

# Hot Dip Galvanized Information Sheet No.3

## Corrosion of Zinc (HDG) 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.

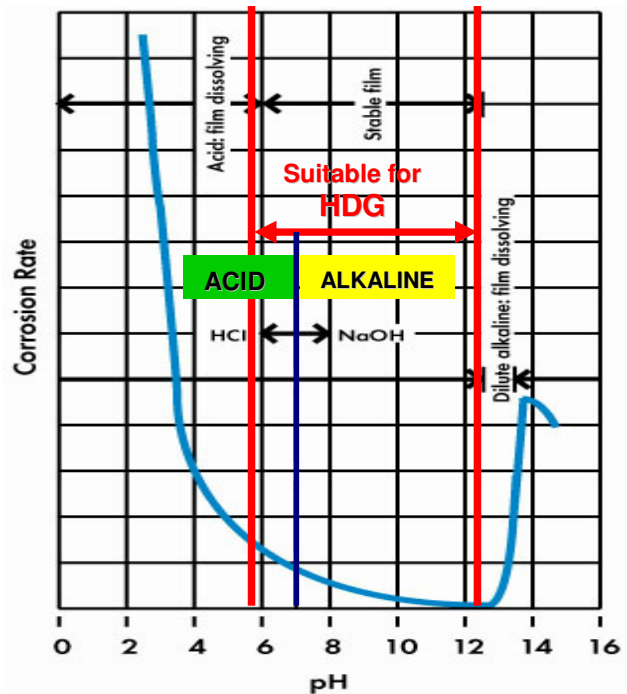
### Influence of pH levels (Refer to the graph)

The pH of water is of major importance as below about 5.5 the rate of corrosion can increase 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" ( $ZnCO_3$ ) film 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 not hindered below pH 5.5 and above pH 12.5. The time factor, the agitation and the temperature affect the formation of such protective films.

A certain time is necessary for formation; stagnation can be unfavourable, but too much agitation will sweep away corrosion products before they can become protective.

This action may be assisted through erosion by suspended matter. At low temperatures, compact, adherent and thus protective deposits may be formed, which at higher temperature may be porous and not protective.



**The reaction of Pure Zinc in a varying pH Environment**

### 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 takes place.

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.

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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 zinc has a long life and the determining factor with pipes can often be the gradual reduction in the effective internal diameter due to the scale or too much scale coming through with the water. For galvanized steel with zinc coating typically 65-100 micron thick the life due to corrosion effects is likely to be as long as needed. Galvanized pipes, water cylinders and tanks are widely used in handling domestic water supplies with satisfactory results. Therefore, quantitative corrosion rates are not of primary interest and limited information is found in the literature.

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 below 55°C for the first year both for this reason and because a more protective deposit is then formed initially.

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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.

Saliva has also been reported as an inhibitor of corrosion of zinc in sodium chloride solutions (Shida, 1955).

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