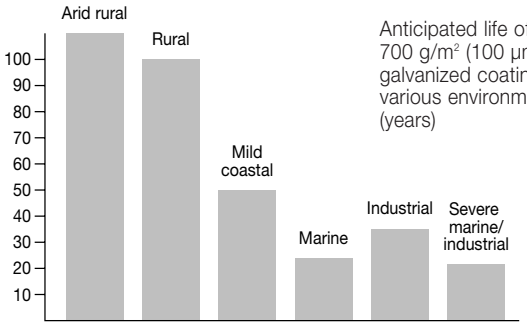
the extremely corrosive conditions of heavy industrial areas it is desirable to reinforce galvanized coatings with a paint system resistant to prevailing conditions.

In these severely corrosive conditions galvanized coatings in combination with suitable paint systems provide longer, more economic life than the best alternative systems. Suitable paint systems and application techniques are described in the section 'Painting galvanized steel'.



Effect of temperature

Hot dip galvanized coatings should not be used in applications where temperatures continuously exceed 200°C, as prolonged exposure to these temperatures will lead eventually to detachment of the coating from the base steel.

Under water

General. The corrosion rate of zinc under immersed conditions can be high in acidic solutions below pH 6 and alkaline solutions above pH 12.5. Between these limits the rate of corrosion is much lower.

In mains supply water of pH 6 to pH 8, calcium carbonate is normally present and this is precipitated onto the galvanized coating as an adherent calcium carbonate scale, together with zinc corrosion products, forming an impervious layer. When sufficiently dense, this layer virtually stops corrosion of the coating, resulting in very long life in many domestic water systems.

Other factors may interfere with this scale deposition. If the water has a high concentration of uncombined carbon dioxide, the protective scale is not formed and full protection never develops. The characteristics of the water supply should be taken into account in the design of domestic water systems. The presence of even small quantities of dissolved copper of the order of 0.1 parts per million in the water may cause corrosion by rapid pitting as discussed under galvanic corrosion page 22.

In unfavourable waters galvanized steel may require the added protection of galvanic anodes or suitable paint coatings.

Pure water. When newly galvanized articles are immersed in pure water such as rainwater there are no dissolved salts present to form the film of insoluble compounds which normally protects the coating from further action. Where practical this condition can be corrected by the addition to the water of controlled amounts of salts during initial immersion.

Most natural waters contain sufficient dissolved salts to prevent initial attack and galvanized tanks and equipment give excellent service.

Effect of water temperature. In cold water of normal composition galvanized coatings are most effective and the rate of consumption of the coating is very low. This has resulted in almost universal use of galvanized steel for tanks for water storage and transport.

At about 60°C to 65°C the rate of corrosion of galvanized coatings increases and continued corrosion resistance depends on early formation of adequate non-flaking scale. Hard water in hot water systems will deposit a scale of calcium and magnesium carbonates on the galvanized surface, nullifying the temperature effect. Soft water may not deposit a protective scale. In such cases galvanized coatings are unsuitable for hot water systems.

Sea water. Galvanized coatings perform relatively well in submerged sea water conditions which are severely corrosive to most protective systems. Dissolved salts present in sea water react with zinc to form a protective layer minimising corrosive action.

The addition to the galvanized coating of a suitable paint system is recommended in areas of severe sea water exposure, particularly in the splash zone. Such duplex systems provide the best available protective coating for steel in sea water. Suitable paint coating systems are listed in table 3, page 69.

Underground

The corrosion behaviour of buried galvanized steel varies greatly with the type of soil. Knowledge of local conditions is therefore essential in estimating the life of galvanized steel pipes. Generally galvanized steel lasts considerably longer than uncoated or painted steels but performance is best in alkaline and oxidising soils, where a 600 g/m² galvanized coating will give an additional life of about 10 years to steel pipes. Highly reducing soil is most aggressive and may consume zinc coatings at more than 13 µm per year.

The life of galvanized steel underground is extended by the use of paint coatings, bituminous compounds, tape wraps or concrete encasement.

In contact with chemicals

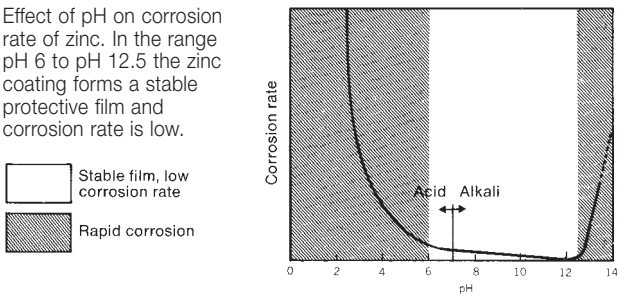
Galvanized coatings are highly resistant to attack over a wide pH range, particularly in moderately alkaline solutions as shown in the diagram below. Unprotected galvanized coatings should not be used with acid solutions below pH 6 or alkaline solutions above pH 12.5.

At intermediate values between these limits a protective film is formed on the zinc surface and the coating corrodes very slowly. Since this range covers most types of water and all but the strongest alkalis, galvanized coatings have wide application for storing and conveying liquids.

Most organic liquids, other than those acid, attack zinc only slightly and galvanized coatings are suitable for storage tanks and equipment for handling a wide range of organic chemicals, including motor fuels, creosotes, phenols and esters.

Galvanized coatings are used in refrigeration equipment circulating brine solutions treated with sodium dichromate inhibitor.

Effect of pH on corrosion rate of zinc. In the range pH 6 to pH 12.5 the zinc coating forms a stable protective film and corrosion rate is low.



Compatibility of galvanized coatings with various media

Compatibility of galvanized coatings with various media is summarised in the table below. Further specific information is available from Galvanizers Association of Australia.

Aerosol propellants		excellent
Acid solutions	weak, cold quiescent strong	fair not recommended
Alcohols	anhydrous water mixtures beverages	good not recommended not recommended
Alkaline solutions	up to pH 12.5 strong	fair not recommended
Carbon tetrachloride		excellent
Cleaning solvents	chlorofluorocarbon	excellent
Detergents	inhibited	good
Diesel oil	sulphur free	excellent
Fuel oil	sulphur free	excellent
Gas*	towns, natural, propane, butane	excellent
Glycerine		excellent
Inks	printing aqueous writing	excellent not recommended
Insecticides	dry in solution	excellent not recommended
Lubricants	mineral, acid free organic	excellent not recommended
Paraffin		excellent
Perchlorethylene		excellent
Refrigerants	chlorofluorocarbon	excellent
Sewage		excellent
Soaps		good
Timber preservatives: Copper-chromium-arsenic, freshly treated After drying is completed Boron		 poor excellent excellent
Trichlorethylene		excellent

*Chromate passivation is recommended because moisture may be present.

Sewage treatment

Galvanized coatings perform extremely well by comparison with other protective coatings for steel in the severely corrosive conditions prevailing in most sewage treatment operations. As a result galvanized steel is used extensively in sewage treatment plants throughout the world.

In contact with building materials

Galvanized coatings give invaluable protection to steel used in all sections of the building industry. The slight etching action upon galvanizing by mortar, concrete and plaster ceases after setting.

When galvanized steel products and fasteners are installed in direct contact with unseasoned timber it may be necessary to protect them by the application of a suitable paint.

Care should be taken that galvanized products are stored and transported under dry ventilated conditions as discussed above right.

In contact with timber preservatives

Timbers freshly treated with acidic preservatives of copper-chromium-arsenic type, such as Celcure, Copas and Tanalith, can be severely corrosive to metallic building materials, including galvanized coatings. Once the timber has dried out the preservatives become fixed, and the performance of galvanized coatings in contact is excellent, even when the timber is again wetted. Galvanized coatings also perform well in contact with boron-treated timbers.

Transport and storage

New galvanized products should be handled, transported and stored with the normal care given to any other surface-finished building material. New galvanized steel surfaces which have not yet developed the patina of protective insoluble basic zinc carbonates which normally contributes to the long life of aged coatings are highly reactive and susceptible to premature corrosion under poor conditions of exposure.

Transport should be under dry, well ventilated conditions. When stored on site, material should be covered where possible and raised clear of the ground on dunnage or spacers. When shelter is not possible material should be stacked to allow drainage of rainwater. Storage in contact with cinders, clinkers, unseasoned timber, mud or clay will lead to surface staining and in severe cases, premature corrosion.

Clearance for ventilation between stacked galvanized products is necessary under damp or humid conditions to avoid the possibility of wet storage stain and the development of bulky white corrosion product. Attack on the galvanized coating producing white corrosion is caused by the retention of condensation or run-off water between contacting surfaces under conditions of restricted air circulation. The attack is frequently superficial despite the relative bulkiness of the corrosion product but may be objectionable because of appearance. In severe cases corrosion product should be removed as described on page 44 to allow the natural formation of protective basic zinc carbonate film.

Where galvanized products are likely to be stored or transported under poor conditions the galvanizer can, on request, apply a simple chromate treatment which will minimise wet storage stain. Under severe conditions chromating should not be relied on and new galvanized products should be packed carefully and protected for shipment and storage.

Continuously galvanized sheet steel products designed for outdoor exposure are normally given a carefully controlled chromate treatment during manufacture. This treatment provides excellent resistance to wet storage staining and against early dulling during initial outdoor exposure. Care should nevertheless be taken to see that sheet and coil is kept dry while awaiting fabrication or erection.

Galvanic corrosion

Galvanic or electrolytic corrosion with resulting rapid consumption of the zinc coating is likely if a galvanized article is installed in contact with brass or copper, particularly in a moist environment. Contact between aluminium or cadmium and galvanized surfaces is normally satisfactory.

Galvanic corrosion occurs for the same electrochemical reasons as those by which zinc provides cathodic protection for steel as explained on page 10, but the rate of consumption of zinc coatings by galvanic corrosion may be extremely high.

A guide to compatibility of metals and alloys in contact is given opposite.