corrosividad para el aluminio

Test site/(Country)	Time of wetness (annual fraction)	Chlorides $mg \cdot m^{-2} \cdot d^{-1}$	SO_2 $mg \cdot m^{-2} \cdot d^{-1}$	Hours of sunshine/year	First year aluminium corrosion rate $g \cdot m^{-2} \cdot a^{-1}$	ISO 9223 [6] Aluminium Corrosity
Pardo/(Spain)	0.366	3.9	6.4	2700	0.15	C1
Panama/(Panama)	0.629	8.3	4.8	1995	0.36	
Esmeraldas/(Ecuador)	0.710	2.1	16.5	1539	0.38	
Cubatao/(Brazil)	0.579	8.1	54.5	1899	0.43	C2
Lumiar/(Portugal)	0.135	19.6	22.6	2802	0.50	
Jubany/(Argentina, Antarctic)	0.293	–	–	434	0.58	
Tablazo/(Venezuela)	0.504	63.3	6.0	2498	0.65	
Punta del Este/(Uruguay)	0.515	147.0	5.0	2338	0.67	C3
La Voz/(Venezuela)	0.483	374.8	29.9	3073	1.31	
Viriato/(Cuba)	0.500	684.0	31.4	2779	1.78	
Lima/(Peru)	0.589	92.1	14.6	1421	5.21	C5

(–) not available

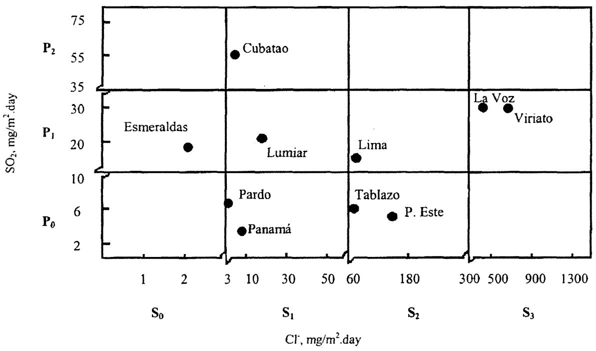

Figure 1. Characterization of atmospheres corresponding to the test stations with regard to SO_2 contamination and salinity, according to ISO 9223[6].

Figura 1. Caracterización de las atmósferas correspondientes a las estaciones de ensayo en función de la contaminación por SO_2 y la salinidad, de acuerdo con ISO 9223[6].

to the SO_2 and Cl^- (salinity) content of the atmosphere, that situates the different testing stations participating in the study. As can be seen in figure 1, the network of testing stations goes from the rural atmosphere of El Pardo, with very low SO_2 contamination, to more industrial atmospheres (Esmeraldas and Cubatao) with a higher SO_2 content. Marine atmospheres are also considered, from those practically without SO_2 contamination (Jubany in the Antarctic, Punta del Este and Tablazo) to others which are more contaminated by SO_2 and with increasing levels of salinity: Panama, Lumiar, Lima, Viriato and La Voz.

Visual inspections and photographic records of the state of the different coatings were carried out every 6 months and the study ended after approximately three years of exposure (36-42 months depending of the different test sites). The specimens corresponding to Esmeraldas station were disappeared after two years of exposure. The inspections in the testing stations referred mainly to the following aspects:

- Presence of dust, adhered soiling, fungi, etc. on the paint surface.
- Qualitative changes in colour and gloss and chalking[7] of the paint films.
- State of the scribe and adjacent coating (undercutting, blistering, filiform corrosion, etc.).

Once the specimens had been withdrawn from the testing stations and taken to the laboratory, an in-depth inspection was made of the state of the different coatings. Of particular importance was the quantification of the variation in colour and loss of gloss experienced by the coatings in the different atmospheres. These measurements were made in the Paints and Coatings Laboratory of INETI (Lisbon, Portugal) with the assistance of a 948 spectrocolorimeter (X-Rite) and a statistical glossmeter (Novo-Gloss), in accordance with the standards ISO 7724 [8] and ISO 2813 [9] respectively.

3. RESULTS AND DISCUSSION

In general terms the anticorrosive behaviour of the paint coatings in the different atmospheres may be considered to be good after three years of atmospheric exposure, with some exceptions that are mentioned below. The deterioration observed on some test specimens and in certain atmospheres has mainly affected the decorative characteristics of the specimens more than their anticorrosive properties. Table II indicates the deterioration recorded for the three paint systems in the different atmospheres.

With regard to the anticorrosive behaviour of the three paint systems after three years of atmospheric exposure, all have provided good protection of the aluminium in the different atmospheres. Attention is drawn only to the occurrence of slight undercutting and/or blistering of the paint films in the zones adjacent to the scribe in the case of paints B and C, the latter in all the atmospheres where it was tested (Table II). Paint B only showed this type of damage in Lima and La Voz atmospheres. In La Voz station, the blistering of some parts of the edge of the specimens seemed to show a similar morphology to filiform corrosion, which nevertheless does not develop in a clear way. In Lima atmosphere, however, filiform corrosion is patently observed on the coating adjacent to the scribe (Fig. 2), and the filaments progress notably with exposure time, after an incubation period of approximately 18 months of exposure.

With regard to the decorative properties of the different coatings, the main changes observed refer to the following aspects: changes in colour, loss of gloss, chalking, presence of fungi on the paint surface and existence of firmly adhered soiling on the paint surface.

With regard to adhered soiling, this damage only occurred in the industrial atmospheres participating in the study (Esmeraldas and

Table II. Damage observed on the paint systems exposed in the different testing stations

Tabla II. Daños observados en los sistemas de pintura expuestos en las diferentes estaciones de ensayo

Test Site	Paint A	Paint B	Paint C
El Pardo	Fungi.	Fungi.	Slight undercutting at scribe edges. Fungi.
Lumiar			Very slight undercutting at scribe edges. Slight adhered soiling. Fungi.
Esmeraldas	Adhered soiling (moderate degree) which increases with time.	Adhered soiling (moderate degree) which increases with time.	—
Cubatao	Adhered soiling (severe degree)	Adhered soiling (severe degree) which increases with time. Fungi.	—
Panama	Slight adhered soiling.	Slight adhered soiling.	—
Jubany			—
Punta del Este			Slight undercutting of the paint adjacent to the scribe, which progresses with time. Fungi.
Lima		After 18 months, start of filiform corrosion in zones adjacent to scribe that progress with time.	—
Viriato	Fungi, preferentially on the downward facing side.	Fungi, preferentially on the downward facing side.	Fungi, preferentially on the downward facing side. Slight blistering at edges and zones adjacent to the scribe.
Tablazo	Fungi.	Fungi.	—
La Voz		Slight blistering at the scribe and edge area, similar to filiform corrosion.	Slight blisterint at the scribe.

—Not tested

Chalking was observed on all three systems and in all the testing stations, to a greater or lesser degree.

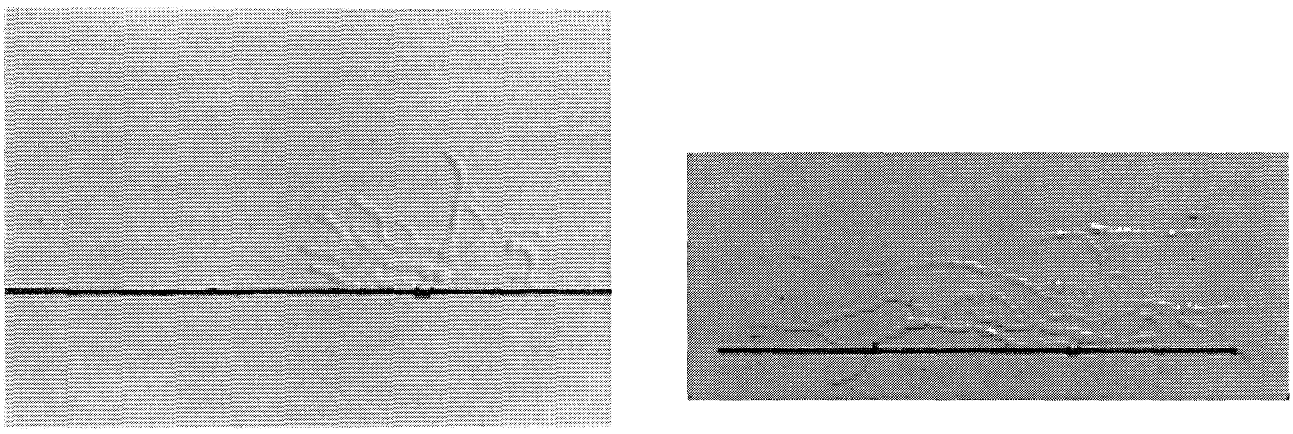

Figure 2. Filiform corrosion of paint B in Lima atmosphere. Note the significant progress of filaments with increasing exposure time.

Figura 2. Corrosión filiforme en la pintura B en la atmósfera de Lima. Préstese atención al significativo progreso de los filamentos con el aumento del tiempo de exposición.

Cubatao), and on the two paints (types A and B) tested in these atmospheres.

The presence of fungi, which could be seen in some inspections and testing stations, did not constitute very significant damage to the paint films. The slight staining that was produced (Fig. 3) disappeared in most of the cases with simple washing of the paint surface with water. The fungi identified on the specimens exposed in Viriato were of the types *Aspergillus Niger* and *Curvularia Harveyi.*

Chalking was observed to a greater or lesser degree on the three paint systems in all the testing stations. Qualitative evaluations of the degree of chalking of the three systems were made during the inspections, leading to the following conclusions:

- Paint C is that which presents the highest degree of deterioration due to this phenomenon, and paint B is the most resistant in terms of this property.
- The degree of chalking increases in general with exposure time.
- As was foreseeable, the degree of chalking is a function of the intensity of solar radiation and hours of sunshine per year at the exposure site. Thus, the highest degrees of chalking were presented in the testing stations of La Voz, Panama and Lumiar, and the lowest in Lima.

The changes of colour have been very slight on the three paints In relation with the loss of gloss experienced by the three paint systems in the different atmospheres. Figure 4 displays the results obtained in the laboratory on specimens aged in the atmospheres for three years of exposure. Data is not presented for Cubatao, since, as has already been mentioned, the specimens suffered heavy soiling in this testing station. From observation of this figure the following conclusions can be drawn:

- Paint C (alkyd) is that which experienced the greatest loss of gloss and paint B the least.
- A certain relationship is observed between the loss of gloss and the hours of sunshine per year at the exposure site. Thus, Viriato (2723 h of sunshine per year) always registers great losses of gloss, while in Lima (1376 h of sunshine per year) the losses of gloss are very low.

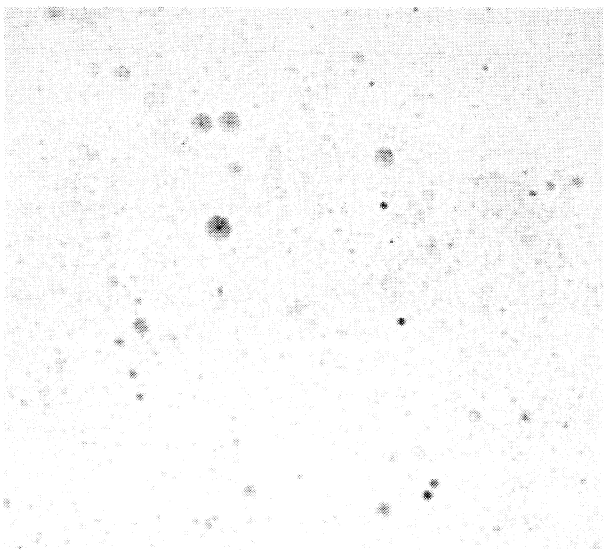

Figure 3. Presence of fungi on the surface of paint C exposed in Lumiar atmosphere.

Figura 3. Presencia de hongos sobre la superficie de la pintura C expuesta en la atmósfera de Lumiar.

4. CONCLUSIONS

After three years of exposure of three paints (polyester (A), polyurethane (B), and long-oil alkyd (C)) on aluminium in different atmospheres of the Ibero-American region, the following conclusions are obtained:

- The three paint coatings provide adequate anticorrosive protection of the base aluminium. Slight undercutting is only seen with the paint C films, in the zones adjacent to the scribe in all the atmospheres, and filiform corrosion on the paint B exposed in the marine atmosphere of Lima.
- The remaining types of damage encountered refer to the decorative properties of the coatings: firmly adhered soiling of the paint film

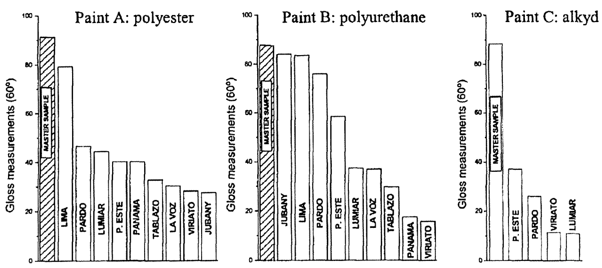

Figure 4. Results of gloss measurements (60 °) of the master sample (not exposed to the atmosphere) and specimens exposed for 36-42 months in the different testing stations.

Figura 4. Resultados de las medidas de brillo (60 °) de la muestra control (no expuesta a la atmósfera) y de las muestras expuestas 36-42 meses en las diferentes estaciones de ensayo.

(industrial atmospheres of Esmeraldas and Cubatao), slight staining by fungi in many of the atmospheres, which disappears after simple washing, as well as chalking and loss of gloss in all the atmospheres. These last two types of deterioration, most pronounced on paint C and least on paint B, present a higher intensity the greater the number of hours of sunshine at the exposure site.

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