Corrosion Protection Performances of Zinc Rich Primers

Comparative Study of Heavy Duty Paint Systems pigmented with different type of Zinc particles

Category C5-M: Coast and offshore areas with high salt content

Zinc pigment types

I. Zinc Dust as Industry Standard (spherical pigment)
II. Zinc Flakes (lamellar pigment)
III. Mixture of Dust and Flakes (25% Dust – 75% Lamellar)

Testing Protocol

EN ISO 12944 Paints & Varnishes - Corrosion Protection of Steel
The EN ISO 12944 standard is intended to assist engineers and corrosion experts in adopting best practice in corrosion protection of structural steel.
EN ISO 12944 is progressively superseding regional standards to become a truly global benchmark in corrosion control

This study was conducted by:

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As accreditated member of:

LABORATORIO REFERENCIA 2014 2015 ASEFAPI

SSPC Corporate Member

INTRODUCTION

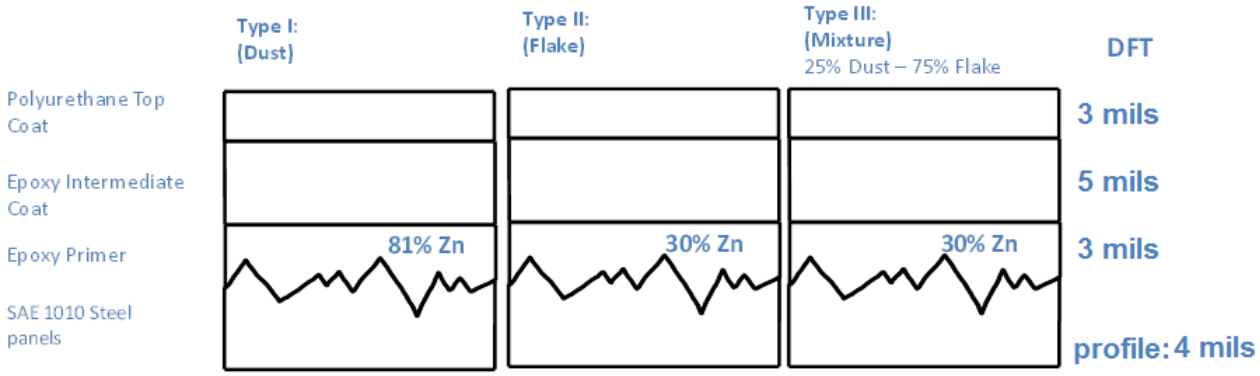
ECKART Suisse S.A. undertakes a study on the comparative performances against corrosion of three coating systems each of them including a zinc rich epoxy primer based on spherical (dust), lamellar (flake) and a mixture of lamellar and spherical morphologies.

The comparative study against corrosion protection for the three zinc rich epoxy primers has been performed by applying the primer on low alloy carbon steel panels to which a "commercial" intermediate coat and "commercial" topcoat have been applied creating a complete paint system similar to Table A5: *"Paint Systems for category C5-M"* referring to No. A5M.02 of the EN ISO 12944-5 standard.

The report presents the results obtained from testing required according to EN ISO 12944-5 and are outlined below:

- Standard Test ASTM B-117: Resistance to neutral salt spray for 1440 hours
- Standard Test ASTM D-2247: Resistance to humidity in condensation-water atmosphere for 720 hours
- Standard Test ASTM D-4541: Pull-off test for adhesion before and after neutral salt spray and humidity resistances described above.

The three paint systems



FORMULATIONS

Three different zinc rich epoxy primer formulations were prepared:

- Type I: Using **Zinc Dust** (spherical morphology), grade 4P16 from Umicore Zinc Chemicals. The final product meets the Standard UNE 48277 requirement

- Type II: Using **Zinc Flake** (lamellar morphology), grade ***STANDART Zinc Flake AT*** from ECKART

- Type III: Using a **Mixture** of Zinc Dust and Zinc Flake with proportion of 25% Zinc Dust and 75% Zinc Flake

The epoxy resin and hardener used are Epidian 115, with a mass solids content of 75 %, and Aradur 3776 XW 55, with a mass solids content of 55 %.

The composition of the three primer formulations are listed below (the solvent content of the resin and hardener have been taken into consideration.

	Type I (Dust)	**Type II** (Flake)	**Type III** (Mixture)
Epoxy resin (Epidian 115)	6.92	11.76	11.76
Additives	2.24	3.30	3.32
Zinc Dust *	**71.99**	--	**5.50**
Zinc Flake	--	**20.81**	**15.59**
Barite	--	14,48	14,49
Talc	1.52	14.48	14.49
Hardener (Aradur 3776 XW 55)	2.70	4.58	4.56
Solvents	14.64	30.58	30.29
Total	100	100	100

Pigment volume concentration (PVC)	57.32 %	46.15 %	46.25 %
Mass solids	85.36 %	69.42 %	69.71 %
Metallic zinc in dry film (*)	81.38 %	29.98 %	29.98 %

(*) *Taking into account a 96.5 % purity of zinc dust 4P16*

PREPARATION OF PANELS

Panel used are of low carbon steel SAE 1010 according to AISI/SAE standard (American Iron and Steel Institute / Society of Automotive Engineers) of approximate size 6’’×3’’and 0.16’’ thick.

Surface preparation of the panels has been carried out by dry abrasive blast cleaning using steel grit abrasive, G030 and G100 types from Ilarduya Productos de Fundición, S.L.U according to Standard SSPC AB-3. The preparation grade has been
SSPC-SP10, Near White Blast Cleaning. The surface profile obtained has been Medium (G) as defined by Standard ASTM D 4417-A see figure 1.

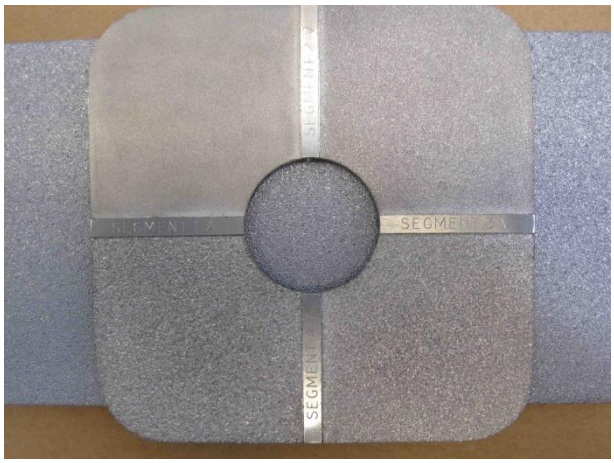


Figure 1
Surface profile obtained and grit comparator according to ASTM D 4417-A

Once the surface preparation has been accomplished, removal of dust produced has been clean up by suction (vacuum cleaning) until a value of Class 1 according to Standard EN ISO 8502-3.

Additionally, the steel surface profile has been determined by the replica tape method according to Standard ASTM D 4417-A see figure 2. The table below shows the mean value obtained from five measurements (expressed in mils) on three different panels.

Panel 1	Panel 2	Panel 3
4.00	4.02	3.82

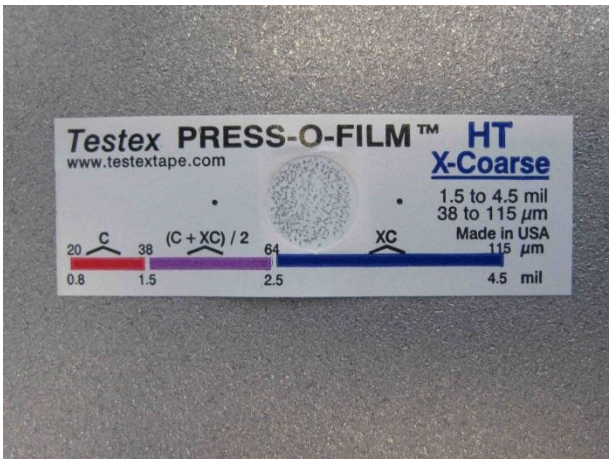


Figure 2

Surface profile according to Standard ASTM D 4417-A

PRIMER COAT APLICATION

Application of primers has been carried out at a temperature of 72 °F ± 6 °F and at a relative humidity between 48 % and 52 %.

The equipment used has been a high pressure pump Airless Professional Series (figure 3) from WIWA Wilhelm Wagner GmbH & Co. KG and a WIWA 500 D Airless high-performance spray gun.

The technical characteristics of the applications have been:

Type I (Dust): Pressure between 57 psi and 64 psi. Spray tip 219. Thinner CP-40: 3 %. Start applying time: 11:20. End applying time: 11:45. The nominal dry film thickness to be applied is 3 mils.

Type II (Flake): Pressure between 43 psi and 64 psi (no filter used, either in pump or in gun). Spray tip 221. Thinner CP-40: 5 %. Start applying time: 10:05. End applying time: 10:35. The nominal dry film thickness to be applied is 3 mils.

Type III (Mixture): Pressure 43 psi (no filter used, either in pump or in gun). Spray tip 221. Thinner CP-40: 5 %. Start applying time: 10:56. End applying time: 11:15. The nominal dry film thickness to be applied is 3 mils.

Figure 3
High pressure pump Airless Professional Series from WIWA Wilhelm Wagner GmbH & Co. KG

The primer coats applied are homogeneous in appearance and are free from sagging, wrinkles and other defects (figure 4)

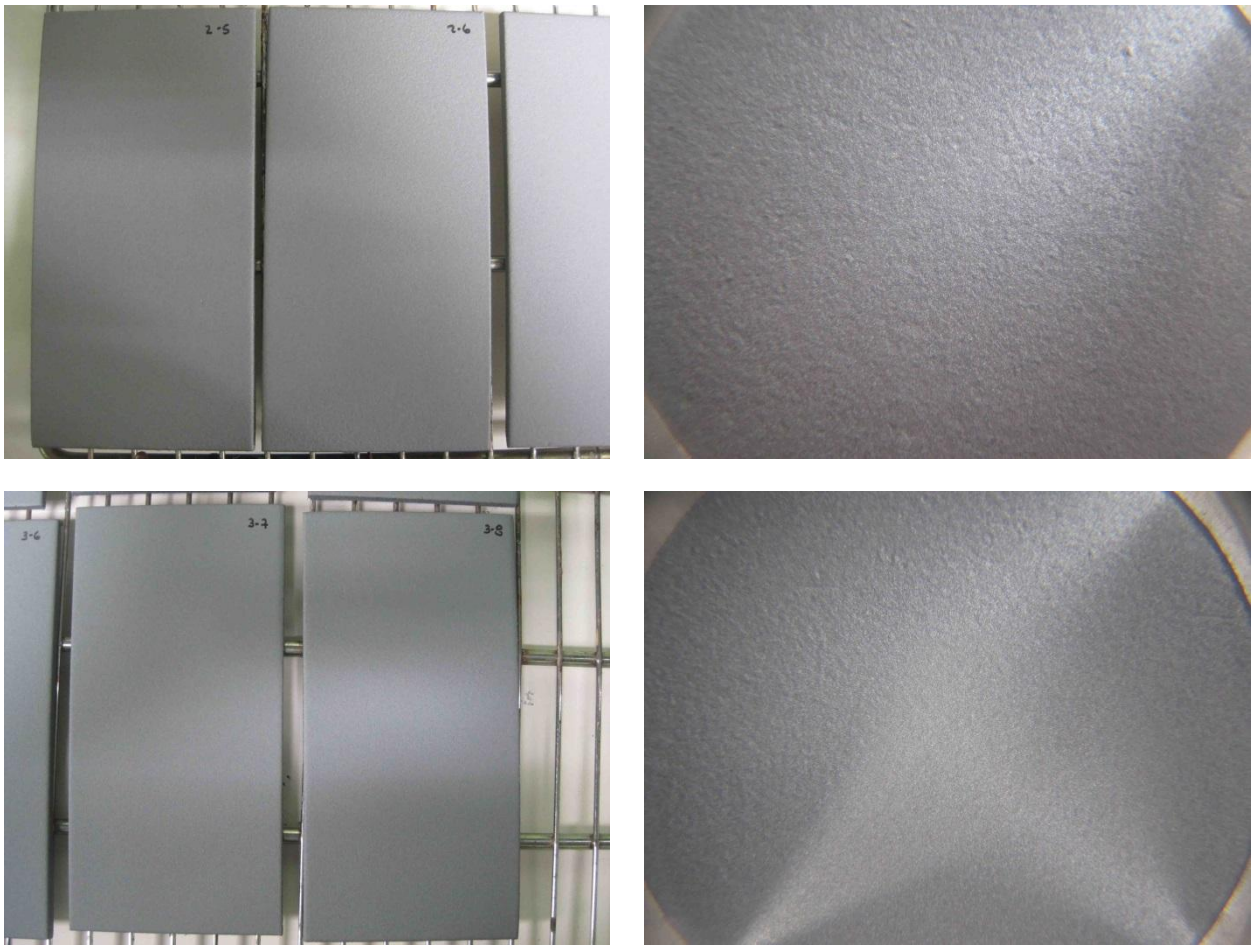


Figure 4

Appearance of the primed panels on left and surface detail (×10) on the right. Type I - Dust (top images), Type II - Flake (central images) and Type III - Mixture (lower images)

PRIMER THICKNESS

The dry film thickness* of the Zinc rich epoxy primer has been measured 24 hours after application and before application of the next coat using a magnetic induction gage according to Standard ASTM E376-11. Thickness measurements are expressed in mils.

Type I Primer (Dust)

Panel	Mean value	Standard deviation	Measurements
I-5	2.60	0.20	6
I-7	2.64	0.24	6
I-8	2.56	0.31	6
I-21	2.76	0.08	6
I-22	2.76	0.43	6
I-23	2.87	0.24	6
I-28	2.68	0.31	6
I-29	2.72	0.20	6
I-30	2.72	0.20	6

Type II Primer (Flake)

Panel	Mean value	Standard deviation	Measurements
II-1	2.83	0.28	6
II-5	2.68	0.20	6
II-6	2.91	0.47	6
II-7	2.80	0.39	6
II-8	2.80	0.35	6
II-9	2.91	0.31	6
II-10	3.11	0.28	6
II-21	3.23	0.28	6
II-30	2.91	0.20	6

Type III Primer (Mixture)

Panel	Mean value	Standard deviation	Measurements
III-9	2.83	0.39	6
III-10	2.87	0.16	6
III-11	2.91	0.24	6
III-12	2.83	0.20	6
III-14	2.95	0.28	6
III-15	2.91	0.31	6
III-23	2.60	0.51	6
III-25	2.80	0.31	6
III-26	2.68	0.28	6

[*] *For the surface roughness achieved, a correction value of 1 mil has been applied.*

INTERMEDIATE COAT APPLICATION

Application of the intermediate coat is an Epoxy resin system. It has been carried out following the requirements indicated in the product data sheet. A 5 % by weight of solvent has been added.

The nominal dry film thickness, of the intermediate coat, to be applied is 6 mils.

Application of intermediate coat has been carried out with the same equipment described previously, at a temperature of 78 °F ± 3 °F and at a relative humidity level of between 45 % and 50 %. Start applying time: 10:05. End applying time: 10:45

The intermediate coat applied is homogeneous in appearance and is free from sagging, wrinkles and other defects (figure 5).

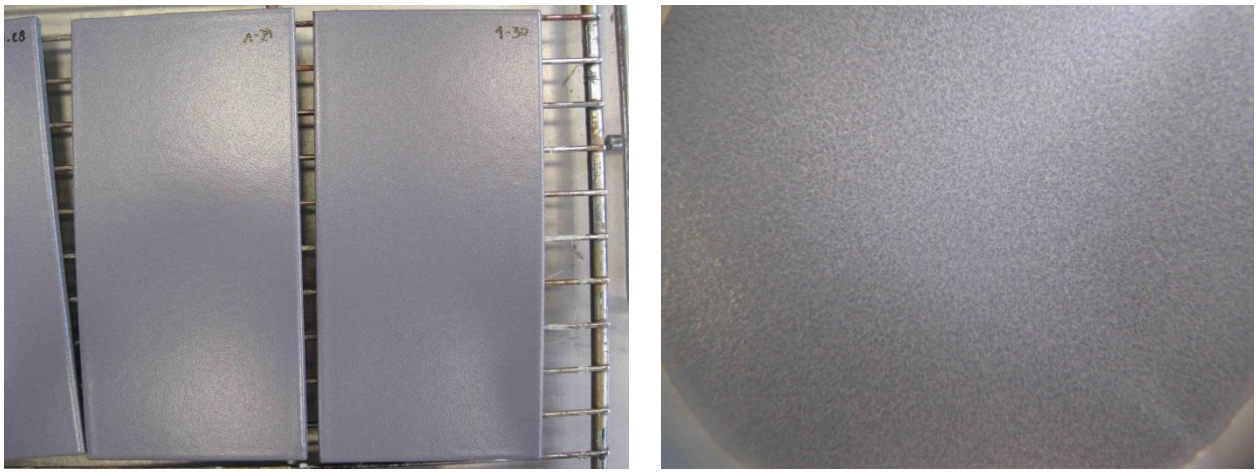


Figure 5
Appearance of panels with the intermediate coat on the left and surface detail (×10) on the right

INTERMEDIATE THICKNESS

The dry film thickness [(~)] of the paint systems, up to the intermediate coat, has been measured 96 hours after application and before application of the next coat, using a magnetic induction gage according to Standard ASTM E376-11. Thickness measurements are expressed in mils.

Type I: Primer (Dust) + Intermediate Coat

Panel	Mean value	Standard deviation	Measurements
I-5	7.60	0.47	6
I-7	7.64	0.67	6
I-8	7.28	0.55	6
I-21	8.15	0.35	6
I-22	7.95	0.59	6
I-23	8.31	0.47	6
I-28	8.82	0.59	6
I-29	8.35	0.20	6
I-30	8.66	0.39	6

Type II: Primer (Flake) + Intermediate Coat

Panel	Mean value	Standard deviation	Measurements
II-1	8.46	0.24	6
II-5	8.19	0.35	6
II-6	8.62	0.71	6
II-7	8.31	0.43	6
II-8	8.19	0.47	6
II-9	8.62	0.47	6
II-10	8.54	0.28	6
II-21	8.19	0.51	6
II-30	8.98	0.59	6

Type III: Primer (Mixture) + Intermediate Coat

Panel	Mean value	Standard deviation	Measurements
III-9	7.95	0.67	6
III-10	8.23	0.47	6
III-11	8.23	0.63	6
III-12	8.19	0.75	6
III-14	8.15	0.47	6
III-15	7.95	0.63	6
III-23	7.68	0.16	6
III-25	7.68	0.39	6
III-26	7.87	0.51	6

(~)For the surface roughness achieved, a correction value of 1 mil has been applied.

TOPCOAT APPLICATION

Application of the Topcoat coat is a Polyurethane resin system. It has been carried out with addition of 5 % by weight of solvent for polyurethane coatings. The nominal dry film thickness, of the topcoat, to be applied is 3 mils.

Application of topcoat has been carried out with the same equipment described previously, at a temperature of 72 °F ± 3 °F and at a relative humidity level of between 60 % and 70 %. Start applying time: 12:20. End applying time: 12:45

The topcoat applied is homogeneous in appearance and is free from sagging, wrinkles and other defects (figure 6).

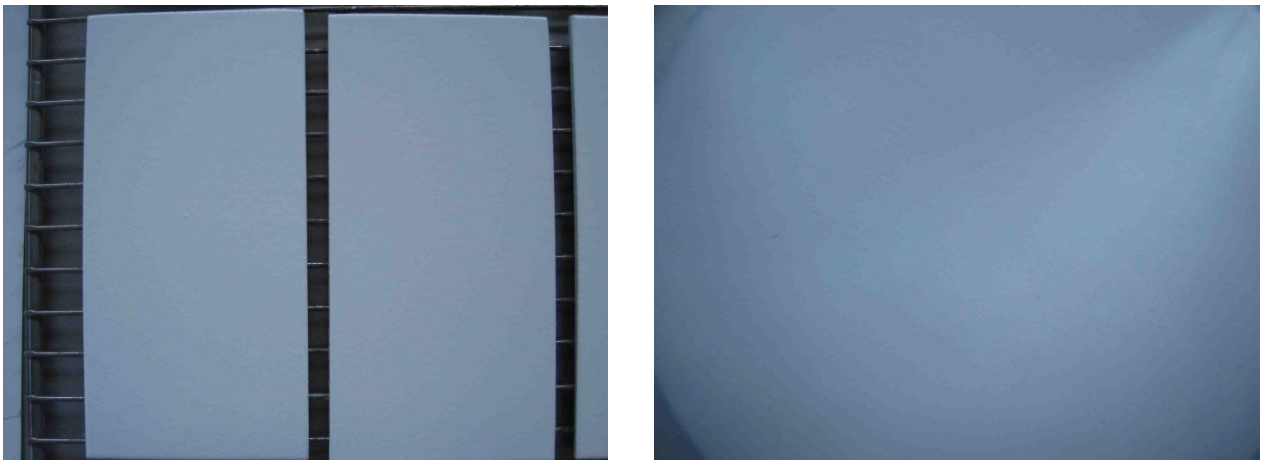


Figure 6
Appearance of panels with the topcoat on the left and surface detail (×10) on the right

TOPCOAT THICKNESS

The dry film thickness(~) of the paint systems, with the topcoat applied, has been measured 24 hours after application, using a magnetic induction gage according to Standard ASTM E376-11. Thickness measurements are expressed in mils.

Type I: Primer (Dust) + Intermediate Coat + Top Coat

Panel	Mean value	Standard deviation	Measurements
I-5	10.67	0.79	6
I-7	10.71	0.98	6
I-8	10.47	0.87	6
I-21	10.98	0.20	6
I-22	10.79	0.63	6
I-23	11.34	0.94	6
I-28	11.65	0.67	6
I-29	11.26	0.51	6
I-30	11.50	0.39	6

Type II: Primer (Flake) + Intermediate Coat + Top Coat

Panel	Mean value	Standard deviation	Measurements
II-1	11.42	0.67	6
II-5	11.30	0.55	6
II-6	12.05	0.51	6
II-7	11.54	0.55	6
II-8	11.34	0.55	6
II-9	11.42	0.31	6
II-10	11.54	0.87	6
II-21	11.38	0.39	6
II-30	12.01	0.35	6

Type III: Primer (Mixture) + Intermediate Coat + Top Coat

Panel	Mean value	Standard deviation	Measurements
III-9	11.38	0.31	6
III-10	11.77	0.55	6
III-11	11.46	0.39	6
III-12	12.44	0.39	6
III-14	11.22	0.47	6
III-15	11.14	0.43	6
III-23	10.91	0.35	6
III-25	11.26	0.35	6
III-26	11.10	0.24	6

(~)For the surface roughness achieved, a correction value of 1 mil has been applied.

PANEL CONDITONING AND PROTECTION

After each coat application the panel are kept vertical until the moment of next application andplaced under a controlled atmosphere at 74 °F ± 3 °F and 50 % ± 5% relative humidity. When the overall paint system was completed, the panels were placed under a controlled atmosphere at 74 °F ± 3 °F and 50 % ± 5% relative humidity for three weeks.

The panel's reverse face has been protected during paint process with the same paint system.

The edges of the panels, which will be subjected to the tests of resistance under neutral salt spray and humidity in condensation-water atmosphere, have been protected with a solvent-free epoxy coating system.

PANEL PREPARATION PRIOR TESTING

Neutral Salt Spray

One scribe 2'' long parallel to the largest dimension and reaching the substrate has been made according to Standard EN ISO 9227 (Not X shape) on panels subject to neutral salt spray test. The panels are:

- Type I (Dust) panels referring to I-21, I-22 and I-23
- Type II (Flake) panels referring to II-1, II-5 and II-6
- Type III (Mixture) panels referring to III-9, III-10 and III-11.

Humidity Exposure

The panels exposed to humidity in condensation-water atmosphere are:

- For the type I (Dust) panels referring to I-28, I-29 and I-30.
- For the type II (Flake) panels referring to II-7, II-8 and II-9.
- For the type III (Mixture) panels referring to III-12, III-14 and III-15.

Adhesion

The panels not exposed to any test before mentioned were used to determine the initial adhesions are:

- Type I (Dust) panels referring to I-5, I-7 and I-8.

- Type II (Flake) panels referring to II-10, II-21 and II-30.
- Type III (Mixture) panels referring to III-23, III-25 and III-2

RESISTANCE TESTING

Resistance to neutral salt spray

The test has been carried out by exposure to a neutral salt spray produced with a sodium chloride (NaCl) solution of 5 % by weight at 100 °F ± 4 °F and pH of 6,5 – 7,2 according to ASTM B-117 standard. The total duration of the test has been 1440 hours, as specified in EN ISO 12944-6 standard, for a corrosion resistance Category C5-M (marine environments) very high corrosive and high durability, as standard of reference.

Degrees of blistering (ASTM D-714), rusting (ASTM D-610), cracking, (ASTM D-661) and flaking (ASTM D-722) have been evaluated, as well as the advancement of any corrosion of the substrate from the incision calculated according DIN EN ISO 4628-8 standard, also briefly described in DIN EN ISO 12944-6, Annex A

Resistance to humidity in condensation-water atmosphere

The test has been carried out by exposure to humidity in condensation-water atmosphere produced by water electrical heated at 100 °F ± 4 °F according to ASTM D-2247 standard. The total exposure time has been 720 h, as specified in EN ISO 12944-6 standard, for a corrosion resistance Category C5-M (marine environments - very high corrosive and high durability)

Degrees of blistering (ASTM D-714), rusting (ASTM D-610), cracking, (ASTM D-661) and flaking (ASTM D-722) have been evaluated.

Adhesion determination

A pull-off test for adhesion, according to ASTM D-4541 standard, has been carried out. The paint system has been cut up to the steel substrate around the circumference of the dolly. Two dollies have been adhered on each one of the panels, using a two-pack epoxy adhesive, after two weeks the period of exposure to the neutral salt spray and humidity in condensation-water atmosphere was ended. The test was carried out three days later using hydraulic equipment with an automatically centered pulling force.

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RESULTS

Adhesion of the overall Paint System (prior neutral salt spray and humidity exposures)

Type I: Primer (Dust) + Intermediate Coat + Top Coat

	Adhesion (psi)	**Failure description**
Panel I-5	2510	20 % B (cohesive failure of the primer coat). 20 % C (cohesive failure of the intermediate coat). 30 % C/D (adhesive failure between intermediate coat and finish coat). 30 % Y/Z ((adhesive failure between the adhesive and the dolly).
	2860	10 % B (cohesive failure of the primer coat). 10 % C (cohesive failure of the intermediate coat). 30 % C/D (adhesive failure between intermediate coat and finish coat). 50 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-7	2910	70 % C/D (adhesive failure between intermediate coat and finish coat). 30 % Y/Z (adhesive failure between the adhesive and the dolly).
	2620	20 % B (cohesive failure of the primer coat). 15 % C (cohesive failure of the intermediate coat). 30 % C/D (adhesive failure between intermediate coat and finish coat). 35 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-8	2800	25 % B (cohesive failure of the primer coat). 10 % C (cohesive failure of the intermediate coat). 55 % C/D (adhesive failure between intermediate coat and finish coat) 10 % Y/Z (adhesive failure between the adhesive and the dolly).
	1780	20 % B (cohesive failure of the primer coat). 10 % C (cohesive failure of the intermediate coat). 30 % C/D (adhesive failure between intermediate coat and finish coat) 40 % Y/Z (adhesive failure between the adhesive and the dolly).

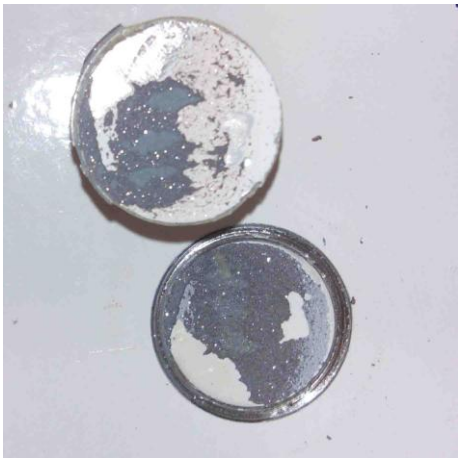


Figure 7

Aspect of the dolly (upper side) and surface (lower side) of pull-off test characteristics

Type II: Primer (Flake) + Intermediate Coat + Top Coat

	Adhesion (psi)	Failure description
Panel II-10	1230	100 % B (cohesive failure of the primer coat).
	1150	100 % B (cohesive failure of the primer coat).
Panel II-21	1020	100 % B (cohesive failure of the primer coat).
	1130	100 % B (cohesive failure of the primer coat).
Panel II-30	1150	100 % B (cohesive failure of the primer coat).
	1058	100 % B (cohesive failure of the primer coat).

Figure 8
Aspect of the dolly (upper side) and surface (lower side) of pull-off test characteristics

Type III: Primer (Mixture) + Intermediate Coat + Top Coat

	Adhesion (psi)	Failure description
Panel III-23	1190	100 % B (cohesive failure of the primer coat).
	1350	100 % B (cohesive failure of the primer coat).
Panel III-25	1420	100 % B (cohesive failure of the primer coat).
	1090	100 % B (cohesive failure of the primer coat).
Panel III-26	1450	100 % B (cohesive failure of the primer coat).
	1130	100 % B (cohesive failure of the primer coat).

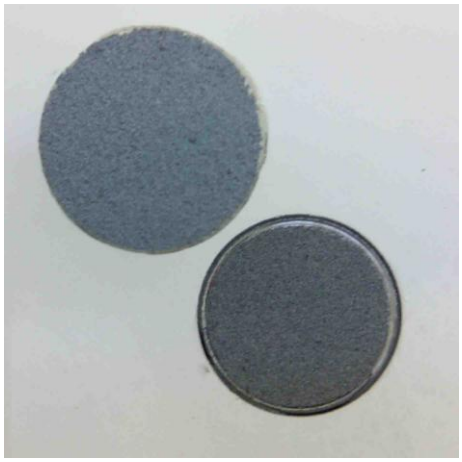
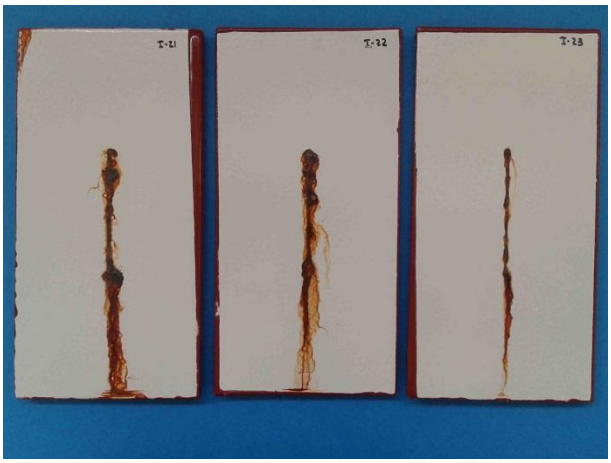


Figure 9
Aspect of the dolly (upper side) and surface (lower side) of pull-off test characteristics

Resistance to neutral salt spray (1440 hours) and his related Adhesion performances

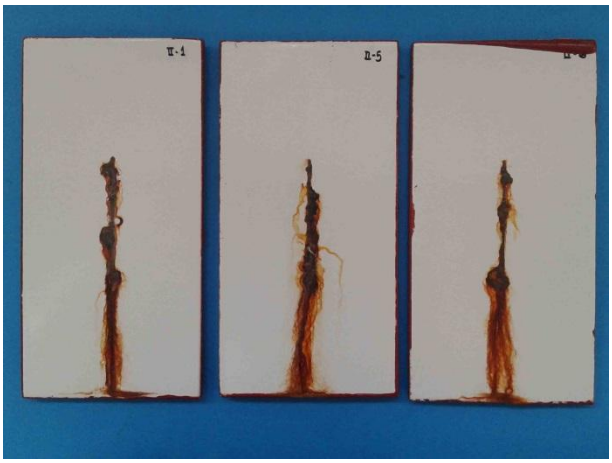
Type I: Primer (Dust) + Intermediate Coat + Top Coat

	Panel I-21	**Panel I-22**	**Panel I-23**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10
 **Figure 10** **Aspect of the panels I-21, I-22 and I-23 after exposure to neutral salt spray.**			
Creepage (mm)	1,5	1,0	0,7

	Adhesion (psi)	Failure description
Panel I-21	2200	20 % A/B (adhesive failure between substrate and primer coat). 80 % Y/Z (adhesive failure between the adhesive and the dolly).
	2230	30 % A/B (adhesive failure between substrate and primer coat). 30 % C (cohesive failure of the intermediate coat). 40 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-22	2360	20 % A/B (adhesive failure between substrate and primer coat). 30 % C (cohesive failure of the intermediate coat). 30 % C/D (adhesive failure between intermediate coat and finish coat). 20 % Y/Z (adhesive failure between the adhesive and the dolly).
	1972	10 % A/B (adhesive failure between substrate and primer coat). 50 % C/D (adhesive failure between intermediate coat and finish coat). 40 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-23	1230	10 % A/B (adhesive failure between substrate and primer coat). 90 % Y/Z (adhesive failure between the adhesive and the dolly).
	1580	50 % A/B (adhesive failure between substrate and primer coat). 10 % C (cohesive failure of the intermediate coat). 40 % C/D (adhesive failure between intermediate coat and finish coat).

Figure 11
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after Salt Spray exposure

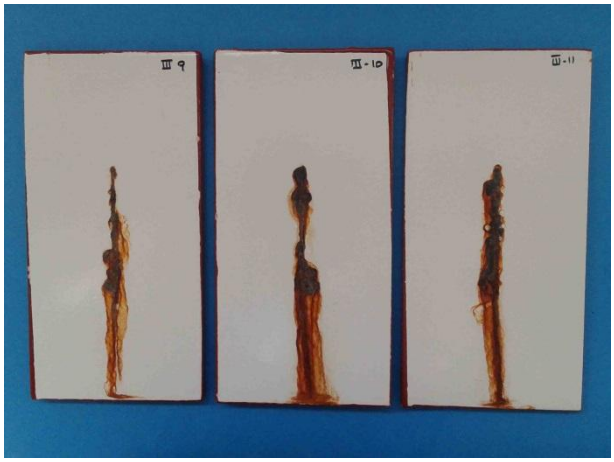
Type II: Primer (Flake) + Intermediate Coat + Top Coat

	Panel II-1	**Panel II-5**	**Panel II-6**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10
 **Figure 12** **Aspect of the panels II-1, II-5 and II-6 after exposure to neutral salt spray**			
Creepage (mm)	1,5	2,0	1,7

	Adhesion (psi)	Failure description
Panel II-1	710	95 % B (cohesive failure of the primer coat). 5 % Y/Z (adhesive failure between the adhesive and t dolly).
	560	100 % B (cohesive failure of the primer coat).
Panel II-5	590	100 % B (cohesive failure of the primer coat).
	900	100 % B (cohesive failure of the primer coat).
Panel II-6	590	100 % B (cohesive failure of the primer coat).
	610	100 % B (cohesive failure of the primer coat).

Figure 13
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after Salt Spray exposure

Type III: Primer (Mixture) + Intermediate Coat + Top Coat

	Panel III-9	**Panel III-10**	**Panel III-11**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10
 **Figure 14** **Aspect of the panels III-9, III-10 and III-11 after exposure to neutral salt spray.**			
Creepage (mm)	1,5	1,9	1,5

	Adhesion (Mpsi)	Failure description
Panel III-9	930	80 % B (cohesive failure of the primer coat). 20 % Y/Z (adhesive failure between the adhesive and dolly).
	930	100 % B (cohesive failure of the primer coat).
Panel III-10	640	95 % B (cohesive failure of the primer coat). 5 % Y/Z (adhesive failure between the adhesive and
	550	80 % B (cohesive failure of the primer coat). 20 % Y/Z (adhesive failure between the adhesive and dolly).
Panel III-11	940	100 % B (cohesive failure of the primer coat).
	680	100 % B (cohesive failure of the primer coat).

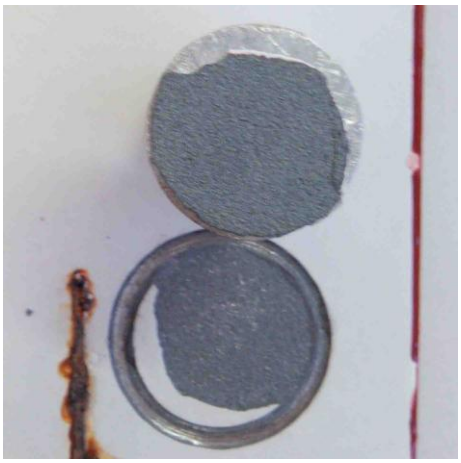


Figure 15
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after Salt Spray exposure

Resistance to Humidity in Condensation Atmosphere (720 hours) and his related Adhesion performances

Type I: Primer (Dust) + Intermediate Coat + Top Coat

	Probeta I-28	**Probeta I-29**	**Probeta I-30**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10

Figure 16
Aspect of the panels I-28, I-29 and I-30 after exposure to humidity in condensation-water atmosphere.

	Adhesion (psi)	Failure description
Panel I-28	1390	100 % A/B (adhesive failure between substrate and primer coat).
	1030	90 % A/B (adhesive failure between substrate and primer coat). 10 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-29	1290	100 % A/B adhesive failure between substrate and primer coat).
	1390	80 % A/B (adhesive failure between substrate and primer coat). 20 % Y/Z (adhesive failure between the adhesive and the dolly).
Panel I-30	1440	100 % A/B (adhesive failure between substrate and primer coat).
	1200	100 % A/B (adhesive failure between substrate and primer coat).

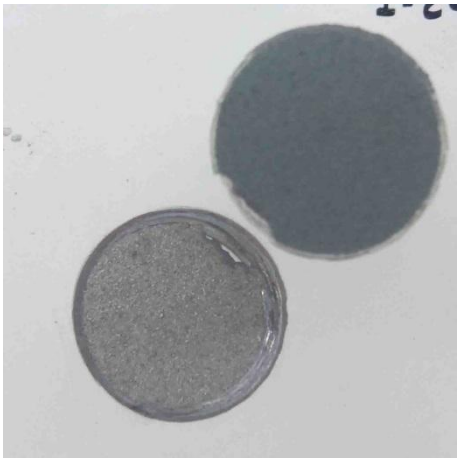


Figure 17
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after exposure in condensation-water atmosphere resistance test

Type II: Primer (Flake) + Intermediate Coat + Top Coat

	Panel II-7	**Panel II-8**	**Panel II-9**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10

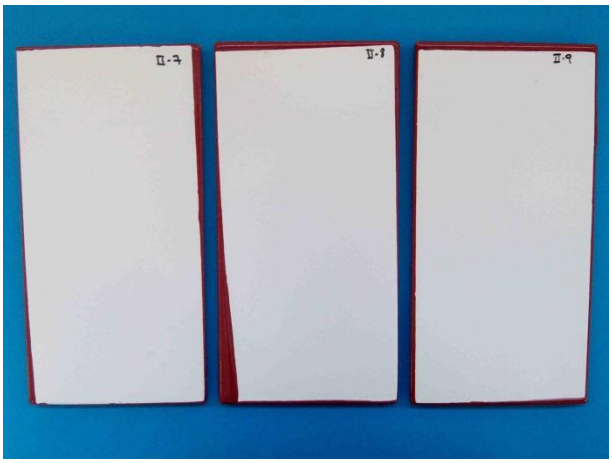


Figure 18
Aspect of the panels II-7, II-8 and II-9 after exposure to humidity

	Adhesion (psi)	Failure description
Panel II-7	1100	100 % B (cohesive failure of the primer coat).
	840	100 % B (cohesive failure of the primer coat).
Panel II-8	1100	100 % B (cohesive failure of the primer coat).
	1190	100 % B (cohesive failure of the primer coat).
Panel II-9	1230	100 % B (cohesive failure of the primer coat).
	1100	100 % B (cohesive failure of the primer coat).

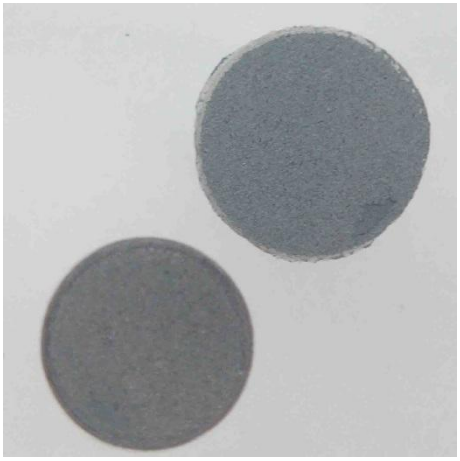


Figure 19
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after exposure in condensation-water atmosphere resistance test

Type III: Primer (Mixture) + Intermediate Coat + Top Coat

	Panel III-12	**Panel III-14**	**Panel III-15**
Degree of blistering *(ASTM D-714)*	10	10	10
Degree of rusting *(ASTM D-610)*	10	10	10
Degree of cracking *(ASTM D-661)*	10	10	10
Degree of flaking *(ASTM D-722)*	10	10	10

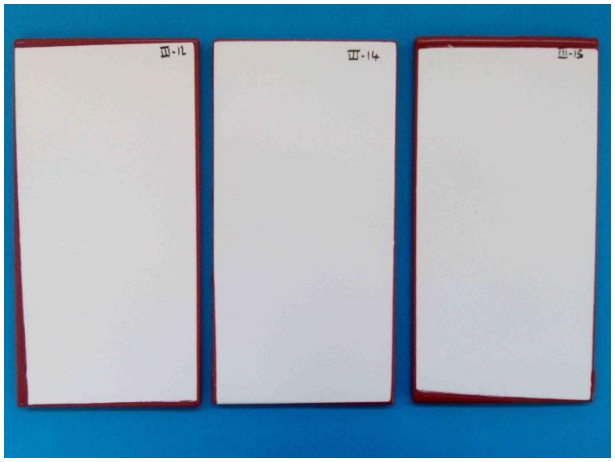


Figure 20.- Aspect of the panels III-12, III-14 and III-15 after exposure to humidity

	Adhesion (psi)	Failure description
Panel III-12	1090	100 % B (cohesive failure of the primer coat).
	1020	100 % B (cohesive failure of the primer coat).
Panel III-14	1130	100 % B (cohesive failure of the primer coat).
	940	90 % B (cohesive failure of the primer coat). 10 % Y/Z (rotura adhesiva entre el adhesivo y sufridera).
Panel III-15	1230	100 % B cohesive failure of the primer coat).
	960	100 % B (cohesive failure of the primer coat).

Figure 25
Aspect of the dolly (upper side) and surface (lower side) of performing pull-off test characteristics after exposure in condensation-water atmosphere resistance test

COMMENTS

According to results obtained in the tests performed, we can say:

Type I: Dust Primer + Intermediate coat + Topcoat (Industry Standard)

This system has a good behaviour in neutral salt spray resistance test for an exposure period of 1440 hours defined in EN ISO 12944-6 standard, for a corrosion resistance category C5-M. Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The system has also a good behaviour in humidity in condensation-water atmosphere resistance test for an exposure period of 720 hours defined in EN ISO 12944-6 standard. Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The initial values of adhesion are in agreement with the requirements specified in the EN ISO 12944-6 standard.

Type II: Flake Primer + Intermediate coat + Top coat

This system has a good behaviour in neutral salt spray resistance test for an exposure period of 1440 hours defined in EN ISO 12944-6 standard, for a corrosion resistance category C5-M. Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The system has also a good behaviour in humidity in condensation-water atmosphere resistance test for an exposure period of 720 hours defined in EN ISO 12944-6 standard. Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The initial values of adhesion are in agreement with the requirements specified in the EN ISO 12944-6 standard.

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Type III: Mixture Primer + Intermediate coat + Top coat

This system has a good behaviour in neutral salt spray resistance test for an exposure period of 1440 hours defined in EN ISO 12944-6 standard, for a corrosion resistance category C5-M. Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The system has also a good behaviour in humidity in condensation-water atmosphere resistance test for an exposure period of 720 hours defined in EN ISO 12944-6 standard.

Also, in complementary evaluation, the results of adhesion tests are in agreement with the requirements of standard before mentioned.

The initial values of adhesion are in agreement with the requirements specified in the standard.

Summary Table

	Specification	Type I (Dust)	Type II (Flake)	Type III (Mixture)
Resistance to Neutral Salt Spray ASTM B-117 (1440 Hours)				
Blistering (ASTM D-714)	Min 10	10	10	10
Rusting (ASTM D-610)	Min 10	10	10	10
Cracking (ASTM D-661)	Min 10	10	10	10
Flaking (ASTM D-722)	Min 10	10	10	10
Creepage (ISO 12944-6, Annex A)		1.1 mm	1.7 mm	1.6 mm

	Specification	Type I (Dust)	Type II (Flake)	Type III (Mixture)
Resistance to Humidity ASTM D-2247 (720 Hours)				
Blistering (ASTM D-714)	Min 10	10	10	10
Rusting (ASTM D-610)	Min 10	10	10	10
Cracking (ASTM D-661)	Min 10	10	10	10
Flaking (ASTM D-722)	Min 10	10	10	10

	Specification	Type I (Dust)	Type II (Flake)	Type III (Mixture)
Adhesion Strength ASTM D-4541				
Prior Salt Spray	Mean of 6(psi)	2580	1120	1280
	Failure	35%B, 15%C, 60%C/D	100%B	100%B
After Salt Spray	Mean of 6 (psi)	1940	610	780
	Failure	70% A/B; 30%C/D	100%B	100%B