

Hot Dip Galvanized Information Sheet No.11

How Does Zinc Protect?

The corrosion protection of hot dip galvanizing (zinc) results from the formation of a dense insoluble “barrier protection” layer of zinc carbonate on the surface of the hot dip galvanized (zinc) coating. Depending on the steel’s chemical composition, particularly the amount of silicon and phosphorous, newly galvanized steel will have surface finishes ranging from a bright shiny finish to a dull grey matt colour.

Initially “new” zinc surfaces oxidise to an unstable water soluble zinc oxide (ZnO), zinc hydroxide ($Zn(OH)_2$), (depending on the moisture content of the atmosphere), and finally to an insoluble dense zinc carbonate ($ZnCO_3$) layer.

The first two products of corrosion, (ZnO & $Zn(OH)_2$) are unstable and easily removed. The $ZnCO_3$ layer, by contrast, is stable, not easily removed, matt grey in colour and it is this stable layer that forms the required “Barrier Protection” for corrosion control. Figure 1 is a simplified diagram used to illustrate the reaction of zinc with an atmosphere.

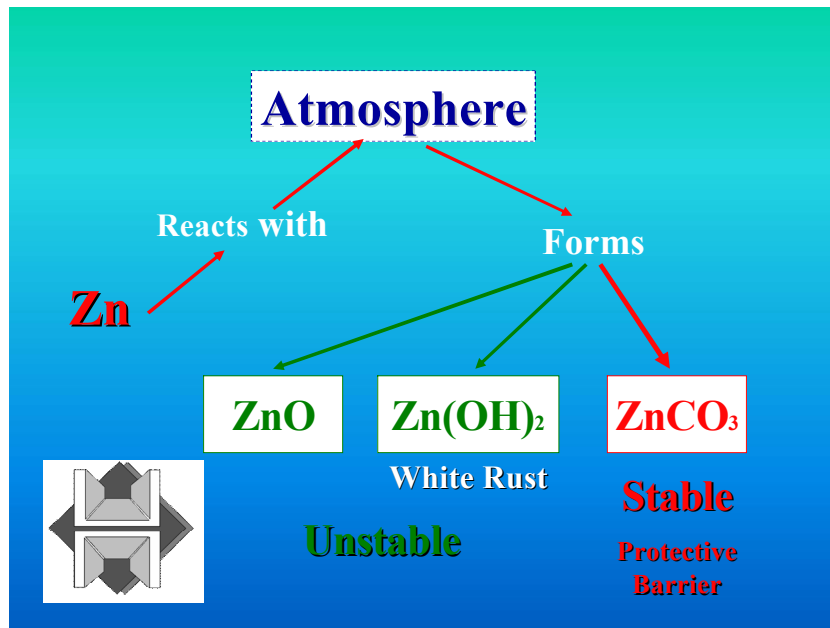


Fig 1: Chemical reaction of pure zinc with the atmosphere, being Oxygen, Moisture and Carbon Dioxide. Products of corrosion formed, are zinc oxide, zinc hydroxide and zinc carbonate.

It is of paramount importance that a freshly galvanized surface is allowed to “weather” and form its zinc carbonate “barrier protection”. $ZnCO_3$ is a slowly corroding barrier reducing the corrosion rate resulting in an extended service life for the steel substrate. Zinc, as a wasting material, is continuously being replaced by the remaining underlying zinc and / or zinc iron alloys. Corrosion control is active as long as zinc is present on the steel surface. The $ZnCO_3$ layer corrodes very slowly, at a rate that depends on the environment in which the zinc coated steel is required to operate. It follows therefore, that the more (thicker) zinc in a coating the longer the resultant service life and the degree of corrosion control achieved in protecting carbon steel components. The $ZnCO_3$ patina, being the formed barrier protection, can be referred to as Zinc’s first line of defence.

Cathodic Protection – Second line of Defence

Should a “small” uncoated area of steel be exposed, such as a zinc chip or some form of mechanical damage, the zinc coating alongside such an exposure area will corrode in preference to the carbon steel and thereby provide corrosion control. This preferential protection is termed cathodic protection. Where such small uncoated areas exist, the corrosion products of zinc will tend to seal the exposed area re-establishing the barrier protection.

More importantly, zinc being electro-negative to carbon steel under-film corrosion creep (attack under the coating) is impossible as long as zinc remains available. Under-film corrosion creep is a common failure mechanism with pure barrier protection, (no cathodic protection) where rust will spread from any damaged or exposed areas under a corrosion control coating.

Corrosion Cell or Bimetallic Couple

Where two dissimilar metals are in electrical contact with each other and within an electrolyte (environment), a small electrical voltage appears between them. Electrons flow to and from the dissimilar metals; one of the metals (anode) corrodes in preference to the other (cathode). This is called cathodic protection. In other words, we use the physics of the corrosion cell (bimetallic couple), as a weapon to combat the onset of corrosion of the material that we use for our steel structures.

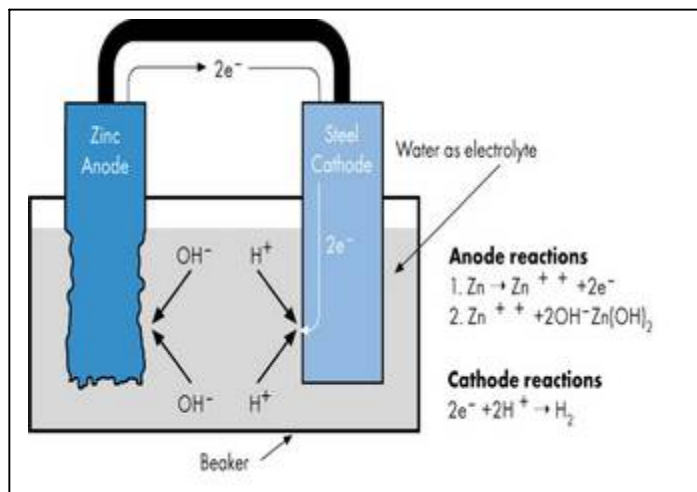


Fig 2:
Illustration of a corrosion cell also known as a by-metallic couple

This diagram also illustrates the process known as “galvanic corrosion”

Figure 3 lists a selected number of metals and is used to explain why a zinc anode will “sacrifice” itself in order to protect carbon steel cathode. The metals that are electro-negative to carbon steel will provide electrochemical protection (cathodic protection) are magnesium, aluminium, cadmium and of course zinc. Of these only zinc is the most economical and practical for the use in the hot dip galvanizing process.

Other metals such as nickel, copper and brass, i.e. electro-positive to steel, are used in electro-plating. Should the pure barrier protection afforded by these metal coatings, be perforated (pinholes) the steel (iron) will corrode in order to protect the more noble (electro-positive) metal coating. This will be evidenced by what we refer to as under corrosion creep of the protective coating.

Electrochemical Protection

Generally we refer to electrochemical protection as “sacrificial protection”. This is because the zinc will sacrifice itself in order to protect the steel to which it is alloyed. It will continue to do this almost to the last atom of zinc. You can be sure that so long as some zinc or zinc iron alloy remains, even though it is in poor condition, after many maintenance free years, the underlying steel will retain its structural integrity. No other non-zinc coating can offer this benefit. Scratch type damage to the hot dip galvanized coating is often filled by oxides and carbonates formed from the zinc, tending to heal the damage and retard the rate of further corrosion.

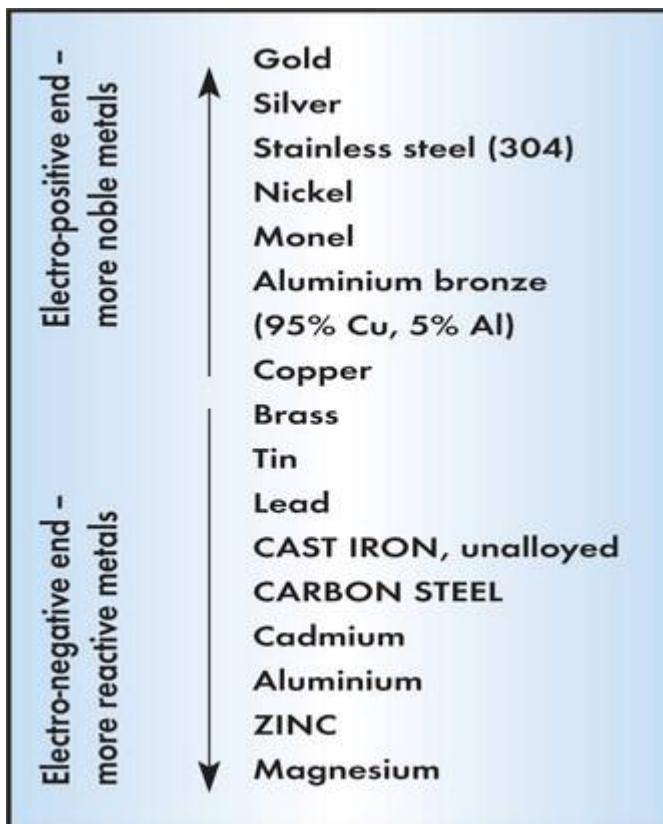


Fig 3:

Galvanic series of a series of selected metals

Zinc will be the “anode” due to the fact that it is electro-negative to carbon steel “cathode”

Zinc will sacrifice itself to protect the carbon steel