40 - PREDICTING THE LIFE OF GALVANIZED COATINGS

INTRODUCTION

The major component in hot dip galvanized coatings is zinc. Zinc-based coatings in one form or another, have been used to protect steel from corrosion for more than 150 years. As a result, a great deal of performance data has been accumulated on the performance of zinc-based coatings in a wised range of environments.

White rust on newly galvanized guard rail section caused by nesting items in wet conditions.

The vast majority of galvanized products are used in atmospheric exposures, and in this environment, it is possible to accurately predict the life of a galvanized coating, given that its original coating thickness is know and the environment in which it is exposed is correctly classified.

Unlike most other protective coating systems that fail by other mechanisms, galvanized coatings always fail from the outside, in. This occurs through weathering of the zinc's surface through a range of oxidation reactions that are determined by the variables of the local environment.

ZINC CORROSION MECHANISMS

In the hierarchy of metals, zinc is relatively reactive, but like aluminium, relies on oxide films that develop on its surface to provide its superior corrosion resistance in atmospheric environments. Zinc is also an amphoteric metal, in that it reacts with both acids and alkalis.

These old (l) and new (r) fence panels show the life cycle of a galvanized coating. Galvanized coatings are slowly eroded by oxidation of the surface. The oxidised lower layers of the zinc-iron alloy layer of the galvanized coating indicate that the coating is nearing the end of its life.

This means that zinc works best as a protective coating in pH conditions that are in and around the neutral range of pH 7.

When steel is freshly galvanized, the zinc coating has not developed any protective oxidation films. Many manufacturing processes, such as hot dip galvanizing, apply a passivation film (usually sodium dichromate based) to the zinc's surface to provide protection from accelerated corrosion in the youth period of the coating.

The type of oxide film formed on the surface will depend on the exposure location and condition. In normal atmospheric exposures, the main reactions are as follows:

1. Initial oxidation $2Zn + O_2 = 2ZnO$ (unstable)
2. Hydration $2Zn + 2H_2O + O_2 = 2Zn(OH)2$ (unstable)
3. Carbonation $5Zn(OH)2 + 2CO_2 = 2ZnCO_3.3Zn(OH)2 + 2H_2O$ (stable)
4. In salty air $6Zn + 4CO_2 = 8NaCl + 7O_2 + 6H_2O = 4Zn(OCl)2 + 2Zn(HCO_3)2 + 8NaOH$ (unstable)
5. Industrial atmospheres $Zn + O_2 + SO_2 = ZnSO_4$ (unstable)

For these reactions to proceed, moisture must be present. If the surface remains dry, very little oxidation will occur. Thus, the time of wetness of the surface is an important factor in the determination of zinc coating life.

For the carbonation phase of the oxidation to occur, good air circulation is necessary to provide a source of carbon dioxide.

Very rapid corrosion of zinc coatings can occur in their 'youth' period if they are stored in poorly ventilated, damp conditions. The oxidation reaction proceeds to the hydration stage (Point 2 above),

and will continue while moisture is present. Nested galvanized products are particularly prone to this form of accelerated corrosion, which is commonly called white rust or white storage stain.
The stable carbonate film, formed on the zinc's surface are relatively thin – usually only a few microns in thickness. Any action that removes these oxide films by abrasion or erosion will accelerate the consumption of the underlying zinc, as more zinc is consumed in the re-formation of the oxide films.


Severe marine environments such as this ocean front site may have zinc corrosion rates of around 20 microns or more per year. In this environment, the galvanized coating on the guardrail has a predicted life of 3-5 years.

While sulfates arising from industrial activities can significantly increase the corrosion rate of zinc coatings, the stringent controls on sulfur-based emissions from industry has reduced the levels of sulfur oxides in the atmosphere by more than 90% since the 1970's.

The main drivers of corrosion of zinc coatings are the time the coating is wet and the presence of chlorides. Much of Australia's urban areas are in maritime environments, influenced to a greater of lesser degree by airborne chlorides generated from ocean surf.

There is a large body of data on the performance of zinc in contact with chemicals of all types. The large number of chemicals contained in this data makes it impractical to reproduce the information in the INGAL Specifiers Manual.

Should you require information about the performance of zinc (galvanized) coatings in contact with any specific chemical, contact our technical services section at tech@iindgalv.com.au .

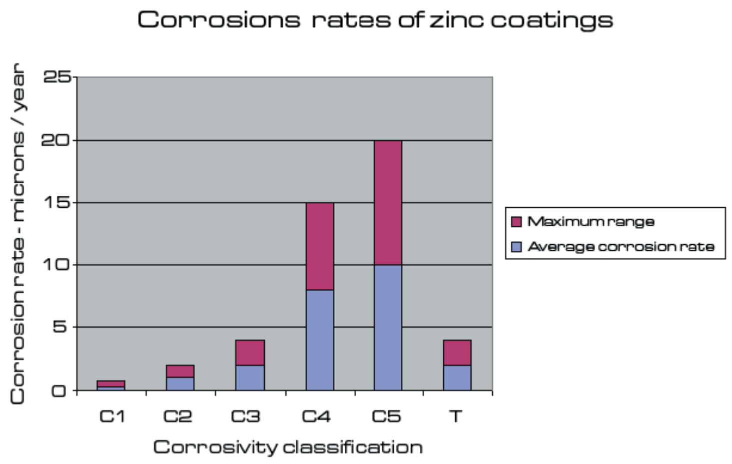
CORROSION RATES OF ZINC COATINGS
While galvanized coatings are frequently specified in terms of coating mass (grams per square metre), in practice, coating thickness is used as a measure of the coating's compliance with standards, as it can be readily measures non-destructively.

If galvanized coatings are exposed to a particular environment, they will corrode at an approximately linear rate over time. One this corrosion rate is established, the expected life of the coating can be calculated with a high degree of confidence.

For example, a typical hot dip galvanized coating on a structural steel section is in the order of 100 microns in thickness. The corrosion rate zinc in the Western Suburbs of Sydney is typically 1-2 microns per year. On that basis, the 100 micron coating in that area should have a maintenance-free life of 50-75 years.

There are a number of Australian Standards either published or in draft form that contain information on the classification of the corrosivity of atmospheres. These include AS/NZS 2312 and AS/NZS 2699.

Unfortunately, the corrosivity classification system in the existing Australian Standards is inconsistent. For example, AS/NZS 2312 uses an A,B,C,D, E & F category classification which is largely narrative and somewhat subjective.



AS/NZS 2699, on the other hand, uses an R0, R1, R2, R3, R4 and R5 rating criteria that is based on airborne salt (chloride) deposition.

The draft standard – AS 4312 Corrosivity zones in Australia, uses a C1,C2, C3, C4 and C5 rating system that is consistent with the system used in International (ISO) standards, specifically ISO 9223.

The corrosivity classifications in each of these standards are essentially guidelines. Industrial Galvanizers INGAL Corrosion Mapping System has been developed in partnership with CSIRO to better estimate the corrosivity of atmospheres throughout Australia. Details of this service are provided elsewhere in the INGAL Specifiers Manual.

The corrosivity classifications in the above charts are detailed below in condensed form.

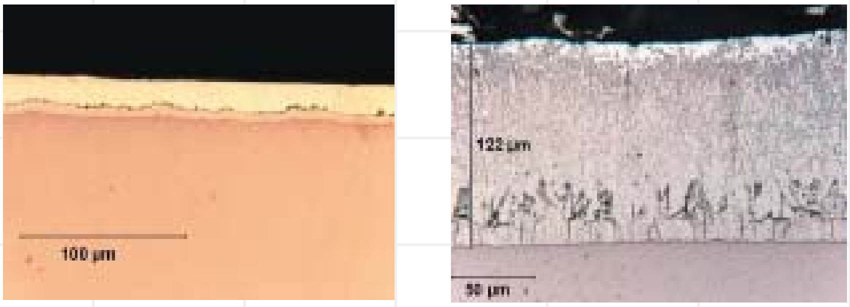
C1	Very low – internal and sheltered locations remote from marine influence.
C2	Low – Rural areas, inland towns and cities.
C3	Medium – Most coastal urban areas more than one kilometer from the ocean surf
C4	High - Within one kilometer of ocean surf, depending on prevailing wind direction and topography.
C5	Very high – Ocean front locations subject to ocean surf aerosols.
T	Tropical – Northern Australian regions subject to monsoon seasonal conditions.

For any corrosivity categories of C3 or below, galvanized coatings will provide whole-of-life protection for steel against corrosion.

OTHER FACTORS AFFECTING COATING LIFE

Hot dip galvanized coatings versus zinc.
Hot dip galvanized coatings are not technically zinc coatings, but are largely made up of zinc-iron alloys that usually comprise between 50% to 100% of the coating. The thicker the galvanized coating, the closer the percentage of zinc-iron alloys approached 100%.

The corrosion characteristics of the zinc-iron alloy layer has not been investigated to the extent of pure zinc coatings. However, research undertaken by CSIRO and observations of hot dip galvanized items in service indicate that the corrosions rate of the alloy layers is significantly lower that that of pure zinc. At a marine test site at Point Fairy, Victoria, hot dip galvanized coatings have been found to corrode at less than half the rate of zinc coatings exposed at the same site.



These two micrographs illustrate the difference between a continuously galvanized coating (l) and a hot dip galvanized coating (r) The continuously galvanized coating is almost 100% zinc while the hot dip galvanized coating, as well as being significantly thicker (122 microns versus 20 microns) is almost 100% zinc-iron alloy.

The shape of the steel structure

The shape and orientation of a structure can have a significant influence on the durability of the galvanized coating. The time the structure remains wet, and its ability to collect corrodents on its surface will affect the durability of the galvanized coating.

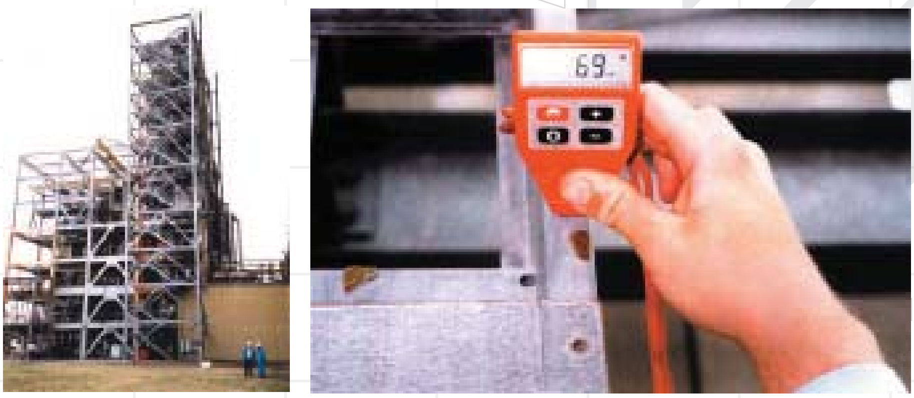
For example, standard high voltage lattice towers constructed from steel angles bolted together are always hot dip galvanized. The galvanized coating on these structures has a much shorter service life that an identical thickness coating used on steel monopole structures in the same environments.

This is because the monopoles have smooth vertical surfaces with no overlapping joints or flat surfaces. They dry quickly and do not accumulate contaminants.

SUMMARY

The thickness of a galvanized coating is the factor that determines its durability. Once the environmental conditions have been identified, it is a simple task to calculate the expected life of a galvanized coating of known thickness with a high degree of confidence.

The shape of a structure will have a significant impact on durability of the galvanized coating. The lattice tower has many overlap[ping joints and horizontal or upward facing surfaces. The galvanized monopole's surface is smooth and vertical. The galvanized coating on the pole will have at least 2X the life of that on the lattice tower.



The Orica petrochemical plant at Port Botany, Sydney was galvanized in 1977. Thickness testing of the galvanized coating after 25 years indicated that the coating has a remaining service life exceeding 30years, with nearly 70 microns of coating remaining of the original 100 microns.

INGAL
SPECIFIERS MANUAL

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

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