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Effect of Anticorrosive Pigmentation on the Performance of Vinyl Coatings

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Effect of Anticorrosive Pigmentation on the Performance of Vinyl Coatings*

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Introduction

THE CORROSION OF STEEL requires the presence of both oxygen and water. It has been long known that coatings which provide an effective barrier to one or both of these elements will effectively reduce corrosion. Tar and grease are well-documented examples of such coatings. As coatings technology developed, it was discovered that certain compounds provided additional anticorrosive properties. Thus, when drying oils began to be used, the technique of incorporating certain pigments, particularly derivatives of lead, became popular because of the additional protection they provided. With the advent of synthetic resins, technologists continue to use those formulating principles.

While the mechanism by which anticorrosive pigments provide a corrosion retarding effect to coatings is not entirely understood, it has been shown empirically that compounds of lead and zinc are particularly effective for this purpose. The corrosion protection afforded by these two pigment types is quite different. While lead pigments are believed to retard corrosion primarily through the generation of an alkaline environment, zinc pigments are thought to be effective primarily through metal passivation caused by the slow release of zinc or chromate ions. While the presence of ions has been demonstrated to be of considerable help in reducing corrosion, it has also been demonstrated that a salt of high solubility such as sodium chromate does not protect the substrate, and can actually be harmful. Therefore, an effective anticorrosive pigment should have proper balance between solubility and insolubility.

The development of highly hydrophobic and chemically insensitive high performance polymers in the last few decades has provided a level of resistance properties unknown in earlier types of coatings. However, the earlier principles of formulation were so deeply entrenched that many of these newer high performance binders were formulated into coatings according to established pigmentation rules. However, new forces in t chnical and regulatory areas foster change constantly. There is considerable stimulus to eliminate the presence of heavy metals such as lead and chromium (as chrome) from paint formulations. Vinyl coatings have been used for many years with and without anticorrosive pigments both in government paint specifications and proprietary compositions.

Methodology

The severe raw material shortages following the oil embargo of 1973 convinced many researchers and engineers that it was time to develop data enabling the formulator to select suitable alternative paint ingredients. The prospect of shortages and regulatory limitations was the basis of the PACE (Performance of Alternate Coatings in the Environment) project at the Steel Structures Painting Council in Pittsburgh, Pennsylvania.

After an industry-wide search, a critical survey of alternatives, and selection of the most promising candidates, a broad range of products was evaluated. Some of these were: free of pigments, resins, and solvents which could be potentially hazardous during application, use, and removal; products low in volatile organic pollutants; surface preparation methods that are safe and nonpolluting; and improved primers and pretreatments.

These coatings were exposed in five typical environments in a statistically designed experiment in which they were directly compared with reproducible standard products, the performance of which had been documented over many years. The program was administered by a balanced committee of producers and users who selected promising products for evaluation.

The evaluation of a variety of anticorrosive pigments in vinyl coatings was one of the earliest series started. Thanks to the early initiation of tests, panels in this particular series have logged a substantial length of exposure, and have reached a point where the results yield valid conclusions. While the PACE program continues to evaluate a variety of coatings, the branch on pigmentation of vinyl coatings has provided valuable information which is presented here.

A small segment of this work considered the performance of vinyls over hand cleaned, rusty, and intact millscale surfaces with a thick coat of wash primer. Three primer formulations were exposed in three environments.

The vinyl formulation described in Mil. Spec. MIL-P-15929 was chosen. A variety of pigments were substituted for red lead at a constant pigment volume concentration: aluminum flake, calcium boro silicate, zinc molybdate, barium metaborate, zinc sulfo oxide complex, micaceous iron oxide, and red iron oxide/barytes. These primers were applied to steel panels blast cleaned to either white metal (SSPC-SP 5) or near white (SSPC-SP 10) using steel grit or shot abrasives, and primed with wash primer conforming to Mil. Spec. MIL-P-15328. The standard United States Navy vinyl alkyd (MIL-P-16188) was used as topcoat.

Film thicknesses were well-controlled (Tables 1, 2, and 3) to minimize the thickness-related effects. Ten percent of the panels were selected randomly and replicated to establish a statistical measure of precision.

Panels were immersed at room temperature in fresh (distilled) and synthetic sea water (ASTM D-1141-52) and exposed to salt fog (ASTM B-117), and to a severe industrial atmosphere at a coke works. Initially, only the panels exposed at the industrial site were scribed. The salt fog panels were still in excellent condition after 8000 hours exposure. At this point, they were scribed and reexposed for an additional 3500 hours.

Exposure Results

As shown in Table 4, all but one of the panels were still perfect after 5700 hours of fresh or salt water immersion. Similarly, the panel surfaces exposed in the severe industrial

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**Steel Structures Painting Council.

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TABLE 1 — Film Thickness Summary: Wash Primer

Environment	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW-111	Halox CW-221	Halox CW 2230	Zinc Phosphate	Busan 11	Moly-White 101	Nalzin SC-1	Nalzin CR-42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR-42	Red Iron Oxide/Barytes
Salt Water	Steel Grit	0.2	0.4	0.4	0.3	0.4	0.4	0.5	0.2	0.3	0.4	0.2	0.2	—	—	—
Immersion	G14															
	SSPC-SP 5	0.2	—	—	—	0.2	—	—	—	—	—	—	0.2	—	—	—
	Steel Grit	0.2	0.4	0.4	0.3	0.5	0.5	0.7	0.3	0.3	0.5	0.2	0.2	0.7	0.7	0.7
	G14															
	SSPC SP 5	—	—	0.4	—	—	—	0.6	—	—	—	0.2	—	—	—	—
Fresh	Intact	—	—	—	—	—	—	—	—	—	—	—	—	1.1	1.1	1.1
Water	Millscale															
Immersion	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	1.0	1.2	1.1
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	0.8	0.8	0.9
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit	0.2	0.4	0.4	0.2	0.5	0.5	0.2	0.4	0.3	0.4	0.2	0.2	0.5	0.6	0.5
	G14															
	SSPC-SP 5	—	—	—	—	0.5	—	—	—	0.3	—	—	—	—	—	—
	Steel Shot	0.2	0.3	0.3	0.2	0.5	0.4	0.2	0.2	0.3	0.4	0.2	0.2	—	—	—
	S280															
	SSPC-SP10	—	0.4	—	—	—	0.4	—	—	—	—	—	—	—	—	—
Coke	Intact	—	—	—	—	—	—	—	—	—	—	—	—	1.0	1.1	1.1
Works	Millscale															
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	1.1	1.2	1.1
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	0.8	0.8	0.6
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit	0.4	0.3	0.4	0.3	0.4	0.5	0.2	0.3	0.3	0.4	0.2	0.2	0.6	0.6	0.8
	G14															
	SSPC-SP 5	—	—	0.3	—	—	—	—	—	—	0.4	0.2	—	—	—	—
	Steel Shot	0.3	0.4	0.3	0.2	0.5	0.4	0.2	0.2	0.3	0.4	0.2	0.2	—	—	—
	S280															
	SSPC-SP10	—	—	—	0.4	0.2	—	—	0.2	—	—	—	—	—	—	—
Salt	Intact	—	—	—	—	—	—	—	—	—	—	—	—	1.2	1.2	1.1
Fog	Millscale															
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	1.1	1.1	1.0
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	0.9	0.8	0.8
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: Film Thickness: mils (1 mil = 25.4 μm)

TABLE 2 — Film Thickness Summary: Wash Primer Plus Three Primer Coats

Environment	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW-111	Halox CW-221	Halox CW-2230	Zinc Phosphate	Busan 11	Moly-White 101	Nalzin SC-1	Nalzin CR-42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR-42	Red Iron Oxide/Barytes
Salt Water	Steel Grit	4.0	4.6	4.1	3.8	5.2	5.6	4.9	4.7	4.4	6.2	4.5	5.8	—	—	—
Immersion	G14															
	SSPC-SP 5	4.1	—	—	—	5.6	—	—	—	—	—	—	4.7	—	—	—
	Steel Grit	4.0	4.1	4.2	3.6	5.7	5.8	5.0	4.4	4.8	6.4	5.0	5.0	4.5	6.1	6.0
	SSPC-SP 5	—	—	4.4	—	—	—	4.4	—	—	—	4.7	—	—	—	—
Fresh	Intact	—	—	—	—	—	—	—	—	—	—	—	—	3.2	4.9	3.9
Water	Millscale															
Immersion	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	3.5	5.3	3.7
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	4.3	5.7	4.8
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit	4.1	4.4	4.4	3.6	5.9	5.5	4.0	4.5	4.5	6.0	4.6	4.5	4.4	5.6	5.7
	G14															
	SSPC-SP 5	—	—	—	—	5.8	—	—	—	4.8	—	—	—	—	—	—
	Steel Shot	4.1	4.5	4.2	4.2	5.6	5.8	4.7	4.0	4.7	6.3	4.6	3.2	—	—	—
	S280															
	SSPC-SP10	—	4.1	—	—	—	5.6	—	—	—	—	—	—	—	—	—
Coke	Intact	—	—	—	—	—	—	—	—	—	—	—	—	3.8	5.1	3.7
Works	Millscale															
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	3.5	5.0	3.8
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	4.3	5.6	3.6
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit	4.4	4.1	4.7	3.8	5.9	4.8	4.3	4.2	5.0	6.7	4.3	4.8	4.8	6.2	6.3
	G14															
	SSPC-SP 5	—	—	4.3	—	—	—	—	—	—	6.2	4.2	—	—	—	—
	Steel Shot	4.6	4.9	4.2	3.5	5.8	5.5	4.4	3.9	4.7	6.3	4.1	3.0	—	—	—
	S280															
	SSPC-SP10	—	—	—	4.4	4.6	—	—	4.2	—	—	—	—	—	—	—
Salt	Intact	—	—	—	—	—	—	—	—	—	—	—	—	3.6	5.3	3.8
Fog	Millscale															
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty	—	—	—	—	—	—	—	—	—	—	—	—	3.5	4.9	3.5
	Millscale															
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	4.4	6.3	4.8
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: Film Thickness. mils (1 mil = 25.4 μm).

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TABLE 3 — Film Thickness Summary: Full System (Wash Primer Plus Three Primer Coats Plus Topcoat)

Environment	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW 111	Halox CW 221	Halox CW 2330	Zinc Phosphate	Busan 11	Moly White 101	Nalzin SC-1	Nalzin CR 42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR 42	Red Iron Oxide/Barytes
Salt Water Immersion	Steel Grit G14	51	62	59	51	72	67	67	66	56	82	66	.67	—	—	—
	SSPC-SP 5	59	—	—	—	76	—	—	—	—	—	—	60	—	—	—
	Steel Grit	56	62	58	52	76	71	70	60	59	83	68	59	71	80	80
Fresh Water Immersion	SSPC-SP 5	—	—	61	—	—	—	56	—	—	—	70	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	63	65	67
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	66	73	60
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	84	95	82
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coke Works	Steel Grit G14	54	60	56	51	76	66	52	58	56	76	77	57	76	82	80
	SSPC SP 5	—	—	—	—	78	—	—	—	60	—	—	—	—	—	—
	Steel Shot S280	57	57	59	64	76	69	60	51	61	83	72	76	—	—	—
	SSPC-SP10	—	62	—	—	—	71	—	—	—	—	—	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	63	79	64
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	66	73	62
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	79	93	76
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Salt Fog	Steel Grit G14	59	62	67	49	73	70	56	55	66	84	62	62	70	83	85
	SSPC-SP 5	—	—	65	—	—	—	—	—	—	84	70	—	—	—	—
	Steel Shot S280	60	67	59	47	75	68	60	58	63	79	69	73	—	—	—
	SSPC-SP10	—	—	—	58	64	—	—	54	—	—	—	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	64	83	55
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	72	73	58
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	75	107	77
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note Film Thickness, mils (1 mil = 25.4 μm)

TABLE 4 — Fresh and Salt Water Immersion Data Summary (5700 Hours)

Rating Method	Environment	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW 111	Halox CW 221	Halox CW 2330	Zinc Phosphate	Busan 11	Moly White 101	Nalzin SC-1	Nalzin CR 42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR 42	Red Iron Oxide/Barytes
Rusting ASTM D-610	Salt Water Immersion	Steel Grit G14	10	10	10	10	10	10	10	10	10	10	10	10	—	—	—
		SSPC-SP 5	10	—	—	—	10	—	—	—	—	—	—	10	—	—	—
	Fresh Water Immersion	Steel Grit G14	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
		SSPC SP 5	—	—	10	—	—	—	10	—	—	—	10	—	—	—	—
		Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
		SSPC SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
		SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
		SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Blistering ASTM D714	Salt Water Immersion	Steel Grit G14	10	10	10	10	10	10	10	10	10	10	10	10	—	—	—
		SSPC-SP 5	10	—	—	—	10	—	—	—	—	—	—	10	—	—	—
	Fresh Water Immersion	Steel Grit G14	10	10	10	4F	10	10	10	10	10	10	10	10	10	10	10
		SSPC-SP 5	—	—	10	—	—	—	10	—	—	—	10	—	—	—	—
		Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	9M	10	10
		SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	4M	4M	4M
		SSPC SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
		SSPC SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 5 — Coke Works Data Summary (24 Months)

Rating Method	Pigment / Surface Perparation	Red Lead (Standard)	Halox CW-111	Halox CW-221	Halox CW-2330	Zinc Phosphate	Busan 11	Moly-White 101	Nalzin SC 1	Nalzin CR-42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR-42	Red Iron Oxide/Barytes
	Steel Grit G14	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	SSPC-SP 5	—	—	—	—	10	—	—	—	10	—	—	—	—	—	—
Rusting	Steel Shot S280	10	10	10	10	10	10	10	10	10	10	10	10	—	—	—
	SSPC-SP10	—	10	—	—	—	10	—	—	—	—	—	—	—	—	—
(ASTM D-610)	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit G14	4	6	10	6	2	6	6	4	10	4	5	2	6	6	8
	SSPC-SP 5	—	—	—	—	3	—	—	—	8	—	—	—	—	—	—
Scribe	Steel Shot S280	4	6	8	6	4	6	8	8	8	4	6	2	—	—	—
Undercutting	SSPC-SP10	—	8	—	—	—	4	—	—	—	—	—	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	14	20	26
32nd inch	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	6	32	26
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 6 — Salt Fog Data Summary

Rating Method	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW 111	Halox CW 221	Halox CW 2330	Zinc Phosphate	Busan 11	Moly White 101	Nalzin SC 1	Nalzin CR 42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR 42	Red Iron Oxide/Barytes
	Steel Grit G14	10	10	10	9	10	10	10	7	5	9	10	10	10	10	10
	SSPC SP 5	—	—	10	—	—	—	—	—	—	9	10	—	—	—	—
Rating ASTM D-610	Steel Shot S280	10	10	10	9	10	9	10	10	10	10	10	10	—	—	—
	SSPC SP10	—	—	—	10	10	—	—	6	—	—	—	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
(11,500 Hours)	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit G14	5F	5F	5F	5F	6MD	5F	5F	3MD	5D	6F	10	10	5M	6MD	6F
	SSPC-SP 5	—	—	5F	—	—	—	—	—	—	6F	10	—	—	—	—
Blistering	Steel Shot S280	5F	5F	4F	6F	10	5MD	6F	4F	6F	10	10	10	—	—	—
	SSPC-SP10	—	—	—	5F	10	—	—	3MD	—	—	—	—	—	—	—
ASTM D714	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	10	6F
(11,500 Hours)	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	10	2F	10
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	10	10	10
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit G14	0	0	2	2	4	0	6	6	6	4	2	4	4	4	2
	SSPC SP 5	—	—	4	—	—	—	—	—	—	2	6	—	—	—	—
Scribe	Steel Shot S280	4	4	4	2	4	4	4	2	4	2	4	6	—	—	—
Undercutting	SSPC-SP10	—	—	—	5	[illegible]	—	—	8	—	—	—	—	—	—	—
	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	6	4	8
32nd inch	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	6	4	8
(3535 Hours)	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	6	6	6
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

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TABLE 7 — Experimental Design

Environment	Pigment / Surface Preparation	Red Lead (Standard)	Halox CW 111	Halox CW 221	Halox CW 2230	Zinc Phosphate	Busan 11	Moly White 101	Nalzin SC 1	Nalzin CR-42	Micaceous Iron Oxide	Red Iron Oxide/Barytes	Aluminum Flake	Busan 11	Nalzin CR 42	Red Iron Oxide/Barytes
Salt Water Immersion	Steel Grit G14	DPJ	DPK	DPL	DPM	DPN	DPO	DPP	DPQ	DPP	UPS	FPK	FPQ	—	—	—
	SSPC-SP 5	DPJ1	—	—	—	DPN1	—	—	—	—	—	—	FPQ1	—	—	—
	Steel Grit G14	DPT	DPU	DPV	DPW	DPX	DPY	DPZ	DQA1	DQB	DQC	FPL	FPR	FPW	FPZ	FQC
	SSPC-SP 5	—	—	DPV1	—	—	—	DQA	—	—	—	PPL1	—	—	—	—
Fresh Water Immersion	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKN	FKW	FLF
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	.20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKQ	FKZ	FLI
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa. Sand	—	—	—	—	—	—	—	—	—	—	—	—	FKK	FKT	FLC
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit G14	DQD	DQF	DQH	DQJ	DQL	DQN	DQP	DQR	DQT	DQV	FPM	FPS	FPX	PQA	PQD
	SSPC-SP 5	—	—	—	—	DQL1	—	—	—	DQT1	—	—	—	—	—	—
	Steel Shot S280	DQE	DQG	DQI	DQK	DQM	DQO	DQQ	DQS	DQU	DQW	FPN	FPT	—	—	—
	SSPC-SP10	—	DQG1	—	—	—	DQO1	—	—	—	—	—	—	—	—	—
Coke Works	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKO	FKX	FLG
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKR	FLA	FLJ
	SSPC-SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	FKL	FKU	FLD
	SSPC-SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Steel Grit G14	DQX	DQZ	DRB	DRD	DRF	DRH	DRJ	DRL	DRN	DRP	FPO	FPU	FPY	FQB	FQE
	SSPC-SP 5	—	—	DRB1	—	—	—	—	—	—	DRP1	FPO1	—	—	—	—
	Steel Shot S280	DQY	DRA	DRC	DRE	DRG	DRI	DRK	DRM	DRO	DRQ	FPP	FPV	—	—	—
	SSPC-SP10	—	—	—	DRE1	DRG1	—	—	DRM1	—	—	—	—	—	—	—
Salt Fog	Intact Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKP	FKY	FLH
	SSPC-SP 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20% Rusty Millscale	—	—	—	—	—	—	—	—	—	—	—	—	FKS	FLB	FLK
	SSPC SP 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pa Sand	—	—	—	—	—	—	—	—	—	—	—	—	FKM	FKV	FLE
	SSPC SP10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 8 — Steel Structures Painting Council Paint Spec. No. 9

Ingredients	Wt%	Pounds/100 Gallons	Vol.%
Pigment			
Titanium Dioxide, Unextended	12.0	100	2.9
Vehicle (88% maximum)			
Vinyl Resin A (Hydroxyl-Containing)	8.0	66.7	5.9
Vinyl Resin B (Carboxyl-Containing)	8.0	66.7	5.9
Tricresyl Phosphate or Dioctyl Phthalate	3.0	25.0	2.5
Methyl Isobutyl Ketone	34.5	288.0	43.0
Toluene	34.5	288.0	39.8
	100.0	834.4	100.0

atmospheres (Table 5) have not shown any signs of rust after two years. However, there are differences in the amount of undercutting at the scribe. Scribe results show essentially no difference between the steel shot and grit abrasives used in blast cleaning.

Salt fog exposure performance data are given in Table 6. No signs of rusting were evident after 11,500 hours. Slight blistering was noted only after 6000 hours. After 11,500 hours, there was little difference in blistering among the 12 systems. Aluminum flake and iron oxide were slightly better than the rest. These small differences, however, may very well fall within the range of experimental error.

A small set of panels was prepared to test the effect of a thick coat (over 0.5 mils) of wash primer when used with vinyl primers containing both rust-inhibitive and noninhibitive pigments. Standard practice calls for a maximum of 0.5 mils for the wash primer (SSPC-PT 3). One purpose of this test was to determine if a vinyl coating could be applied successfully over hand-cleaned steel (both intact and partially rusted millscale) if a thick coat of wash primer is applied. It is important to note that no controls were included to establish the performance of a thin coat. Except for the thick wash primer, the vinyl systems used here were identical to those used in the main vinyl pigmentation study. Four surfaces were used: sand-blasted, grit-blasted, intact millscale, and partially rusted millscale. Three exposure environments were chosen: (1) fresh water immersion; (2) salt fog; and (3) severe industrial. Data for this small side study are given in the last three columns of Tables 1 through 7.

The blast-cleaned panels with the thick wash primer remained in excellent condition after 5700 hours of fresh water immersion. The hand-cleaned panels, however, started to blister, particularly the partially rusted millscale panels.

After two years of severe industrial atmospheric exposure, all panels, including the hand-cleaned ones, were rust-free. The hand-cleaned panels, on the other hand, showed a

TABLE 9 — Vinyl Type White (or Gray) Paint F rmula V-766e

Ingredients	Wt%
Vinyl Resin, Type 3 (Copolymer Resin)	5.6
Vinyl Resin, Type 4 (Carboxylated Terpolymer Resin)	11.6
Titanium Dioxide and (for Gray) Carbon Black	13.0
Diisodecyl Phthalate	2.9
Methyl Isobutyl Ketone	32.0
Toluene	34.7
Orthophosphoric Acid	0.2
	100.0

TABLE 10 — VP-3639 White High Build Vinyl Anticorrosive Paint

	Pounds/100 Gallons	Gallons/100 Gallons	Wt%
Methyl Butyl Ketone	52.27	7.80	5.25
Cellosolve Acetate	365.86	45.17	36.76
Xylene	36.57	5.04	3.67
Toluene	57.50	7.94	5.78
VM&P Naphtha	10.46	1.66	1.05
Flexol 10-10	39.00	4.85	3.92
UCAR Resin VMCA	217.97	19.67	21.90
Thixotropic Agent	9.18	1.08	0.92
Titanium Dioxide	114.72	3.45	11.53
Zinc Phosphate	91.78	3.34	9.22
	995.31	100.00	100.00

large area of scribe undercutting. Thick wash primer had no noticeable effect on scribe undercutting for blast-cleaned steel.

There was no difference in scribe ratings at the industrial site between the shot- and grit-blasted panels. However, the sand-blasted panels had better scribe performance than either shot- or grit-blasted panels. Even CR-42, which had the most scribe undercutting in the pigment section of this branch study had an excellent scribe rating when applied over a thick wash primer on the sand-blasted panels. However, this surface had poorer performance in the salt fog tests.

After 11,500 hours of salt fog exposure, the vinyl performance on hand-cleaned steel, coupled with thick wash primer, was comparable to that of blast-cleaned steel.

Experience with Alternative Pigmentation

The use of alternative pigmentation in vinyl systems is not new. There are numerous examples of coating systems which have been used for many years and have provided a highly reliable level of performance.

One of these is Spec. SSPC-9, which covers a vinyl coating pigmented only with titanium dioxide. Table 8 shows the formulation of this paint, which was first adopted in 1964. Since this coating contains a carboxylated resin, the paint is suitable for direct application over steel, while it is also self-topcoatable; therefore, an entire system can be based on it. One such system is described in SSPC paint system #4.

An example of the use of paint SSPC-9 in a difficult environment is that defined by the American Water Works Association in Spec. AWWA D102-78. In the inside painting system No. 2, this specification indicates that the first coat on the system directly on steel consists of SSPC Paint No. 9

Numerous other examples could be cited. One, included in the United States Army Corps of Engineers Spec. CW-09940, System No. 3, is a 4 coat system in which the primer consists of Formule D-766, which is pigmented with titanium dioxide only. This formula is shown in Table 9. The United States Army Corps of Engineers has numerous case histories where this type of paint has been applied for over 20 years under conditions of continuous immersions such as river locks and dams.

A recent example of the use of zinc phosphate as an alternative anticorrosive pigment is illustrated in Formula VP-3639, shown in Table 10. Because of its neutral nature, zinc phosphate can be used in combination with a carboxylated vinyl resin such as VMCA for the formulation of coatings that are applied directly over steel. VP-3639 is one such example; this particular paint with an antifouling topcoat has been totally immersed for over 5 years at a test station in Florida. The results of this test are excellent.

Summary

In vinyl vehicles, a variety of alternative pigments were at least equivalent to the established red lead formulations. This conclusion applies to vinyl systems only. Another portion of the SSPC PACE program dealt with a similar series of experiments aimed at evaluating alternative pigments in alkyd coatings. Here, the replacement appears to be more difficult, pointing to the fact that permeability of the polymer itself is an important factor on the allowable formulating latitude.

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