DETERMINING THE SERVICE LIFE OF HOT DIP GALVANIZED COATINGS

Galvanized coatings have limited performance in ocean-side environments, although vertical structures such as poles are longer lasting than horizontal structures like the guard rail. Corrosion rates in these locations can exceed 15 microns/year.

INTRODUCTION

When a protective coating is applied to steel, it is intended to provide protection from corrosion for a pre-determined period of time. The way that protective coatings work is determined by their technology and a number of interrelated factors. One of the most important, along with the design characteristics of the coating itself, is the adequacy of surface preparation.

Most applied coatings (paints) protect the substrate by inserting a barrier between the steel and the external environment. The priming systems used with these coatings may also have a chemical interaction with the steel's surface that assists in inhibiting corrosion, through the use of pigments such as zinc phosphate, zinc dust or other proprietary ingredients.

Metallic coatings used for corrosion prevention are almost all exclusively zinc-based, as either hot dipped or electrolytically applied zinc or zinc alloys. Of these galvanized coatings are the most common; either continuously applied or batch galvanized. It is the unique characteristics of zinc-based coatings that allow their service life to be estimated with a high degree of confidence.

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.

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.

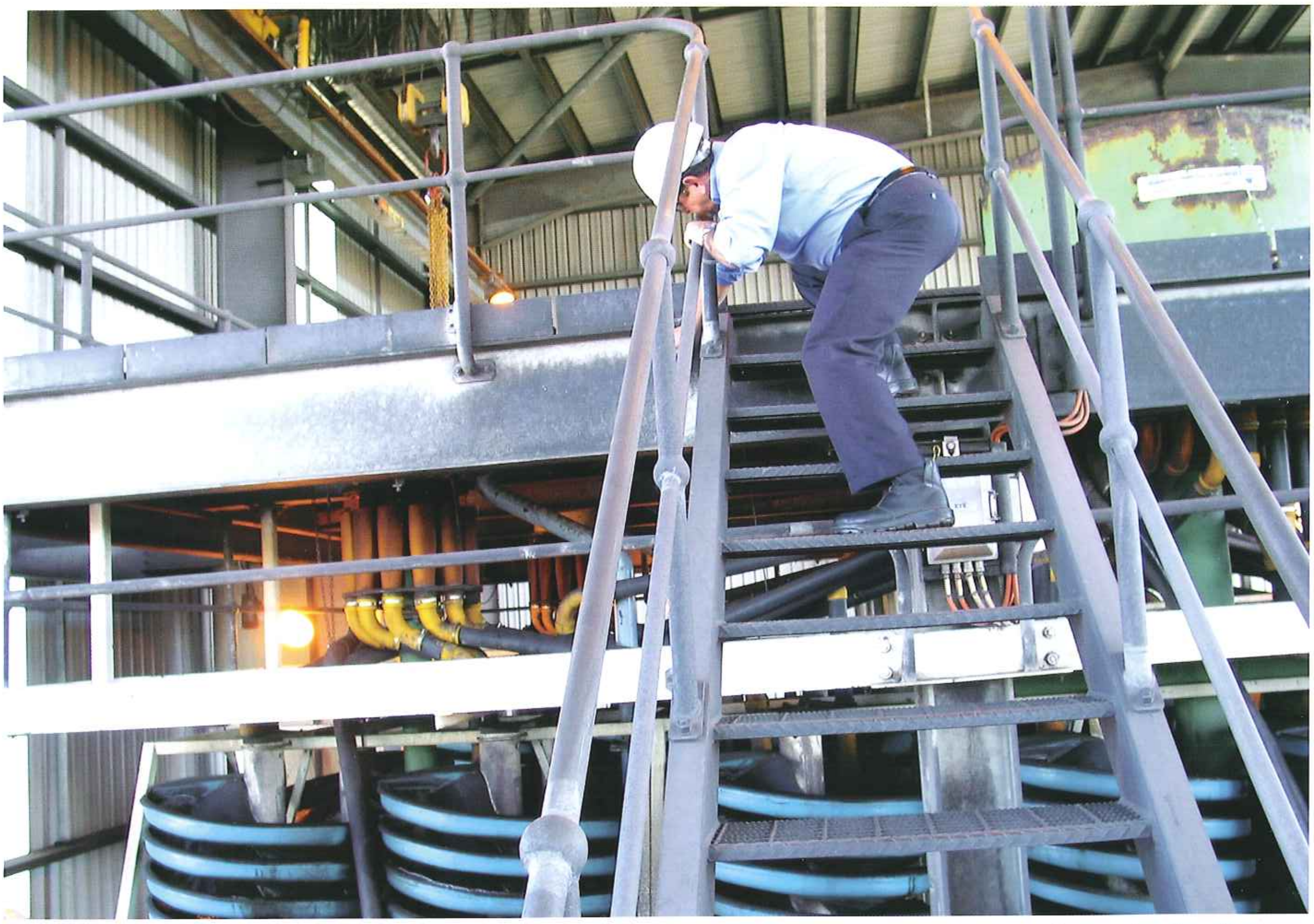
Unlike most other protective coating systems that fail by other mechanisms, galvanized coatings always fail from the outside, in. This occurs through weathering of the zinc's surface through a range of oxidation reactions that are determined by the variables of the local environment.

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.

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.



Coal treatment plants were originally considered too aggressive an environment for galvanized coating. This central Queensland hot dip galvanized coal treatment plant was subject to a detailed coating survey after 12 years of operation and no significant coating loss was found throughout the facility. Case history studies remain the most effective measure of coating performance.

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 (see left - point 2), 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.

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.

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. Once this corrosion rate is established, the expected life of the coating can be calculated with a high degree of confidence.

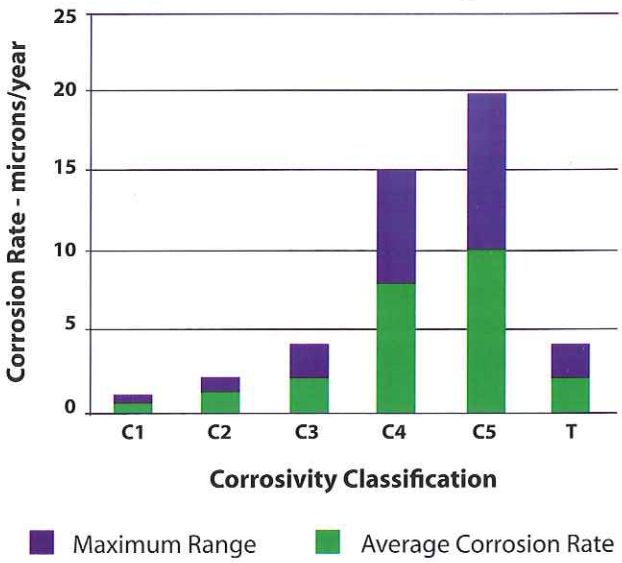
For example, a typical hot dip galvanized coating on a structural steel section is in the order of 100 microns in thickness. The corrosion rate zinc in the Western Suburbs of Sydney is typically 1-2 microns per year. On that basis, the 100 micron coating in that area should have a maintenance-free life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

There are a number of Australian Standards 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. *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.

Corrosion Rates of Zinc Coatings



This galvanized bracket is believed to be one of the oldest hot dip galvanized items in Australia, originally imported from Holland for the Townsville to Charters towers telegraph line in 1888. Remaining galvanized coating thickness exceeds 300 microns, indicating a coating life exceeding 500 years had it remained in service.

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.

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.

Galvanized power and lighting poles are a good indicator of local corrosion rates for galvanized coatings. most poles of this type can be accurately dated. This one was installed in May, 1989 and inspected after 18 years in service.

Practical Assessment of Galvanized Coating Life

In service, galvanized coatings will often last a lot longer than desktop assessments would indicate. This can be due to micro-environmental factors that reduce the corrosion stress on the coating, or simply that the environment may be much more benign that remote assessment may indicate.

This is particularly true of many coastal locations, that may be classified as marine or severe marine in standard corrosion maps. Topographical features such as coastal orientation, headlands, cliffs, height above sea level and prevailing wind direction will have a significant effect of the corrosivity of the location.

Tropical environments were once considered to be aggressive with respect to metal corrosion, but for galvanized coatings, this is not the case. High temperatures, high humidity and high levels of UV radiation make the tropics a tough place to be for paint coatings, but provide a much happier climate for galvanizing. This is so because the high ambient temperatures and seasonal nature of the rainfall means that the time of wetness is short and metal surfaces remain dry for much longer periods than is the case in temperate regions of Australia.

In addition, most of tropical Australia is not subject to ocean surf because of reefs and islands acting as a barrier, so the level of airborne chlorides is very low compared to the southern regions of the country.

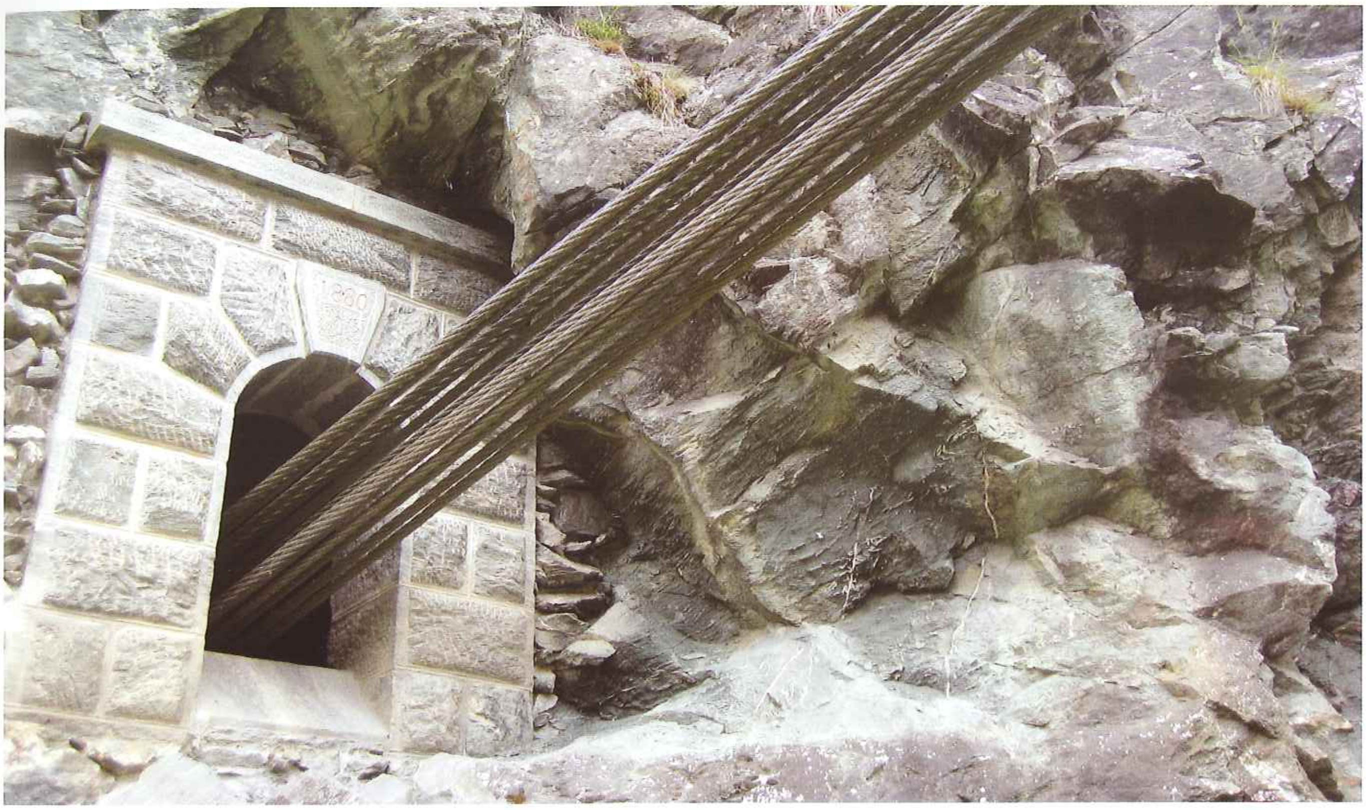
As galvanized coatings corrode at an approximate linear rate, and they have been used almost everywhere for a very long time, there are few places in Australia that do not have existing galvanized structures in their vicinity.

Such items as sign posts, guard rail, galvanized roofing, street lighting poles and fencing will all provide accurate indication of local corrosion rates of galvanized coatings. If the installation date of these items can be determined, simple measurement of the thickness of the zinc coating compared to its time in service will give a good indication of their remaining service life and the local corrosivity classification.

OTHER FACTORS AFFECTING COATING LIFE

Time of Wetness

Moisture is necessary for the corrosion process to take place. Water can come in contact with steel from precipitation (rainfall) or condensation. Water will condense on steel if the combination of humidity and temperature combine to reduce the temperature to the Dew Point. Moisture films on metal surfaces arising from condensation may be virtually invisible, but never the less, they will be a major driver of corrosion.



These galvanized cables hold up the famous Bungee Jumping bridge over the Shotover River near Queenstown, NZ. The bridge was built in 1888. Cold, non-maritime climates are relatively benign for galvanized coatings.

This is particularly important where airborne chlorides can accumulate on the surface of steel that is not subject to regular wash-down from rainfall. Small amounts (milligrams/day) of aerosol chlorides deposited in a sheltered surface can lead to very high salt concentrations when thin layers of condensation form on the surface and re-hydrate the sodium chloride crystals.

Where steel surfaces are sheltered from ventilation and sunlight, time of wetness will be prolonged as evaporation of the water will be delayed. For this reason, the underside of a metal roof may corrode more quickly than the upper surface. The classic failure of older galvanized iron roofs, made from many overlapping sheets, is in the overlapping areas. Water caught in the overlaps accelerates the corrosion of the galvanized coating in these areas.

Contact With Other Metals

Zinc is up near the top of the electrochemical series of metals, will be cathodic to many other metals to which it comes in contact. It is this characteristic that makes it such an excellent anti-corrosion performer on steel. If the galvanized coating is damaged, the zinc will cathodically protect the exposed steel. It is this characteristic that makes the use of pre-galvanized steel products practical.

Many wire, sheet and tube products are continuously galvanized and are cut, punched and formed into the finished product. These manufacturing processes leave all these products with exposed, uncoated edges. As most are relatively thin, less than 3 mm, the zinc on the adjacent surfaces is close enough to cathodically protect the uncoated steel.

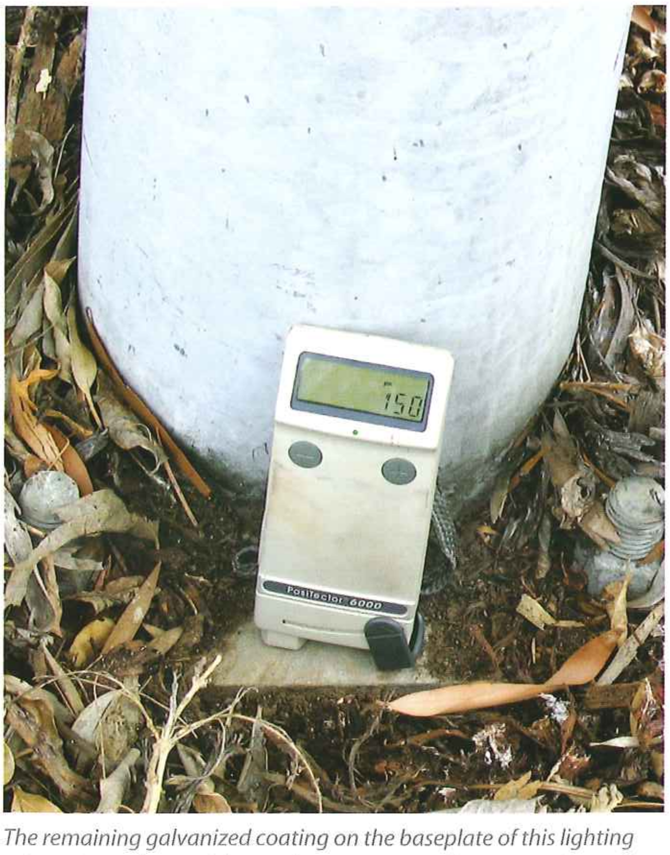
Contact with more noble metals such as stainless steel and copper alloys will produce higher corrosion currents and can lead to rapid consumption of the galvanized coating with which they are in contact. Copper alloys are particularly aggressive to zinc coatings in this respect.

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 have 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 than 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.

The ubiquitous roll top mesh fence is a good local corrosivity indicator for galvanized coatings. This widely used fencing system can usually be dated by the facility owners and galvanized coating thickness is fairly consistent on this type of product. This one is around 30 years old.



The remaining galvanized coating on the baseplate of this lighting column in Brisbane, Qld exceeds 100 microns after 21 years in service, indicating a remaining coating life exceeding 50 years.

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.