ArmorGalv®
THERMAL ZINC DIFFUSION
Environmentally friendly corrosion protection

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CORROSION PERFORMANCE IN VARIOUS ENVIRONMENTS

The excellent corrosion resistance of galvanized coatings in the atmosphere, soil, concrete and in most natural waters is due to the formation of a protective layer or patina which consists of insoluble zinc oxides, hydroxides, carbonates and basic zinc salts, depending on the environment. When the protective patina has stabilized, reaction between the coating and its environment proceeds at a greatly reduced rate resulting in long coating life.

Thermal diffusion coatings are not unlike the alloy layers formed in the galvanizing process but have several significant differences in their application. They are not new, having initially been developed by Englishman Sherard Cowper-Coles in 1900. He gave his name to the process commonly called sherardizing. For much of the 20th Century, sherardizing was confined to the thermal diffusion coating of small parts – particularly fasteners.

The unique feature of this thermal diffusion process is that the zinc-iron alloy is formed on the steel's surface at temperatures below the melting point of zinc – in other words, it is a solid-state reaction.

While the thermal diffusion coating is similar to a reactive HDG coating, its proportion of zinc to steel in the alloy formed tends to be more uniform in the outer layers of the coating, and of higher steel content in the thin gamma layer adjacent to the steel's surface.

The beneficial characteristics of this type of coating include its uniformity on all surfaces, its enhanced anti-corrosion properties because the coating has no free zinc exposed on its surface, its hardness (abrasion resistance) and its anti-galling properties, once again as a result of there being no free zinc on the surface of the coating.

COATING THICKNESS

ArmorGalv is designed to protect ferrous products against corrosion and wear. The service life of such coatings in a given environment is approximately proportional to the coating thickness.

Thickness requirements as per AS/NZS ISO 17668:2022

Class of Coating AS 4312 and AS/NZS 2312.2	Class of Coating AS/NZS ISO 17668:2022	ArmorGalv thickness minimum um	ArmorGalv mass minimum g/m2
C 1	Class 10	10	72
C 2	Class 15	15	108
C 3	Class 30	30	216
C 4	Class 45	45	324
C 5	Class 60	60	432
C X	Class 75	75	540

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CORROSIVITY IN THE AUSTRALIAN ATMOSPHERE

Two key Australian Standards, AS 4312 and AS/NZS 2312.2, provide considerable information on the corrosion rate of steel and zinc respectively under various conditions of atmospheric service. In addition, over the last few decades the CSIRO and others have carried out extensive mapping to establish the corrosivity of the Australian climate. AS 4312 is the best source of Australian data for corrosivity of steel in the local environment.

It is important to note the corrosion rate estimates for steel and zinc in the various Standards are consistent and are interchangeable with the International Standards ISO 9223 and ISO 14713.1 for service life estimate purposes.

There is a body of evidence that supports the fact that thermal diffusion coatings as applied by ArmorGalv have superior corrosion resistance to plain zinc-based coatings. Exposure testing by CSIRO at its marine exposure site at Point fairy in Victoria, and other laboratory-based accelerated weathering testing done by the thermal diffusion coating industry had indicated that the corrosion rate of zinc-iron alloys is typically 2-3 times lower than that of pure zinc.

The deterioration or weathering of a zinc coating is an oxidation process that consumes the zinc at a rate that is determined by the environment to which it is exposed. The process is as follows:

1. The oxidation reaction $2Zn + O_2 \rightarrow 2ZnO$

2. The hydration reaction $2Zn + 2H_2O + O_2 \rightarrow 2Zn(OH)_2$

3. Carbonation $5Zn(OH)_2 + 2CO_2 \rightarrow 2ZnCO_3.3Zn(OH)_2 + H_2O$

The zinc requires the carbonation process to form the stable oxide film on its surface to limit the rate of oxidation over time. Interference with the formation of this carbonate oxidation layer through exposure to chlorides, sulfates or pH solutions outside the pH6-8 range can compromise the durability of the zinc coating.

An additional standard component of the ArmorGalv process is an immersion passivation stage following the application of the thermal diffusion coating. This performs an accelerated carbonation function that significantly reduces the surface oxidation of the coating in its early life – a factor that results in the coating loss in the first 12 months of a hot dip galvanized coatings life in normal atmospheric exposure, being 3-5 times higher than that achieved when its passivation films are stabilized over time.

Zinc is an amphoteric metal and will react with both acids and alkalis. Iron performs poorly in acidic exposures but has excellent performance in alkaline environments. The zinc-iron alloy in a thermal diffusion coating thus has quite different and superior corrosion resistance characteristics than standard zinc coatings.

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Estimated corrosion rates of steel & zinc in Australia developed from AS 4312 and AS/NZS 2312.2					
Category, description & typical environment			Corrosion rate for the first year (µm/y)		
			Mild steel	Hot Dip Gal - Zinc	ArmorGalv
C1	Very low	Dry indoors	≤1.3	≤0.1	≤0.03
C2	Low	Arid/Urban inland	>1.3 to ≤25	>0.1 to ≤0.7	>0.03 to ≤0.23
C3	Medium	Coastal or industrial	>25 to ≤50	>0.7 to ≤2.1	>0.23 to ≤0.7
C4	High	Calm seashore	>50 to ≤80	>2.1 to ≤4.2	>0.7 to ≤1.85
C5	Very High	Surf seashore	>80 to ≤200	>4.2 to ≤8.4	>1.85 to ≤2.8
CX	Extreme	Ocean/Off-shore	>200 to ≤700	>8.4 to ≤25	>2.8 to ≤8.3

The measured corrosion rate during the first year of exposure for steel and zinc is usually higher than the measured long-term rate. The long-term corrosion rate for both steel and zinc slows over time and in the first 20 years corrosion rates are not linear. At some point in time after 20 years the corrosion product layer stabilises, and at this point, the corrosion rate becomes linear with time, because the rate of metal loss becomes equal to the rate of loss from the corrosion product layer. In addition, it is known that the rate of corrosion in the first 12 months is affected by the environment experienced by the metal in the first few weeks of exposure, but long-term rates are usually unaffected by the first exposure rate. Notwithstanding the issues outlined above, the durability of an item is usually calculated on the estimated first year corrosion rate and this will normally provide a conservative prediction of the durability of an item if long term corrosion protection is desired.

Environments which appear similar often produce considerable differences in corrosivity due to relativity minor variations in conditions, such as prevailing winds, proximity to corrosive effluents and general atmospheric conditions.

In warm dry atmospheres zinc is very stable. The patina formed during initial exposure remains intact preventing further reaction between the galvanized coating and the air, and protection continues indefinitely.

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In the presence of atmospheric moisture, the zinc oxide film is quickly converted to zinc hydroxide, and carbon dioxide present in the air reacts to form basic zinc carbonates. These stable inert compounds resist further action and ensure long life for the protective galvanized coating.

In rural areas the life of galvanized coatings is often over 100 years but may be reduced due to micro-environments created by the effects of aerial spraying of fertilizers or insecticides. In dry form most fertilizers and insecticides are harmless to zinc coatings but when wetted by rainwater or irrigation spray water, aggressive solutions can be formed which will attack galvanized coatings until washed off by further wetting.

Near the seacoast the rate of corrosion is increased by the presence of soluble chlorides in the atmosphere. The performance of galvanized coatings relative to other protective systems is outstanding, particularly when used as part of a *duplex system consisting of paint over galvanizing*.

In industrial areas the presence of atmospheric impurities such as sulfurous gases and chemicals results in the formation of soluble zinc salts. These are removed by moisture, exposing more zinc to attack. In light industrial areas galvanized coatings give adequate protection, but in the extremely corrosive conditions of heavy industrial areas it is desirable to reinforce galvanized coatings with a paint system resistant to the chemical attack.

SUMMARY

Thermal Zinc Diffusion coatings are particularly well suited to applications in many industries and solve several problems related to the use of hot dip galvanized coatings on various products.

The limitations of traditional thermal zinc diffusion coating processes have been their inability to process anything other than small components. The development of the ArmorGalv process in Australia has allowed much larger products to be thermal zinc diffusion coated successfully at an economical cost and offer a highly durable solution to corrosion management in various industries.

In addition, the ArmorGalv process has a high environmental rating, as there are no chemical residues, fumes or solid waste products arising from the process