

Hot Dip Galvanized Information Sheet No.3

Corrosion of Hot Dip Galvanized Steel (Zinc) in Water

Corrosion of zinc by water is affected by various conditions. The chemical composition of the water is most important, but temperature, pressure, flow rate, agitation and the distribution and replacement of oxygen should be considered.

Influence of pH levels (Refer to the graph)

The pH of water is of major importance as below about 5.5 the rate of corrosion of zinc increases sharply unless inhibitors are present. Fundamentally, however, the speed of corrosion is dependent on the type, quality and mode of precipitation of corrosion products, with the most important zinc "product of corrosion" being zinc carbonate ($ZnCO_3$). The formation of such a tightly adhering stable "Barrier Protective" ($ZnCO_3$) patina is required for the effective corrosion protection of carbon steel.

The zinc corrosion products in acids ($pH < 5.5$) e.g. chlorides, sulphates and acetates are readily soluble in water. In strong alkaline solutions ($pH > 12.5$) water-soluble zincates are formed and thus corrosion attack is unhindered in both increasing acid and alkaline. Hot dip galvanizing (zinc) is therefore suitable in a pH range of > 5.5 and < 12.5 .

Time factors, agitation and temperature affect the formation of $ZnCO_3$ protective films.

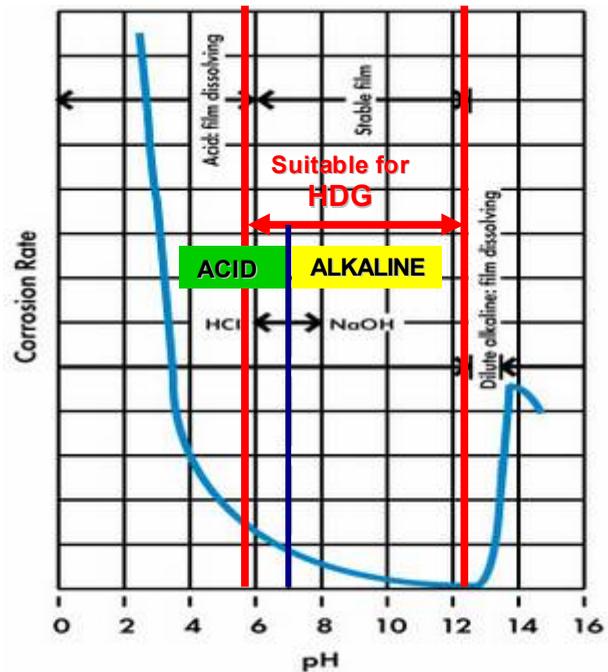
Stagnant water can be unfavourable, but too great agitation will sweep away corrosion products before they can be established as a barrier protective patina. Suspended solids in turbulent water will increase the erosive action on the protective film. At low temperatures, compact, adherent and thus protective deposits can form, which at higher temperatures will increase porosity and reduce corrosion control characteristics.

Differential Aeration Cells

The uniform distribution of oxygen in the water has a significant effect on the corrosion rate. This is more pronounced at higher water conductivity levels. In a differential aeration cell, hardly any corrosion occurs at oxygen rich areas, which are cathodic in relation to anodic oxygen deficient areas where corrosion will be evident.

Such differential aeration cells can occur in drops of liquid or in crevices. Solid deposits or other inhomogeneities on the zinc surface may induce the formation of a differential aeration cell with the zinc being attacked. Differential aeration cells are evident in several aspects of zinc corrosion, notably in the formation of wet-storage stain.

Additional protection by way of a protective surface film can result in the propensity for local pitting attack to occur if the uniform film has not fully developed. If local discontinuities are present or the film is removed in small isolated areas, corrosion attack will be concentrated at these sites where the underlying zinc is exposed. This attack can be particularly severe if the protective film itself is electrically conducting and will act as cathode to the small area of exposed metal anode.



The reaction of Pure Zinc in water with a varying pH

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Although the protective films at anodic areas mostly form by reaction of the nascent zinc ions with anions of the electrolyte, they may spread laterally and even cover cathodic regions. This is very important in the protection of steel by zinc coatings at scratches and other areas where steel is locally exposed. The initial protection by sacrificial action of the adjacent zinc can gradually change to barrier protection of the steel by zinc corrosion products.

Flow Rate of Water

For adequate protection, the freshly formed corrosion products must be able to attach themselves securely to the metal; movement of the water may interfere with this. If solid matter is present in the moving water, an actual scouring action can arise. **German Specification DIN 50930 sets a flow rate limit of 0.5m/sec in connection with corrosion by water.**

As a result of the importance of oxygen in the corrosion reaction, corrosion is particularly severe when the attacking medium, with un-exhausted content of oxygen and sometimes other aggressive substances, is continuously circulated over the bare metal surface. Turbulent agitation of the attacking medium is thus unfavourable.

Temperature and Pressure

Every chemical reaction is accelerated by rise of temperature; in general, the speed of reaction is doubled by a temperature rise of 10°C. This applies to corrosion of zinc by water, but there may be other temperature dependent reactions, which reduce corrosion, such as the precipitation of carbonates by displacement of the chalk-carbonic acid equilibrium, or reduction in the dissolved air or oxygen.

Pressure per se is not a major factor in corrosion of zinc. However, it can have indirect effects such as increasing the oxygen retained in the water at low temperatures.

In general terms, galvanized steel is best suited to hard waters. Galvanized steel is prone to severe attack in soft waters having less than 50mg/litre calcium carbonate.

With scale-forming waters (hard water) zinc coatings have an extended service life, but a determining factor with pipes can often be the gradual reduction in the effective internal diameter due to excessive scale build-up. Hot dip galvanized carbon steel pipes have zinc coatings typically in a range of 60-100 micron (μm) and a service life, due to corrosion effects, is likely to be longer than a design life. Hot dip galvanized pipes, water cylinders and tanks are widely used in handling domestic water supplies with satisfactory results.

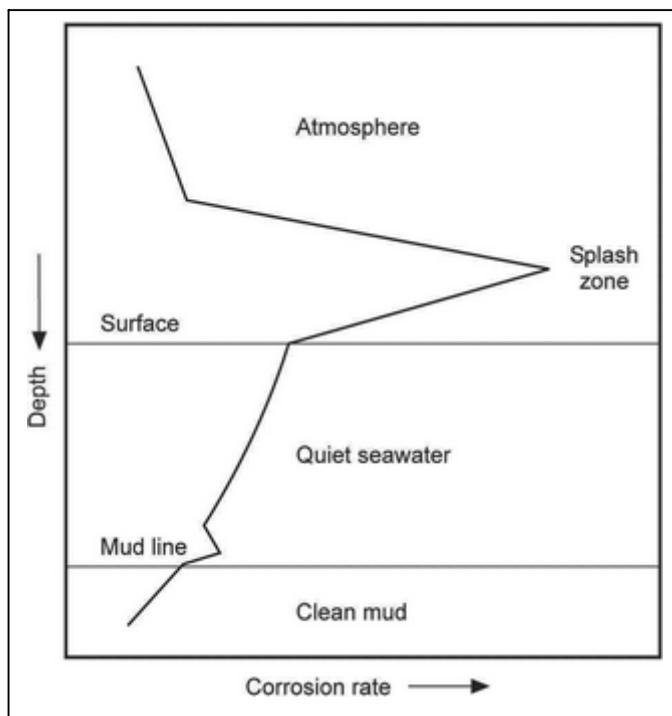
In hot water the story is different. Although a scale will form, at water temperatures above about 55°C (Thomas, 1980), the corrosion products that form on zinc have a coarse-grained structure and have less adhesion to the zinc surface. Corrosion of the zinc will still occur locally due to discontinuities in the scale or local electrochemical action. When this local attack develops into a pit that exposes steel, attack will continue on the steel rather than on the zinc. This is because at hot water temperatures there is a reversal of electrochemical polarity and the steel becomes anodic to the zinc. With most tap waters reversal occurs at about 65°C and it is good practice to run in a new water system at a temperature of below 55°C for the first year. This practice will allow the formation of a more protective deposited patina to form.

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Sea Water

A broad distinction must be made between seawater in the tropics and that in more temperate climates. Corrosion in temperate seawater can be as much as half of that in the tropics. All seawater contains magnesium salts, which act as an inhibitor reducing the rate of corrosive attack. In tidal areas or the “splash zone”, the corrosion rate may be typically twice as great as that for completely immersed areas. At 20°C soluble chromates retard the corrosion of zinc in sodium chloride solutions, but at higher temperatures with the same concentration of chromate zinc is not protected from corrosion (Rotheli and Cox, 1931). In the presence of insufficient amounts of chromate, there is a danger of pitting corrosion.



Typical corrosion profile of carbon steel being immersed into sea water

For additional information on the subject matter refer to information sheet no.6 “Corrosion Control by Hot Dip Galvanized Steel in Water”

The information used to produce this information sheet is an extract from the book by Frank Porter, titled ZINC HANDBOOK properties, processing and use in design.