Hot Dip Galvanized Information Sheet No.8
Corrosion of Zinc – Corrosivity of Atmospheres

Used by the HDGASA to determine Service Life of Hot Dip Galvanized Steel Exposed to Various Atmospheric Environments

Reference Source: ISO 9223:2012

Summary of ISO 9223 Specification

The ISO 9223 specification considers key factors in determining the atmospheric corrosion rate of carbon steel, zinc, copper and aluminium. These factors are:

1) Time of wetness, Table B.1 – Classification of time of wetness (τ) being the period that the zinc surface is covered by liquid containing the corrosive elements (Electrolyte).
2) Outdoor concentration, Table B.2 – Some of the most important range of pollutants
3) Pollution by sulphur containing substances represented by (SO_2, Table B.3
4) Airborne pollution containing salinity, Table B.4 – represented by chloride usually in the form of chlorides carried in the prevailing winds from off the sea.

NB: This information sheet will only consider the corrosion rates of zinc.

Classification of atmospheric corrosivity include three additional ISO specifications, these are:

1. Guiding corrosion values of each category for specific metals ISO 9224
2. Measurement of environmental parameters affecting atmospheric corrosivity ISO 9225 and
3. Determination of corrosion loss on standard specimens ISO 9226

Tables used in the Development of the Atmospheric Classifications (Reference source ISO 9223:2012)

Various tables are published within the ISO 9223:2012 specifications and are listed here for reference purposes. Detailed data pertaining to each of these tables are contained within the ISO 9223:2012 specification.

Table B.1 – Time of wetness in different exposure conditions (τ)
Table B.2 – Outdoor concentration of some of the most important pollutants in different types of environments (a range of pollutants)
Table B.3 – Grouping of pollution by sulphur containing substances represented by SO_2
Table B.4 – Grouping of pollution by airborne salinity represented by chloride
Table C.1 – Description of typical atmospheric environments related to the estimation of corrosivity categories

Table 1 – Description of Typical Atmospheric Environments related to the Estimation of Corrosivity Categories

Category	Corrosivity	Typical environments - Examples	
		Indoor	**Outdoor**
C 1	Very Low	Dry, air-conditioned with low relative humidity and insignificant pollution, e.g. offices, schools, museums.	Dry zone very low pollution and time of wetness, e.g. certain deserts, central Artic/Antarctica
C 2	Low	Unheated, no air-conditioning with restricted variation in temperature, humidity and minimum condensation and pollution, e.g. storerooms, sports halls	Temperate zone (dry or cool) with minimum pollution ($SO_2 < 5$ µg/m³), short time of wetness, e.g. rural areas, subarctic areas, some arid and desert areas, small villages or towns
C 3	Medium	Moderate frequency of condensation, pollution from process plant, e.g. food-processing, laundries, breweries, dairies	Temperate zone with medium (SO_2 5 to ≤ 30µg/m³) or some effect of chlorides, e.g. urban areas, between one to thirty kilometres (depending on prevailing winds, buildings, vegetation and topography) from the ocean, or within one hundred metres of sheltered coastal areas with low chloride deposits
C 4	High	High frequency of condensation, time of wetness, high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate, subtropical to tropical, low to high pollution (SO_2 30 to ≤ 90µg/m³) or substantial chloride effect, e.g. < one kilometre of the ocean or within one hundred metres of sheltered coastal areas and outside the splash zone of salt water
C 5	Very High	High frequency of condensation, periods of time of wetness, and/or high pollution from production process, e.g. certain mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones	Subtropical to tropical, periods of time of wetness, very high industrial pollution (SO_2 90 to ≤ 250µg/m³) or significant chloride effect/deposits, e.g. industrial polluted areas, jetties and offshore structures, within a few hundred metres of the ocean and certain exposed areas along the coastline
CX	Extreme	Almost permanent condensation or extended periods of exposure to extreme humidity and/or high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and other pollutants and particulate matter	Subtropical to tropical, extended time of wetness, very high industrial pollution (SO_2 >250µg/m³) or significant and extended chloride effect/deposits, e.g. highly industrialised and polluted areas, jetties and offshore structures, within a few hundred metres of the ocean with extended periods of on-shore prevailing winds and certain exposed areas along the coastline and within the splash zone of salt water

The typical descriptions detailed in Table 1 are intended as a general guide only and it is recommended that a review of actual site conditions should be undertaken before finalising the applicable corrosive category. A general review of existing hot dip galvanized structures is an ideal method used to establish the corrosive conditions in the general area of a particular site.

Table 2 – Estimated Service Life for Hot Dip Galvanized Steel (Zinc) complying with SANS 121 (ISO 1461:2009) and subjected to Atmospheric Environments Classified in terms of ISO 9223:2012

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

The conservative and wide range of service life estimates shown in Table 2 are only intended as a general guide. It is a recommended requirement that a more detailed assessment of the actual site environmental conditions should be investigated in order to refine longevity expectations for hot dip galvanized carbon steel.

Duplex Systems

Duplex systems (hot dip galvanizing plus a suitable paint system) provide synergy by virtue of the fact that the durability of the combined hot dip galvanized substrate and top organic coating system is greater than the sum of the separate durability's of the two forms of corrosion control.

Synergistic effect can be estimated mathematically as follows:

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

Table 3 - Synergistic Protection Provided by the Combined use of a Zinc Coating and a Paint Coating. (Refer Jan van Eijnsbergen and Porter)

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

The synergy factors vary from 1,5 in the extreme corrosive environments to 2,7 in less-aggressive environments. In a highly aggressive environment (ISO 9223:2012 C4, C5 and CX corrosivity categories) hot dip galvanizing on its own tends to become marginal in terms of service life. Duplex systems have been shown to provide a significant service life extension. On the bases of the synergistic effect increase factor of 1.5, table 4 has been developed.

Table 4 - Estimated Service Life for Duplex system (zinc plus paint) Complying with SANS 121 (ISO 1461:2009) and Subjected to Atmospheric Environmental Classified in terms of ISO 9223:2012

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

** Assumes the worst case in terms of hot dip galvanizing figures used in calculating Duplex service life. The document "*Duplex Coating – An overview*", is available from the Association