The effective multilayer coating systems.

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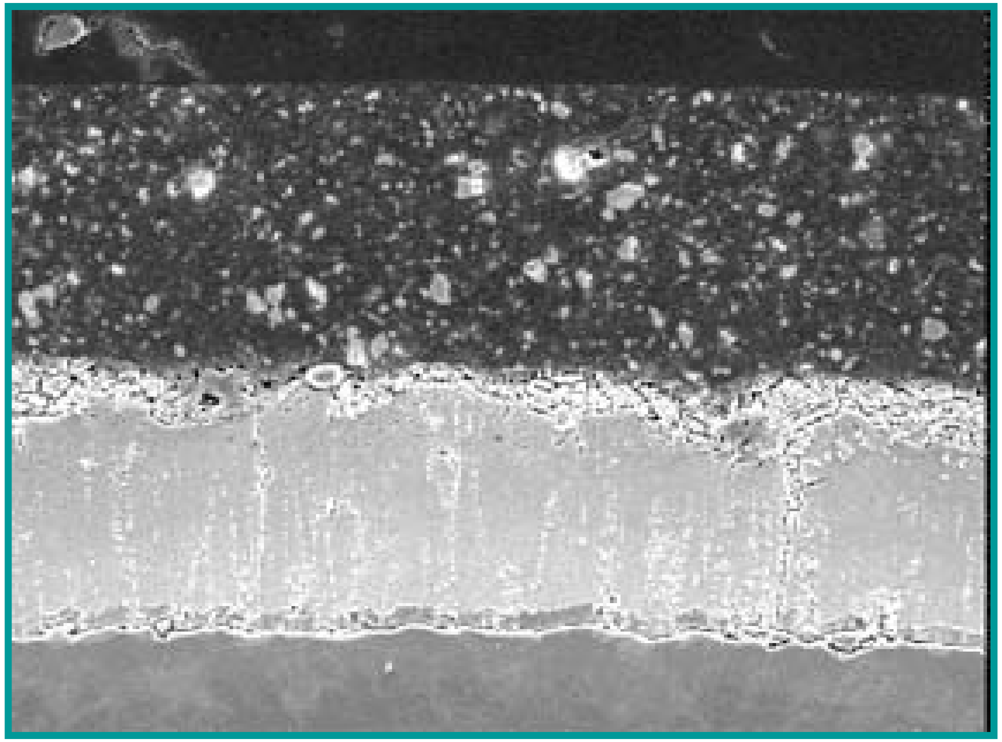
Two or more coating components are used in conjunction, creating superior multifunctional properties.

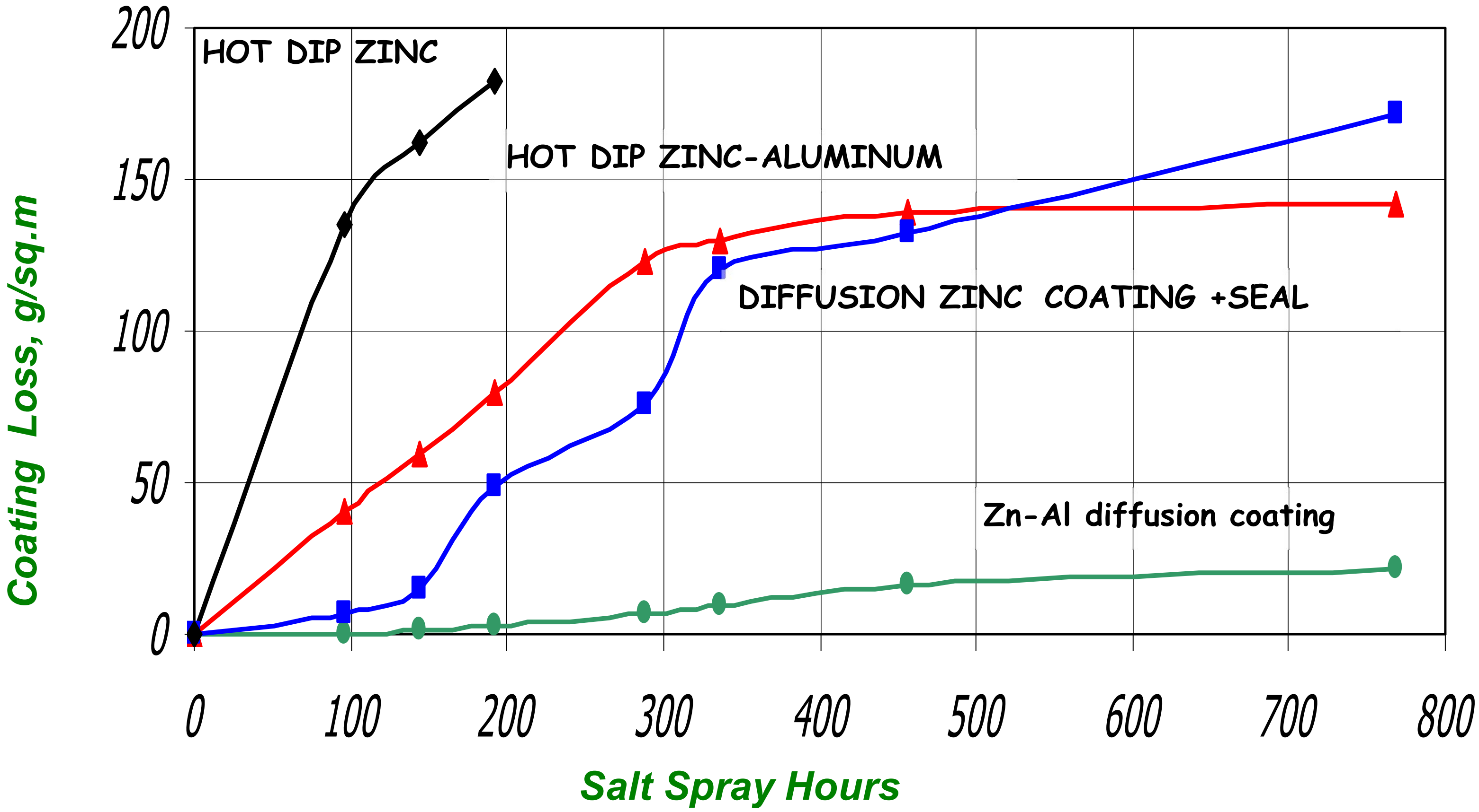


Duplex coatings for outdoor corrosion protection of steels

"Duplex coatings" –coating systems for corrosion protection of steel by sacrificial coating plus additional barrier protection coating as organic or organosilicate paint systems, powder coatings or topcoats.

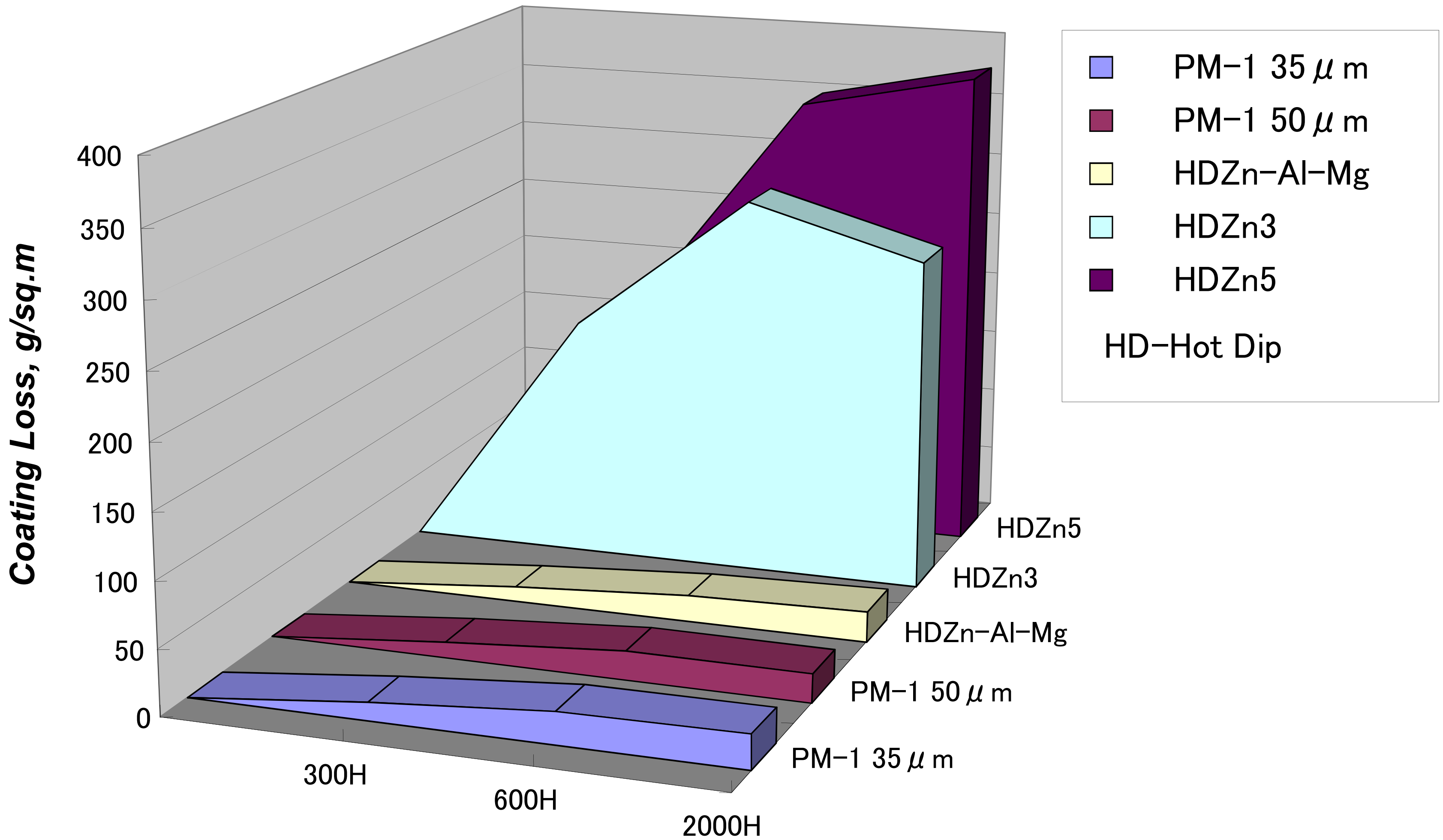
The purpose is to provide additional corrosion protection in highly corrosive environments at temperatures up to ~650ºC, with other benefits of visibility, camouflage, or when an aesthetic appearance is required, including various color combinations.

ASTM 117 Salt Spray Test, 1



Failure is reached when the area of substrate corrosion exceeds 5% of the total sample area.

ASTM 117 Salt Spray Test, 2

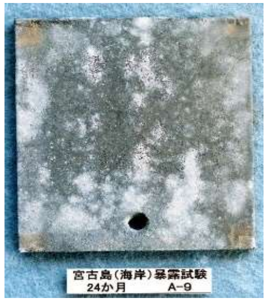


Miyakojima sea shore exposure 24 Months

PM-1 45µm

Zn galvanizing 68µm

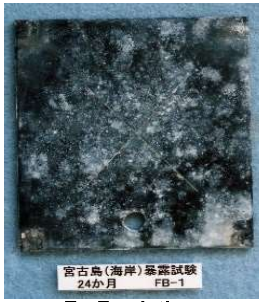
Zn galv. 112µm



Zn-Al-Mg galv.73µm

Dacro10µm

Zn-Fe plating. No baking



Zn-Fe plating
after baking

SUS304

SUS316

PM-1 -35µm

Zn galv. 77µm

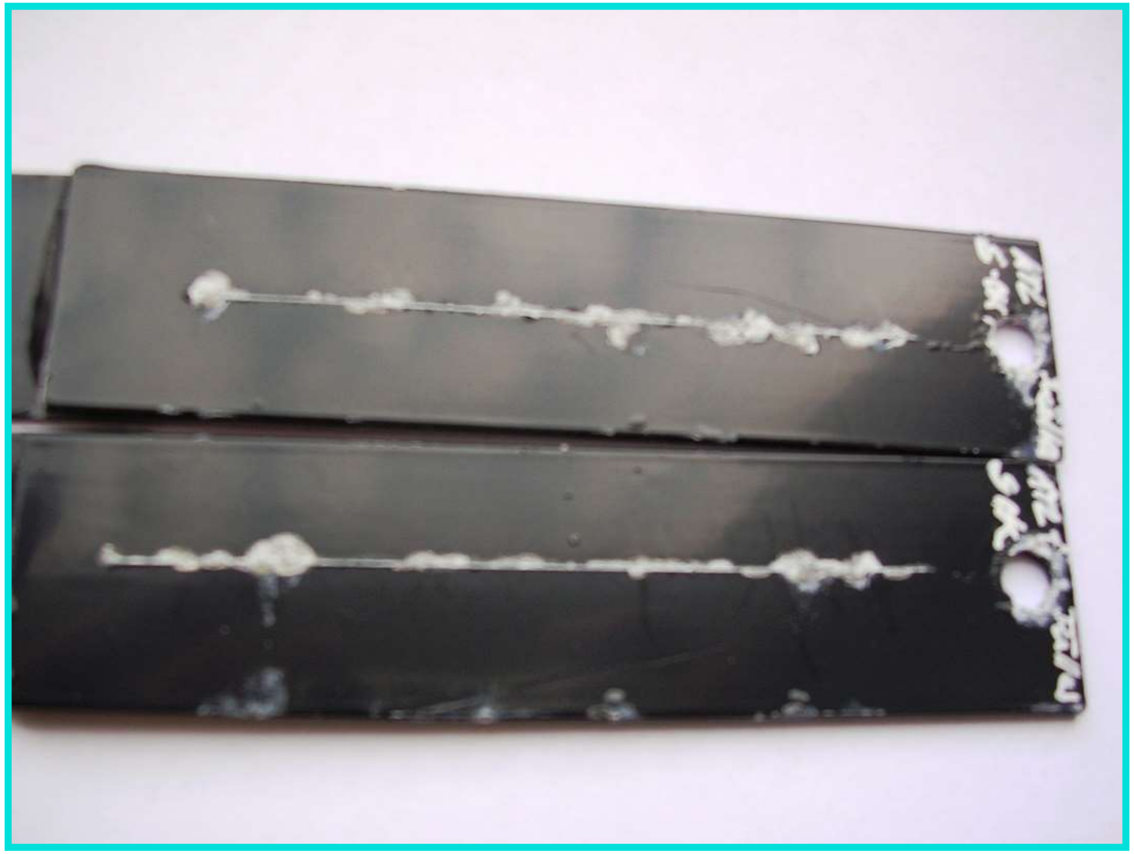
Zn galv. 49µm

Zn-Al-Mg galv. 49µm

Dacro

Zn-Fe plating after baking

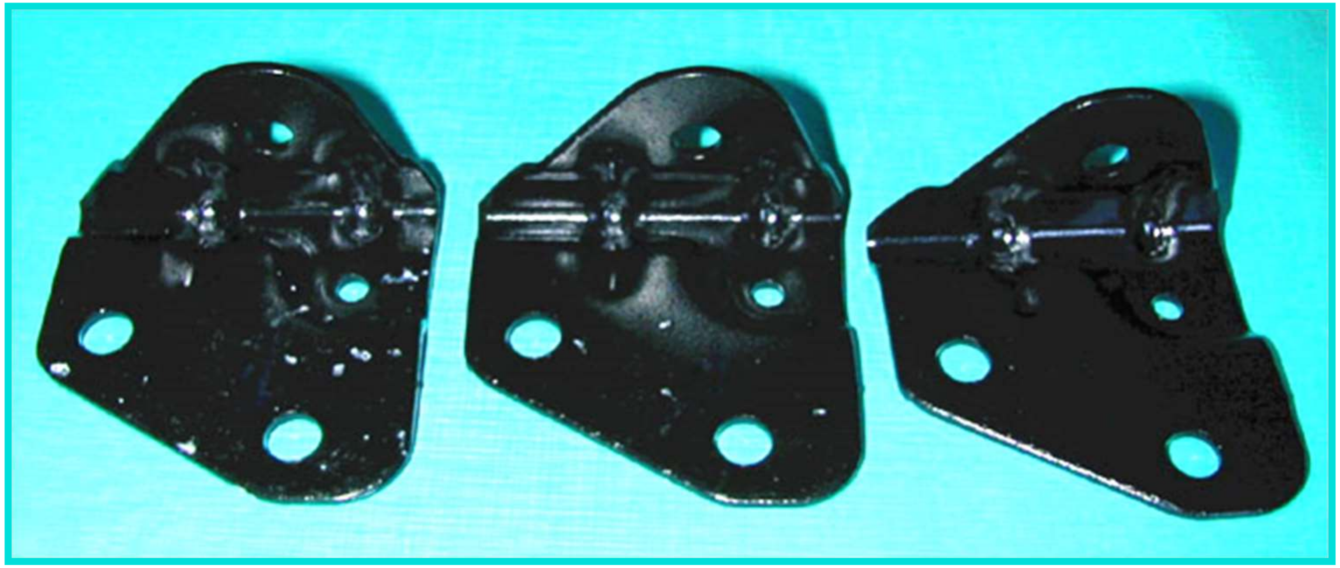
Zinc corrosion problem for duplex coatings



Typical corrosion resistance of duplex coatings: competitive Zn-Ni coating as a base for epoxy e-coating after 720 hrs testing in neutral salt spray chamber.

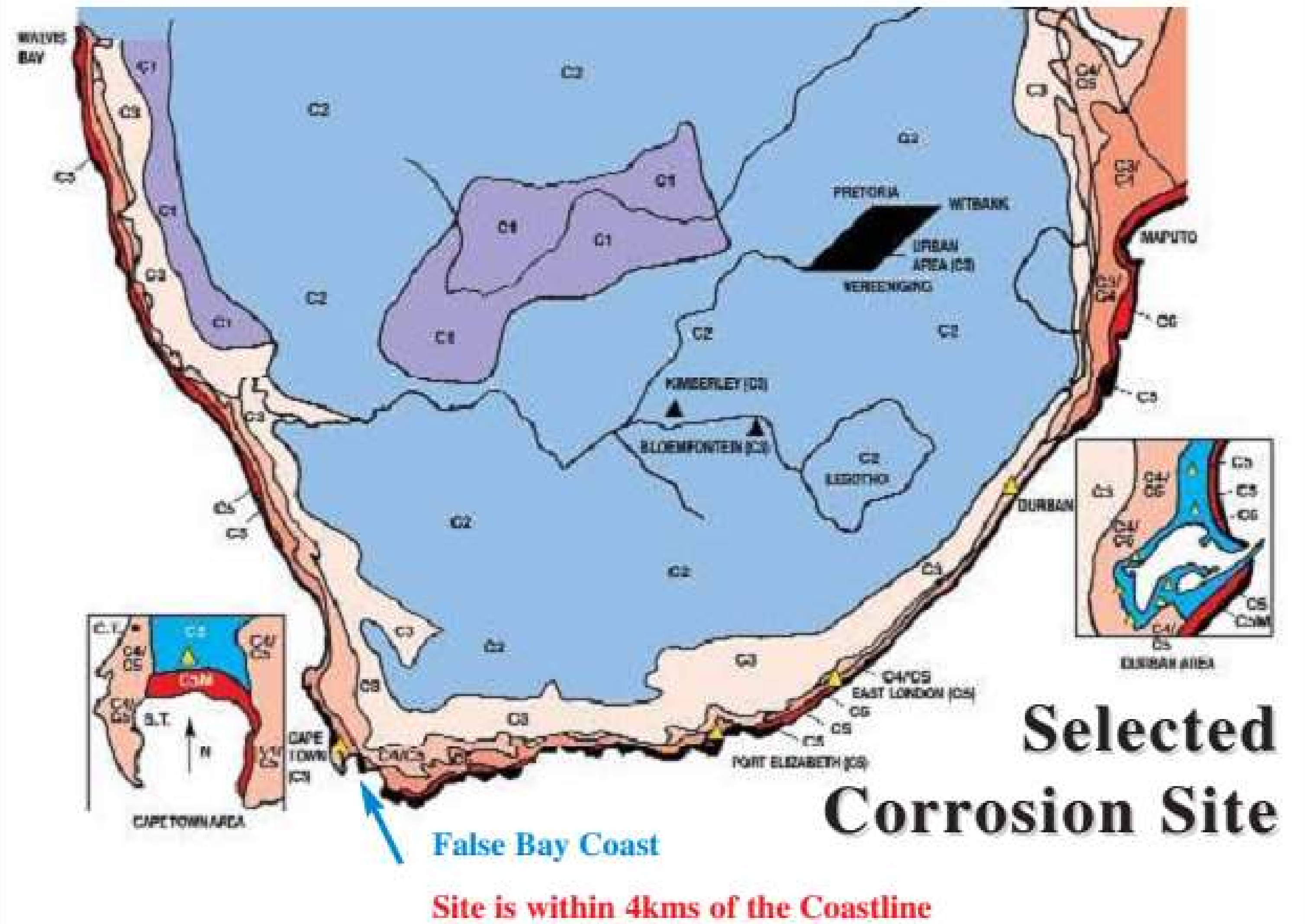
Corrosion Resistance of Duplex Coatings

- Duplex coating: Poly-metal Zn-Al diffusion coating + e-coating. PM-10 thickness is ~15 µm. E-coating thickness is ~15 µm.
- Two coated parts after 1009 hrs testing in neutral salt spray chamber (the most extreme, left, and medium) and of one non-tested part (right).



Corrosivity Category	Corrosion Rates (r_{corr}) and Service Life in Years for Hot Dip Galvanized Coated Steel (Ref ISO 1461:2009 and ISO 9223:2012)				
	Units	**Zinc**	**55µm mean coating thickness for steel ≥ 1.5 mm to ≤ 3mm (years)**	**70µm mean coating thickness for steel > 3 mm to ≤ 6 mm (years)**	**85µm mean coating thickness for steel > 6 mm (years)**
C 1	µm/a	$r_{corr} \leq 0.1$	> 80	> 80	> 80
C 2	µm/a	$0.1 < r_{corr} \leq 0.7$	< 78	> 80	> 80
C 3	µm/a	$0.7 < r_{corr} \leq 2.1$	26 to ≤ 78	33 to < 80	40 to > 80
C 4	µm/a	$2.1 < r_{corr} \leq 4.2$	13 to ≤ 26	16 to ≤ 33	20 to ≤ 40
C 5	µm/a	$4.2 < r_{corr} \leq 8.4$	6.5 to ≤ 13	8.3 to ≤ 16	10 to ≤ 20
CX	µm/a	$8.4 < r_{corr} \leq 25$	2.2 to 6.5	2.8 to 8.3	3.4 to ≤ 10

ATMOSPHERIC CORROSION OF ZINC

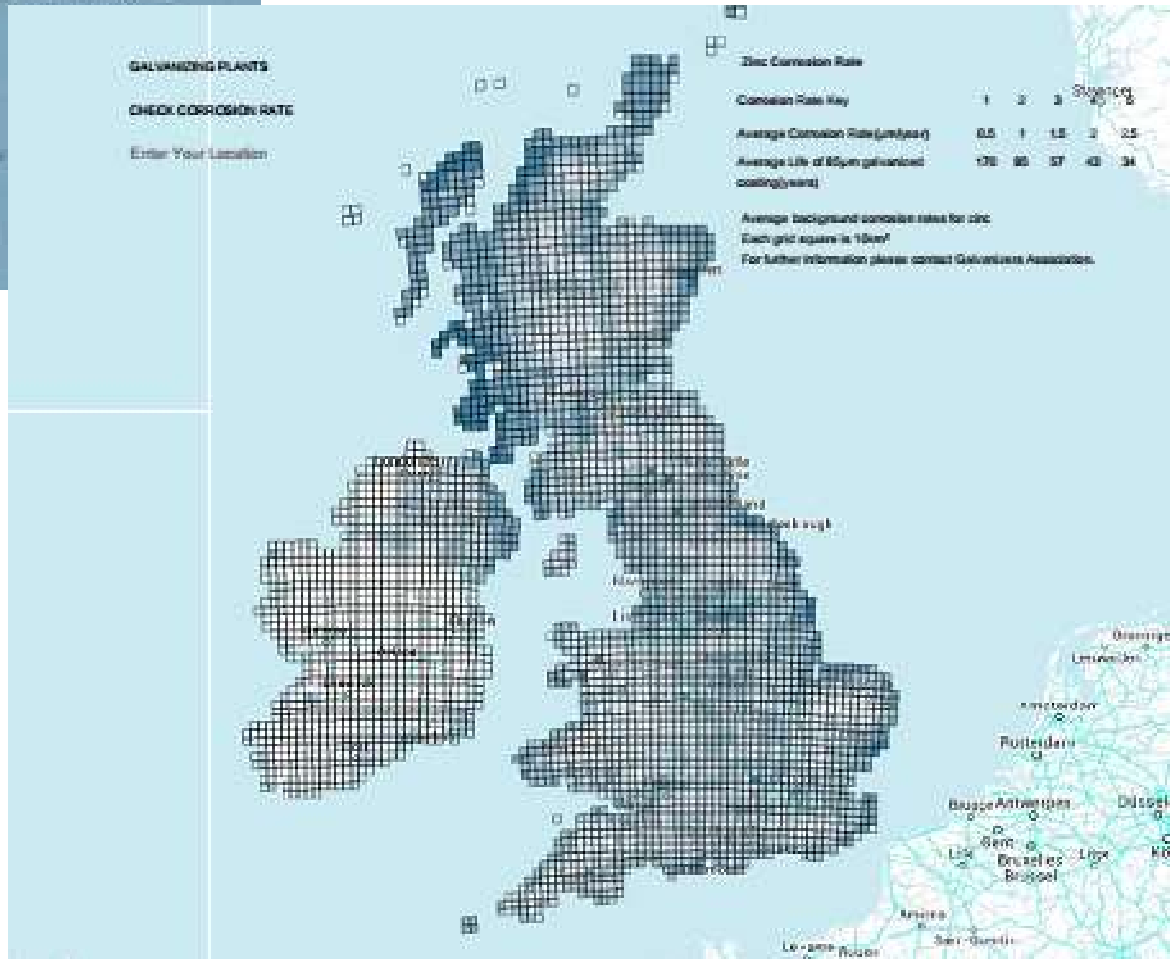


TO BE READ IN CONJUNCTION WITH ATMOSPHERIC CORROSIVITY CATEGORIES OVERLEAF

Performance Ranking			2-Year Exposure Grams Lost *		
Zinc	Steel	Location	Zinc	Steel	Steel:Zinc Loss Ratio
1	1	Norman Wells, N.W.T., Canada	0.07	0.73	10.3
2	2	Phoenix, Ariz.	0.13	2.23	17.0
3	3	Saskatoon, Sask., Canada	0.13	2.77	21.0
4	4	Esquimalt, Vancouver Island, Canada	0.21	6.50	31.0
5	6	Fort Amidor Pier, Panama, C.Z.	0.28	7.10	25.2
6	8	Ottawa, Ontario, Canada	0.49	9.60	19.5
7	22	Miraflores, Panama, C.Z.	0.50	20.9	41.8
8	28	Cape Kennedy, 1/2 mile from Ocean	0.50	42.0	84.0
9	11	State College, Pa.	0.51	11.17	22.0
10	7	Morenci, Mich.	0.53	7.03	18.0
11	15	Middletown, Ohio	0.54	14.00	26.0
12	9	Potter County, Pa.	0.55	10.00	18.3
13	20	Bethlehem, Pa.	0.57	18.3	32.4
14	5	Detroit, Mich.	0.58	7.03	12.2
15	36	Point Reyes, Calif.	0.67	244.0	364.0
16	19	Trail, B.C. Canada	0.70	16.90	24.2
17	14	Durham, N.H.	0.70	13.30	19.0
18	13	Halifax (York Redoubt), N.S.	0.70	12.97	18.5
19	18	South Bend, Pa.	0.78	16.20	20.8
20	27	East Chicago, Ind.	0.79	41.1	52.1
21	29	Brazos River, Texas	0.81	45.4	56.0
22	23	Monroeville, Pa.	0.84	23.8	28.4
23	34	Daytona Beach, Fla.	0.88	144.0	164.0
24	32	Kure Beach, N.C. 800-foot Lot	0.89	71.0	80.0
25	17	Columbus, Ohio	0.95	16.00	16.8
26	12	Montreal, Quebec, Canada	1.05	11.44	10.9
27	16	Pittsburgh, Pa.	1.14	14.90	13.1
28	10	Waterbury, Conn.	1.12	11.00	9.8
29	25	Limon Bay, Panama, C.Z.	1.17	30.3	25.9
30	21	Cleveland, Ohio	1.21	19.0	15.7
31	24	Newark, N.J.	1.63	24.7	15.1
32	33	Cape Kennedy, 60 yds. from Ocean, 30-ft. Elev.	1.77	80.2	45.5
33	35	Cape Kennedy, 60 yds. from Ocean, Ground Level	1.83	215.0	117.0
34	31	Cape Kennedy, 60 yds. from Ocean, 60-ft. Elev.	1.94	64.0	33.0
35	26	Bayonne, N.J.	2.11	37.7	17.9
36	37	Kure Beach, N.C. 80-ft Lot	2.80	260.0	93.0
37	30	Halifax (Federal Building) N.S.	3.27	55.3	17.0
38	38	Galeta Point Beach, Panama, C.Z.	6.80	336.0	49.4

* Total weight loss for 4" x 6" (10cm x 15cm approx.) test specimens


GALVANIZING PLANTS
CHECK CORROSION RATE
Enter Your Location
Glasgow
Zinc Corrosion Rate
Corrosion Rate Key 1 2 3 4 5
Average Corrosion Rate(μm/year) 0.5 1 1.5 2 2.5
Average Life of 85μm galvanized coating(years) 170 85 57 43 34
Average background corrosion rates for zinc
Each grid square is 10km²
For further information please contact Galvanizers Association.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Rotterdam
Antwerpen
Bruxelles
Brussel

Marine environment, Israel, Hertzlia

The Synergy of Duplex Systems

Duplex systems provide synergistic effect by virtue of the fact that the durability of the combined sacrificial base coating and top organic coating system is greater than the sum of the separate durability of the sacrificial coating and organic coating layer applied separately onto the steel substrate.

For the duplex system based on hot dip Zinc galvanizing the synergistic effect can be estimated mathematically as follows:

Duplex Life = factor x (zinc life + paint life)

The Synergy Of Duplex Systems.
Duplex life Factor

Environment	Synergistic Effect Increase Factor
Industrial and Marine	1,8 to ,2,0
Seawater (immersion)	1,5 to 1,6
Non-aggressive climate	2,0 to 2,7

In an environments as industrial with high humidity or high salinity coastal, ISO 9223 C5 category, where 85µm hot dip galvanizing coating life period is approximately 15 years and paint on its own 10 years, and the factor rate is 1.5, the duplex system would give a service life:

1.5 x (15 years + 10 years) = 37.5 years

Corrosivity Category	Service life in years for Duplex Coated Steel				
	Units	Hot Dip Galvanizing r_{corr}	85µm mean coating thickness for steel > 6 mm (years) **	Estimated service life of a 2 coat paint system 270 to 300µm (years)	Estimated service life of a Duplex system 355 to 385µm (years)**
C 1	µm/a	$r_{corr} \leq 0.1$	> 80	15	Not required
C 2	µm/a	$0.1 < r_{corr} \leq 0.7$	> 80	15	Not required
C 3	µm/a	$0.7 < r_{corr} \leq 2.1$	40 to > 80	12	Not required
C 4	µm/a	$2.1 < r_{corr} \leq 4.2$	20 to ≤ 40	10	(20+10) x 1.5 = 45
C 5	µm/a	$4.2 < r_{corr} \leq 8.4$	10 to ≤ 20	8	(10 + 8) x 1.5 = 27
CX	µm/a	$8.4 < r_{corr} \leq 25$	3.4 to ≤ 10	6	(3.4 + 6) x 1.5 = 14

ISO 12944-1 Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1 : General Introduction

Durability Category	12944:1998	12944-1:2018
Low (L)	2-5 years	Up to 7 years
Medium (M)	5-15 years	7-15 years
High (H)	More than 15 years	15-25 years
Very high (VH)	N/A	More than 25 years

ISO 12944-2 Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2 : Classification of environments.

Corrosivity category	Examples of typical environments (informative only)	
	Exterior	Interior
C1 very low	—	Heated buildings with clean atmospheres , e. g. offices, shops, schools , hotels
C2 low	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e. g. depots, sports halls
C3 medium	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e. g. food-processing plants, laundries, breweries, dairies
C4 high	Indus trial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
C X extreme	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and sub -tropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere
NOTE: ISO 9223.		

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NOTE: ISO 9223.		

Corrosivity category	Examples of typical environments (informative only)	
	Exterior	Interior
C4 high	Indus trial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
C X extreme	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and sub -tropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere
NOTE: ISO 9223.		

Categories for water and soil

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro - electric power plants
Im2	Sea or brackish water	Immersed structures without cathodic protection (e .g . harbour areas with structures like sluice gates, locks or jetties)
Im3	Soil	Buried tanks, steel piles , steel pipes
Im4	Sea or brackish water	Immersed structures with cathodic protection (e .g. offshore structures)
NOTE For corrosivity category Im1 and Im3, cathodic protection can be used with a paint system tested accordingly		

ISO 12944-6:2018

Table 1 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating for atmospheric corrosivity categories

		Test regime 1			Test regime 2
Corrosivity category as defined in ISO 12944-2	Durability ranges according to ISO 12944-1	ISO 2812-2 (water immersion) h	ISO 6270-1 (water condensation) h	ISO 9227 (neutral salt spray) h	Annex B (cyclic ageing test) h
C2	low	—	48	—	—
	medium	—	48	—	—
	high	—	120	—	—
	very high	—	240	480	—
C3	low	—	48	120	—
	medium	—	120	240	—
	high	—	240	480	—
	very high	—	480	720	—
C4	low	—	120	240	—
	medium	—	240	480	—
	high	—	480	720	—
	very high	—	720	1 440	1 680
C5	low	—	240	480	—
	medium	—	480	720	—
	high	—	720	1 440	1 680
	very high	—	—	—	2 688

ISO 12944-6:2018

Table 2 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating for immersion categories

Immersion category as defined in ISO 12944-2	Durability ranges according to ISO 12944-1	ISO 2812-2 (water immersion) h	ISO 6270-1[a] (water condensation) h	ISO 9227[a] (neutral salt spray) h
Im1	high	3 000	1 440	—
	very high	4 000	2 160	—
Im2	high	3 000	—	1 440
	very high	4 000	—	2 160
Im3	high	3 000	—	1 440
	very high	4 000	—	2 160

[a] Only relevant if systems are partially or temporarily immersed/buried.

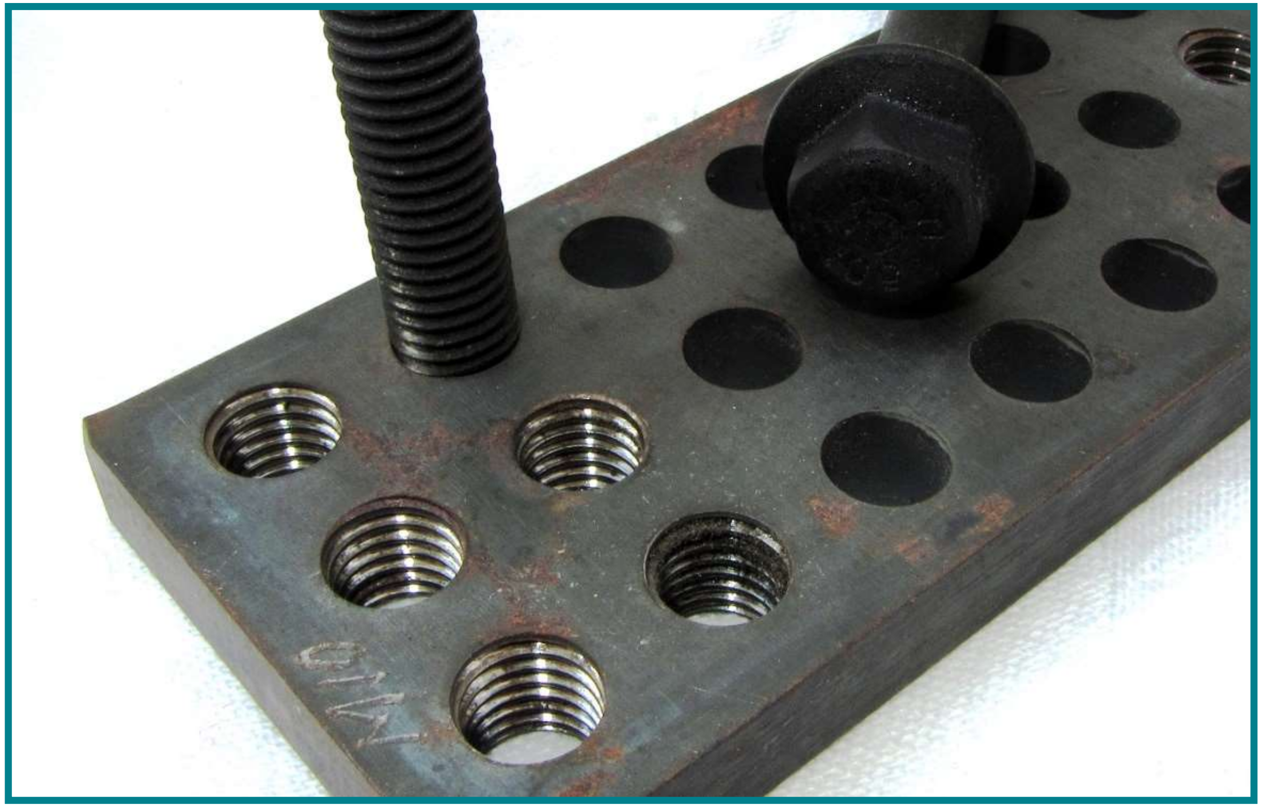
Unique Thin Powder Coatings

- **PET – Epoxy powder topcoat for high corrosion protection.**
- **PPT – Polyester powder topcoat for medium corrosion protection, UV resistant.**
- **PEPT – Epoxy+polyester duplex topcoat for high corrosion protection, UV resistant.**
- **PPAT - Polyamide topcoat for high corrosion protection, UV resistant and wear resistance.**
- **PSiT - Organosilicone topcoat for applications up to 650° C.**
- **Other powder coatings' materials are possible to apply.**

Corrosion resistance duplex coatings for elevated temperature.

Sacrificial diffusion polymetal base coating and barrier organosilicon topcoat.

Corrosion resistance duplex coatings with required friction coefficient.



Thread forming fasteners and other applications.

Many Thanks!

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