THE ENGINEERS & ARCHITECTS' GUIDE:

HOT DIP GALVANIZING

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Literature

The Engineers & Architects' Guide: Hot Dip Galvanizing

The Engineers & Architects' Guide to Nuts and Bolts

Seminar

"Corrosion protection of steel by Hot Dip Galvanizing"

For further information contact Nicky Smith on 0121 355 8838 or email n.smith@hdg.org.uk

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THE ENGINEERS
& ARCHITECTS' GUIDE:

HOT DIP GALVANIZING

Galvanizers Association would like to know what you think of our services and the information we provide. Please use the response sheet on page 51 for your comments on the Guide or for any further information and advice that you may require.

If you prefer, an online comment form is available at www.hdg.org.uk/feedback

STEEL IS A STRONG, VERSATILE AND INEXPENSIVE MATERIAL WITH USES IN MANY DIFFERENT INDUSTRIES. IT HAS, HOWEVER, ONE MAJOR DISADVANTAGE: IT IS PRONE TO CORROSION, EVEN IN INTERIOR ENVIRONMENTS CORROSION PREVENTION IS THEREFORE ESSENTIAL IF STEEL STRUCTURES ARE TO BE ECONOMICAL.

TODAY, INCREASED AWARENESS OF THE LONG-TERM SAVINGS POSSIBLE FROM REDUCED MAINTENANCE COSTS HAVE HIGHLIGHTED THE NEED FOR DURABLE PROTECTIVE SYSTEMS FOR STEEL. THIS GUIDE HAS BEEN PRODUCED TO ASSIST DESIGNERS, SPECIFIERS, FABRICATORS AND USERS OF STEELWORK TO DEVELOP THE MOST EFFECTIVE, PRACTICAL AND ECONOMIC SOLUTIONS.

Hot dip galvanizing has many benefits as a method of corrosion protection. Importantly, it will:

- provide steel with a coating which has a long, predictable and maintenance free life.
- be highly competitive on a first cost basis
- be the most economic way to protect steel over long periods
- be a sustainable solution

This Guide is published by Galvanizers Association, which represents the hot dip galvanizing industry of the UK and Ireland. It contains the essential information needed by architects, consulting engineers and others in selecting a corrosion protection system.

The Guide details the protection given by hot dip galvanizing, where and how to use it and how to specify it. There is also information on the process itself and the economic advantages of galvanizing. Galvanizers Association (GA) has provided authoritative information and advice on hot dip galvanizing to users and potential users since it was first established in 1949.

Our technical team is on hand to give an immediate answer to all your queries about galvanizing. GA also monitors regulations, takes a leading role in standards development and oversees research projects to support and develop the industry.

GA can also visit your company to give a presentation which is approved by RIBA for Continuing Professional Development (CPD). GA publishes a wide range of technical literature, surveys the market and its trends and improves communications about galvanizing.

E&A INTRODUCTION

SECTION
ONE
–
TITLE
GALVANIZING AND
SUSTAINABLE CONSTRUCTION
–
FUTURE TECHNOLOGIES WILL BE LOW ENERGY LOW WASTE. GALVANIZING IS A RECYCLABLE SOLUTION THAT REDUCES THE ENERGY DEMAND OF STRUCTURES.

The pressures on global industry to accept environmental responsibility for its actions is wholly justified, given society's quest for sustainability.

The philosophy of sustainability is quite simple and is concerned with ensuring a better quality of life for everyone - now and, importantly, for generations to come. The concept is common sense based on substantial criteria and principles. It sets out to meet four objectives:

- Social progress, which recognises the needs of everyone
- Maintenance of high and stable levels of economic growth and employment
- Efficient protection of the environment
- Prudent use of natural resources

In respect of efficient protection of the environment and prudent use of natural resources, the hot dip galvanizing process stands up to scrutiny and can be considered as a major contributor towards sustainable construction.

GALVANIZING AND THE ENVIRONMENT
–

Galvanizing, the coating of iron or steel with zinc, is probably the most environmentally friendly process available to prevent corrosion. It is estimated that corrosion costs around 4% of GDP in the USA. Effective corrosion protection is a vital means of reducing the energy demands of buildings and structures.

Every 90 seconds, across the world, one tonne of steel turns to rust; of every two tonnes of steel made, one is to replace rust.

Use of hot dip galvanizing to prevent rust means that for every one tonne of steel protected we conserve enough energy to satisfy an average family's energy needs for several weeks.

Galvanizing is efficient in its use of zinc to protect steel for very extensive periods - saving energy and resources with minimal impact on the environment. Galvanizing will protect steel structures for decades and minimises maintenance.

Zinc, the natural element responsible for this corrosion resistance, is indispensable for humans, animals and plants.

In the galvanizing process, iron or steel articles are dipped into a bath containing molten zinc just above its melting point. Any zinc that does not form a coating on the metal remains in the bath for further re-use. Galvanizing residues are recovered and zinc recycled for further use.

As well as zinc recovered from these residues, recycled zinc from other sources, such as zinc scrap, is often used in galvanizing. Galvanized steel can be recycled easily with other steel scrap in the steel production process.

Improvements in gas burner technology have also greatly improved energy efficiency in heating the galvanizing bath. Exhaust heat is not wasted and is used to heat pre-treatment chemicals or dry work prior to immersion.

The galvanizing industry is committed to understanding and improving the life-cycle environmental performance of its process and products. Galvanizers Association has recently helped establish a Pan-European Life Cycle Inventory database for general galvanizing. This LCI data will allow Environmental Product Declarations and other life cycle assessments to be made on structures involving galvanized steel.

Process emissions

Process emissions from the galvanizing process are very low. Aqueous discharge - all waste liquids - which consist mainly of spent acids used to prepare the steel, are removed by licensed waste management companies in accordance with mandatory procedures, thus protecting surface and ground water. Spent acid is also increasingly used to neutralise other wastes and in the manufacture of water treatment chemicals. The industry has greatly improved its utilisation of process chemicals in recent years - reducing the volumes of acid used per tonne of steel processed.

Emissions to the atmosphere are inherently very low and are strictly governed by the Environmental Protection Act. Galvanizing baths must capture their particulate emissions to air. This is successfully accomplished by the use of bath enclosures together with filters. A survey by the Environment Technology Best Practice Programme concluded that “Galvanizers use less than 25 litres of water per tonne of product, compared with 2000 litres in the general metal finishing industry”.

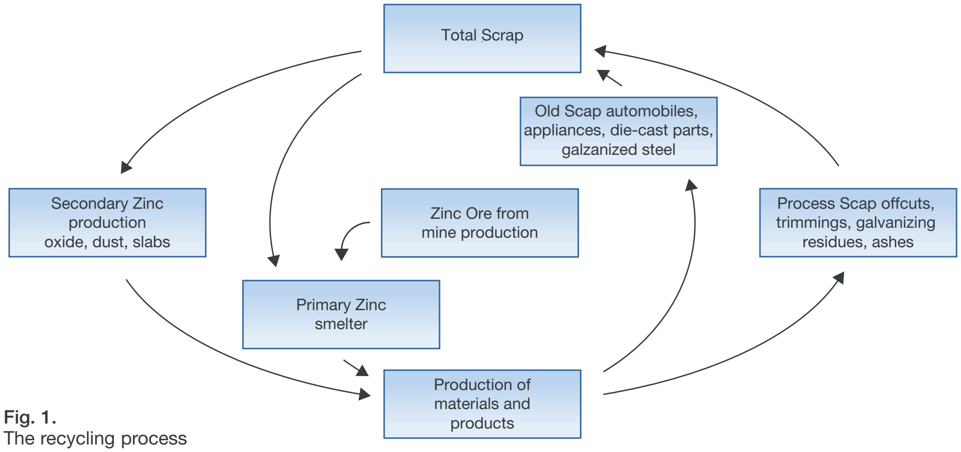

Fig. 1.
The recycling process for zinc in galvanized steel

RECYCLING

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Zinc is the principal raw material in galvanizing.

Zinc is an inherently recyclable non-ferrous metal. It can be recycled indefinitely without any loss of physical or chemical properties. This is a major advantage for the hot dip galvanizing process ensuring its environmental sustainability and its cost effectiveness.

About 30% (2 million tonnes) of the world's zinc consumption is from recycled sources. A figure which is rising with increased environmental awareness and improvements in recycling technology.

Estimates suggest that 80% of zinc available for recycling is in fact recycled (with today's tecnology). This means that much of the zinc in use today has probably been used before.

The presence of a zinc coating on steel does not restrict its recyclability. Galvanized steel is recycled with other steel scrap in the steel production process; it volatilises early in the process and is collected for reprocessing.

Other examples of uses and markets for recycled zinc:

- Zinc oxides - pharmaceuticals, food, fertilisers and for curing rubber.
- Zinc dust - paints, chemicals, lubricants, batteries and in gold recovery.
- Alloyed with other metals - cast into precision parts for appliances, hardware, electronics and toys.

Hot dip galvanizing is very efficient in its use of zinc, as any of the molten metal not forming a coating on the steel will run back into the galvanizing bath.

Three residual products are formed during the process; a zinc/iron mix called dross, zinc ash and flux skimmings. All of these contain valuable zinc and are recovered and recycled by specialist firms and the recycled zinc is often returned to the galvanizer. Zinc oxide is recovered from galvanizers' ashes and used in pharmaceutical/beauty products.

ZINC - NATURAL AND ESSENTIAL FOR HEALTH AND THE ENVIRONMENT

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Zinc is essential to life. It is a natural element found in all plants and animals and plays a crucial part in the health of our skin, teeth, bones, hair, nails, muscles, nerves and brain function. Zinc and its chemistry is found in over 200 enzymes and hormones in man.

Zinc deficiency is a recognised health problem. The Recommended Daily Allowance (RDA) of zinc is 15mg for a male adult, a figure that is easily met by a balanced diet containing meat and vegetables. However, certain people require more zinc than others, pregnant and lactating women for example, may need as much as 19mg a day. The elderly may be zinc deficient because of reduced food consumption, especially of proteins, and so they may need to take a zinc supplement.

Zinc is the 17th most common element in the earth's crust. Most rocks contain zinc in varying amounts and zinc exists naturally in air, water and soil. Due to natural weathering and erosion of rocks, soils and sediments together with volcanic eruptions and forest fires, a small but significant fraction of natural zinc is continuously being mobilised and transported in the environment.

The natural concentrations of zinc in different environments are referred to as background levels and can vary considerably between locations. The animal and plant species within a particular area have evolved to take up zinc from their environment and use it for specific functions in their metabolism. Consequently, all organisms are conditioned to the bio-available zinc concentrations in their environment which are not constant but subject to seasonal variations. Organisms have mechanisms to regulate their internal zinc levels. If uptake levels drop too low, deficiency can occur and adverse effects may be observed.

PUMP ROOMS TENBURY WELLS, WORCESTERSHIRE

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The restoration of this unusual building showed that the galvanized steel cladding and roof sheets, which have protected the building for nearly ninety years, can, at the end of their life be re-galvanized to provide the same protection all over again.

GALVACTION 21 TAKING THE GALVANIZING INDUSTRY FORWARD

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Recently Galvanizers Association launched a major initiative to take the galvanizing industry into the 21st Century with particular focus on the sustainability of the industry. Continuous environmental improvement is a key feature.

Just one example of the initiative in action is a project that has attracted funding from the Department of Trade & Industry (as part of its Recycling Programme) and relates to the recycling of waste hydrochloric acid from the galvanizing process. The project takes spent acid, recycles it and turns it into ferric chloride, a valuable raw material used to remove phosphates from wastewater.

The demand for ferric chloride is driven by the EU's urban wastewater directive, which imposes increasingly stringent controls on consent levels for the discharge of phosphates.

For an information pack on galvanizing and sustainablity including (GalvAction 21) please contact Galvanizers Association or visit our website at www.galvanizing.org.uk

SECTION
TWO
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TITLE
AN INTRODUCTION TO HOT DIP GALVANIZING
–

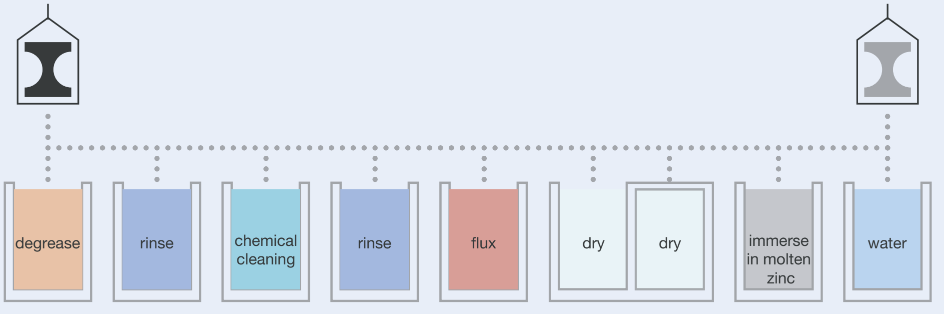
HOT DIP GALVANIZING, HAS GROWN ALMOST CONTINUOUSLY SINCE IT WAS FIRST USED TO PROTECT CORRUGATED IRON SHEETS 150 YEARS AGO. ITS ABILITY TO GROW IN THE FACE OF SOPHISTICATED COMPETITION IS THE RESULT OF THE SIMPLICITY OF THE PROCESS AND THE UNIQUE ADVANTAGES OF THE COATING.

PREPARATION
–

The galvanizing reaction will only occur on a chemically clean surface. Therefore most of the preparation work is done with this objective in mind. In common with most coating processes the secret to achieving a good quality coating lies in the preparation of the surface of the iron or steel. It is essential that this is free of grease, dirt and scale before galvanizing. These types of contamination are removed by a variety of processes. Common practice is to degrease using an alkaline or acidic degreasing solution into which the component is dipped.
The article is then rinsed in cold water and then dipped in hydrochloric acid at ambient temperature to remove rust and mill scale.

Welding slag, paint and heavy grease will not be removed by the above cleaning steps and should be removed before the work is sent to the galvanizer.

After a further rinsing operation, the components will then commonly undergo a fluxing procedure. This is normally applied by dipping in a flux solution - usually about 30% zinc ammonium chloride at around 65-80°C. Alternatively, some galvanizing plants may operate using a flux blanket on top of the galvanizing bath. The fluxing operation removes any of the last traces of oxide from the surface of the component and allows the molten zinc to wet the steel.



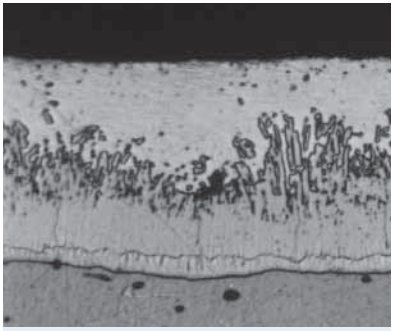


Fig. 2.
Microstructure of a typical hot dip galvanized coating.

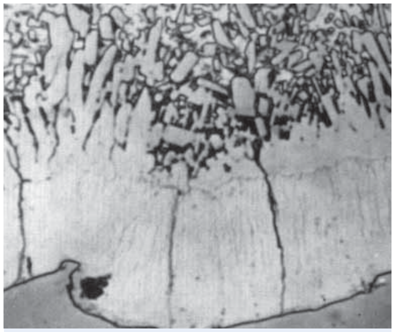
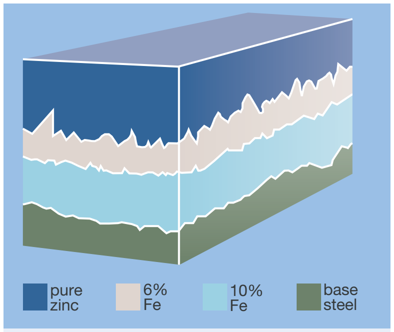


Fig. 3.
Microstructure of a thick coating obtained by grit blasting steel prior to galvanizing.

Fig. 4.
Microstructure of the thick coating obtained using a silicon-rich steel.



Schematic section through a typical hot dip galvanized coating.

THE GALVANIZING PROCESS

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When the clean iron or steel component is dipped into the molten zinc (which is commonly at around 450°C) a series of zinc-iron alloy layers are formed by a metallurgical reaction between the iron and zinc.
The rate of reaction between the steel and the zinc is normally parabolic with time and so the initial rate of reaction is very rapid and considerable agitation can be seen in the zinc bath. The main thickness of coating is formed during this period. Subsequently the reaction slows down and the coating thickness is not increased significantly even if the article is in the bath for a longer period of time.
A typical time of immersion is about four or five minutes but it can be longer for heavy articles that have high thermal inertia or where the zinc is required to penetrate internal spaces. Upon withdrawal from the galvanizing bath a layer of molten zinc will be taken out on top of the alloy layer. Often this cools to exhibit the bright shiny appearance associated with galvanized products.

Post galvanizing treatment can include quenching into water or air cooling.

Conditions in the galvanizing plant such as temperature, humidity and air quality do not affect the quality of the galvanized coating. By contrast, these are critically important for good quality painting.

THE COATING

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When the reaction between iron and zinc has virtually ceased the article is taken out of the galvanizing bath complete with its outer coating of free zinc, the process is complete. A microsection of the galvanized coating will look like the picture above (Fig 2).
In reality there is no demarcation between steel and zinc but a gradual transition through the series of alloy layers which provide the metallurgical bond.

COATING THICKNESS

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The coating thicknesses' are normally determined by the steel thickness and are set out in BS EN ISO 1461 (see Section 7). There are three exceptions to this rule, the first produces a slightly thinner coating, the other two increase it.

Centrifuged galvanized coatings

This involves a process covered in BS EN ISO 1461 and is used for galvanizing threaded components and other small parts. The parts, after preparation, are dipped in the molten zinc in a perforated basket. After the coating has formed this is centrifuged or spun at high speed, to throw off the surplus zinc to ensure a clean profile. Minimum average coating weights for centrifuged work are identified in BS EN ISO 1461 and in BS 7371 Part 6.

Thicker coatings may be produced by one of the following:

Thicker coatings by surface roughening

This is the most common method of achieving thicker coatings.

Grit blasting, to Sa 2½ (ISO 7079), the steel surface prior to immersion, using chilled angular iron grit of size G24, roughens and increases the surface area of steel in contact with the molten zinc. This generally increases the weight per unit area of a hot dip galvanized coating by up to 50% (Fig. 3).
Any steel article can be treated in this way, providing it is thick enough to withstand blasting. It may not be possible to grit blast the inside surface of hollow sections and fabrications, but these are almost always the areas least prone to corrosion.
Thicker coatings than those required by BS EN ISO 1461 should only be specified following consultation with the galvanizer or Galvanizers Association (see also Section 7).

Galvanizing reactive steels

A thicker zinc coating will be obtained if the article to be galvanized is manufactured from a reactive steel. The constituents in steel that have the greatest influence on the iron/zinc reaction are silicon, which is frequently added to steel as a deoxidant during its production, and phosphorous. Silicon changes the composition of the zinc-iron alloy layers so that they continue to grow with time and the rate of growth does not slow down as the layer becomes thicker (Figs 4 & 5). To a lesser degree phosphorus exerts a similar influence on the formation of the coating.

When an article fabricated from a reactive steel is removed from the zinc bath, a zinc layer adheres to the alloy layer as with any other steel article. However, the reaction rate in these steels can be so high that this pure zinc layer is transformed completely to zinc-iron alloy before the article has had time to cool. The result is a coating of equal or increased thickness which can be much darker in appearance as is described in Section 9. The change in appearance does not alter the corrosion resistance of the coating.

POST-TREATMENTS FOR GALVANIZING

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No post-treatment of galvanized articles is necessary. Paint or a powder coating may be applied for enhanced aesthetics or for additional protection where the environment is extremely aggressive. Painting and powder coating is discussed in Section 11.

Chemical conversion coatings and other barrier systems may be applied to minimise the occurrence of wet storage stain (Section 9).

SIZE OF ARTICLES

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Galvanizing is a versatile process and articles ranging in size from nuts and bolts to long structural sections can be treated.
This range, together with the ability to bolt or weld fabrications after galvanizing, allows almost any size of structure to be galvanized. Complex shapes, open vessels and most hollow articles can be galvanized, inside and out, in one operation. Certain hollow fabrications may be galvanized on the outside surface only, however, this requires special designs and galvanizing techniques. The capacity of individual galvanizing plants is detailed in the Directory of General Galvanizers, available free of charge from Galvanizers Association, or viewed at www.galvanizing.org.uk.

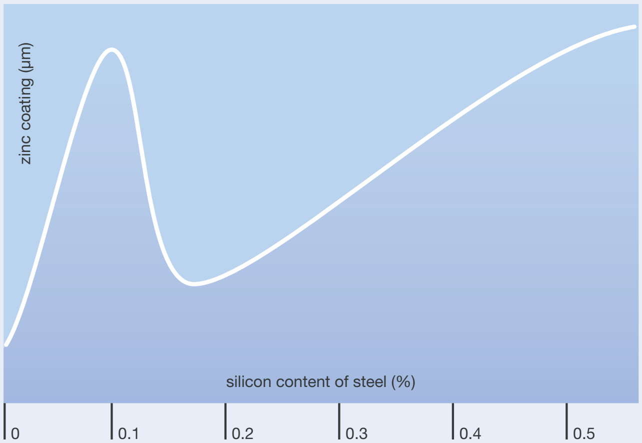

Fig. 5.
Approximate thickness of the zinc coating in relation to the silicon (Si) content of the steel.

(This is a schematic representation, please contact Galvanizers Association for detailed information)

SECTION
THREE
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TITLE
PHYSICAL PERFORMANCE
–

THE UNIQUE NATURE OF THE GALVANIZING PROCESS PROVIDES A TOUGH AND ABRASION RESISTANT COATING WHICH MEANS LESS SITE DAMAGE AND SPEEDY ERECTION OF STRUCTURES.

COHESION
–

Unlike most protective coatings, which rely solely on the preparation of the steel to obtain adequate adhesion, hot dip galvanizing produces a coating which is bonded metallurgically to the steel. In other words, the iron and the zinc react together to form a series of alloys which make the coating an integral part of the steel surface with excellent cohesion.

TOUGHNESS
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Resistance to mechanical damage of protective coatings during handling, storage, transport and erection is very important if the cost of 'touching up' on site is to be avoided. The outer layer of pure zinc is relatively soft and absorbs much of the shock of an initial impact during handling. The alloy layers beneath are much harder, sometimes even harder than the base steel itself. This combination provides a tough and abrasion resistant coating. (Fig 6)

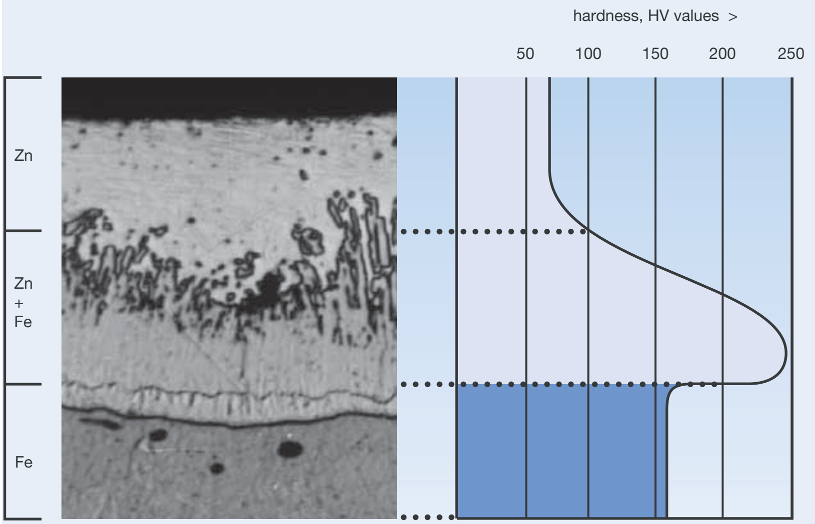

Fig. 6.
Micro section of hot dip galvanized coating showing variations in hardness through the coating. The zinc-iron alloys are harder than the base steel.

SECTION
FOUR
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TITLE
CORROSION PERFORMANCE
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LARGE FALLS IN ATMOSPHERIC POLLUTANTS
MEAN GALVANIZING NOW LASTS MUCH LONGER

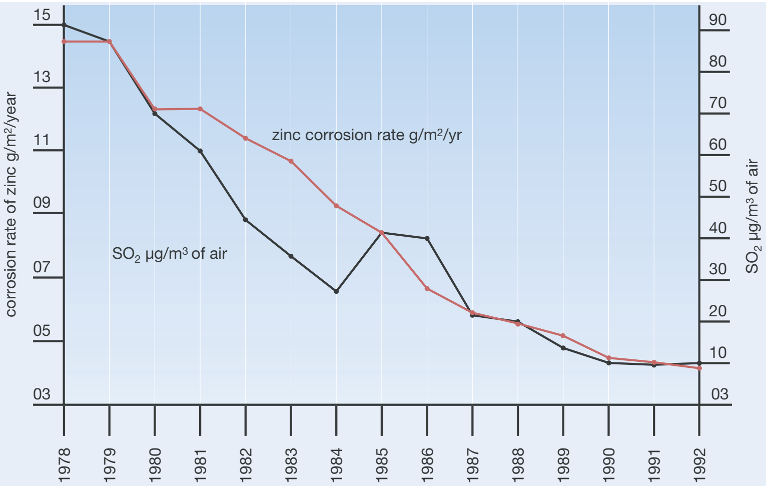

Fig. 7.
Reduction in sulphur dioxide levels in Stockholm since 1978 and accompanying decrease in corrosion rate of zinc.1

1*(Source: Knotkova D and Porter F 1994 Longer life of galvanized steel due to reduced sulphur dioxide pollution in Europe, Ed. proc. Intergalva 94, p GD 8/1-8/20 pub. EGGA, London)*

ATMOSPHERIC CORROSION RESISTANCE
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The resistance of galvanizing to atmospheric corrosion depends on a protective film which forms on the surface of the zinc. When the steel is withdrawn from the galvanizing bath, the zinc has a clean bright, shiny surface. With time this changes to a dull grey patina as the surface reacts with oxygen, water and carbon dioxide in the atmosphere. A complex but tough, stable, protective layer is formed which is tightly adherent to the zinc. Contaminants in the atmosphere affect the nature of this protective film.

The most important contaminant for zinc is sulphur dioxide (SO_2) and it is the presence of SO_2 which largely controls the atmospheric corrosion of zinc.

The corrosion rate for zinc is generally linear for a given environment. A major advantage of this is that it allows predictions of ultimate life to be made on the basis of interim assessments of coating thickness.

Given the wide range of environmental conditions encountered and protective systems available, data on performance can become complex. A number of guides have been produced giving the design life of protective systems in different environments. BS 5493 ‘Code of Practice for Protection of Iron and Steel Against Corrosion’ provided some information but its guidance on the lifetime of galvanized coatings is now out-of-date.

Since BS 5493 was published in 1977, atmospheric sulphur dioxide levels (SO_2) have reduced considerably. A direct relationship exists between the corrosion rate of zinc and airborne SO_2 levels (Fig 7). Therefore, the life of galvanized coatings has increased significantly since the 1970’s and it is important to use up-to-date information in assessments of coating life. BS 5493: 1977 has been replaced in part by the new guidance document BS EN ISO 14713: 1999 (Table 1)

The environments in most corrosion guides are necessarily general. Specific corrosivity values in the UK have been mapped by the Agricultural Development Advisory Service (ADAS). The information was based on data obtained from exposure of zinc reference samples at National Grid Reference points in a large number of 10km square reference areas of the UK.

The results indicated varying rates of corrosion for zinc in exterior locations. Galvanizers Association sponsored the revision of the map, to provide specifiers with the very latest information on zinc corrosion. For the first time the survey was extended to the Republic of Ireland. The same experts that were involved in the development of previous corrosivity maps were contracted to co-ordinate the project.

Comparison of data obtained from The Zinc Millennium Map (page 18-19) with results from previous maps (1982 and 1991) show a clear, and very significant, drop in the corrosion rate for zinc for most atmospheric exposures across the UK and the Republic of Ireland.

In particular, urban locations which, in the past may have been considered aggressive for zinc, will yield significantly enhanced lives for galvanized coatings. In more remote locations these downward trends in SO_2 levels are not so pronounced and the (already low) corrosion rates for zinc would not be anticipated to be further reduced to any significant extent.

A brief inspection of Table 1 and Figure 8 confirms that for most exterior applications of galvanizing the corrosion categories across large areas of the UK and the Republic of Ireland are C2 / C3 ie 0.1μm/yr - 2μm/yr.

The Zinc Millennium Map results show that a standard 85μm galvanized coating may now achieve a coating life of 50 years in most environments. Similarly, a thicker 140μm galvanized coating, often produced on structural steel, may achieve a coating life of over 100 years.

Table 1.
Indicative zinc corrosion rates for different environments *Source: BS EN ISO 14713 (Corrosivity categories from ISO 9223)*

corrosivity category		average annual zinc corrosion rate (μm/year)
C1	interior: dry	<0.1
C2	interior: occasional condensation exterior: rural	0.1 to 0.7
C3	interior: high humidity, some air pollution exterior: urban inland or mild coastal	0.7 to 2
C4	interior: swimming pools, chemical plants exterior: industrial inland or urban coastal	2 to 4
C5	exterior: industrial with high humidity or high salinity coastal	4 to 8

Fig. 8

THE ZINC MILLENNIUM MAP

Annual Average Atmospheric Corrosion of Zinc, UK and Republic of Ireland, 1998-2000

This is an approximate guide and is most relevant to stationary, exterior-exposed structures. You will need to take account of any site specific factors which may affect the corrosion rate.

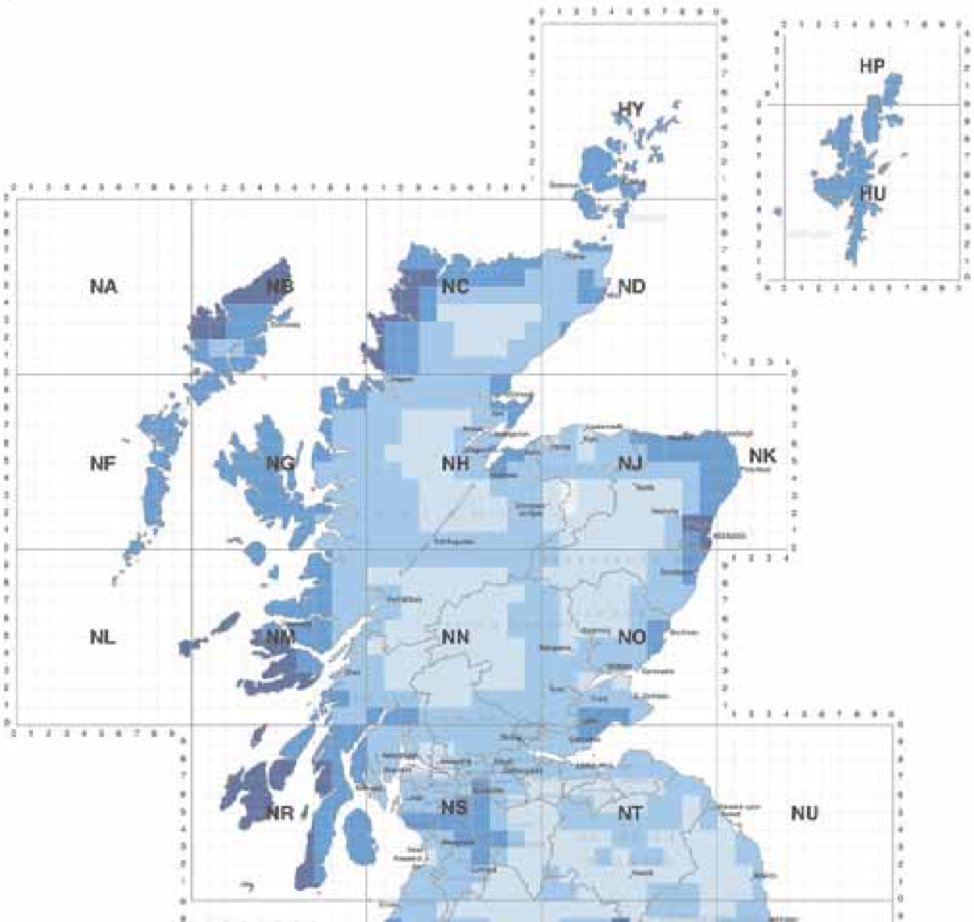
Detailed data for individual sites and advice on its interpretation (e.g. the possible effects of a local micro-climate on the corrosion rate actually experienced by the galvanized structure) is available from Galvanizers Association.

Zinc corrosion rates are represented by five categories indicated by the colour codes shown below.

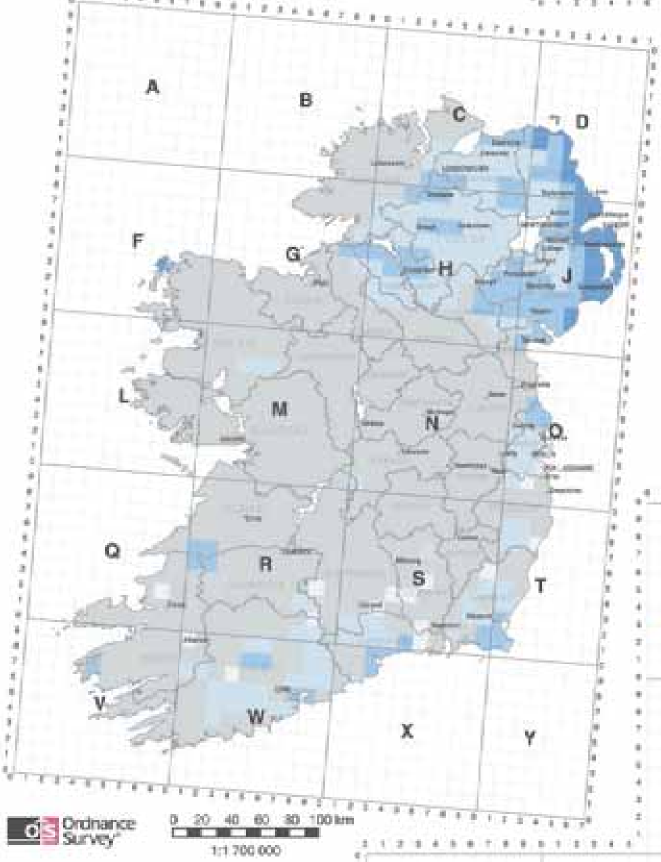
Corrosion Category	1	2	3	4	5
Average Corrosion rate (µm/year)	0.5	1	1.5	2	2.5
Average life of 85µm galvanized coating (years)	170	85	57	43	34

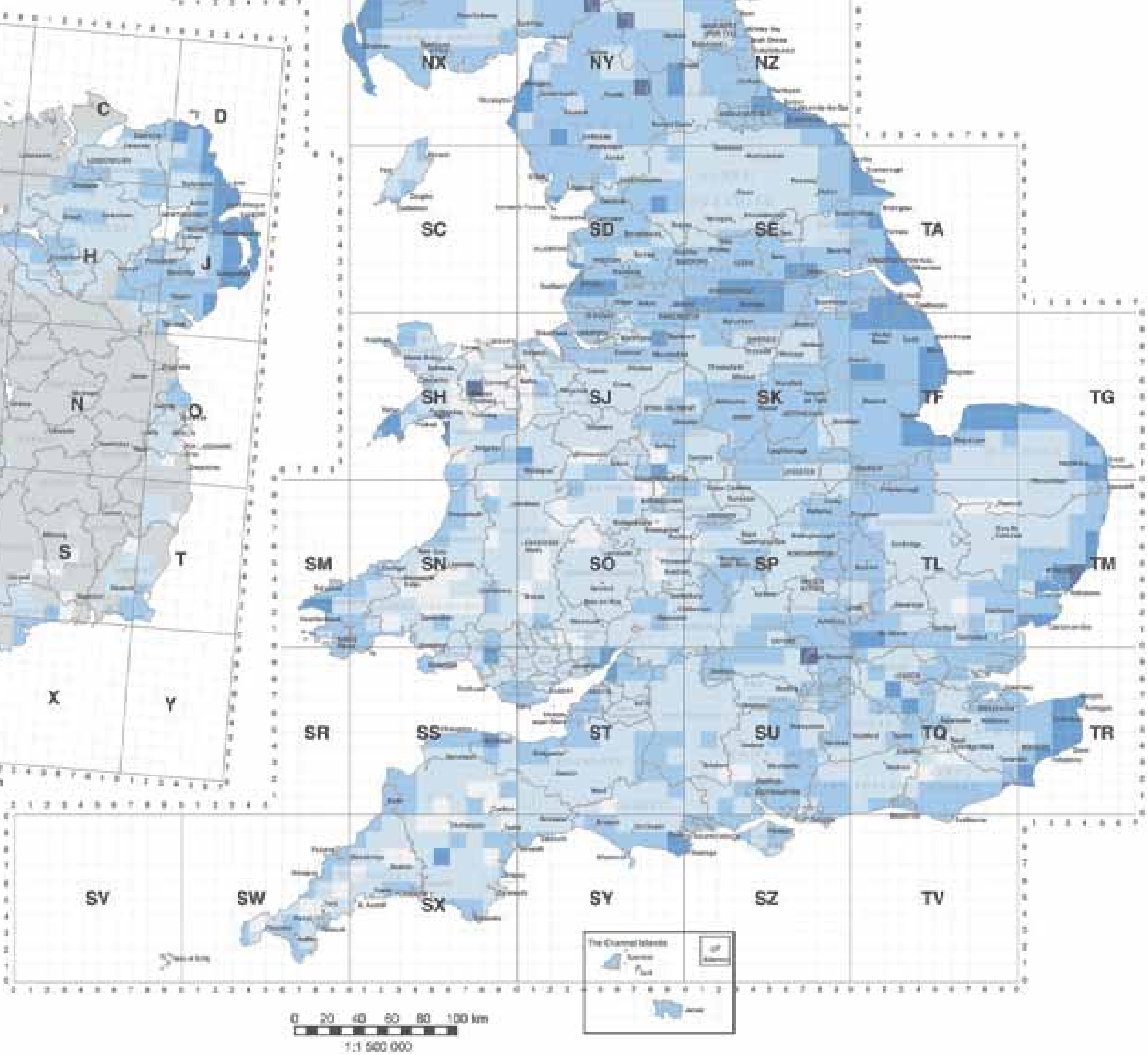
How to use the map

- Locate your project on the map
- Match the colour of the square to the key
- Read off the average background corrosion rate in µm per annum
- Identify the minimum average galvanized coating thickness for steelwork in µm (see section 7)
- Divide the coating thickness by the corrosion rate to obtain the expected minimum life of the galvanized coating



Discover the background corrosion rate for your town @ www.galvanizing.org.uk





ADAS

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- All those who provided sample sites for the project

ADAS Consulting and GA are grateful to Orange Plc for provision of survey sites in the UK and the Irish Electricity Supply Board for survey sites that allowed corrosion rates at key Irish locations to be included in the Zinc Millennium Map.
Further studies are planned to extend survey coverage in the Republic of Ireland. For areas not yet covered, the rates indicated for comparable areas may be used as an indication of likely corrosion rates.

PERFORMANCE IN OTHER ENVIRONMENTS

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Interior environments

A common misconception is that corrosion may not be a problem for interior steelwork which is protected from the elements. If there is frequent condensation on its surface, corrosion of inadequately protected steel will be significant. Under these conditions, hot dip galvanizing may give more than 40 years life. Hot dip galvanizing has also been used extensively to protect interior steelwork in harsh environments such as swimming pools and breweries. Corrosion may also arise on exposed ungalvanized steelwork intended for interior environments if there is a delay in assembly or construction.

Immersed: Cold water

Most waters contain scale-forming salts which can form a protective layer on the inside surfaces of galvanized water distribution systems, hence coatings can have their lives enhanced usually to greater than 40 years. If these salts are not present, as is often the case in soft waters, longer life can be obtained by applying two coats of bituminous solution (to BS3416 Type II for drinking water).

Immersed: Hot water

The scale-forming properties of water are also important in hot water giving normal life expectancies of over 10 years. Above 60°C zinc may become cathodic to steel in some waters and no longer provide sacrificial protection if the coating is damaged.

Where this situation could arise, sacrificial protection can be assured by installing a magnesium anode as ‘back-up’ to the zinc coating.

Immersed: Sea water

Sea water is more aggressive than freshwater. For UK waters the corrosion rate normally lies in the range 10 - 15μm/yr for continuous immersion. Tidal immersion, regular sea spray or immersion in warm tropical sea water can lead to an increased corrosion rate.

Underground

The life of a buried galvanized coating can vary depending on, for example, the type of soil - its acidity and whether it has been disturbed, (contact Galvanizers Association for further advice). A pH range of 5.5 to 12.5, ie. weakly acid to alkaline, is favourable. Soils containing ashes and clinkers are especially harmful. In many cases, the application of a bituminous solution (to BS3416 Type 1) over the zinc coating is beneficial - particularly where galvanized steel is buried in the ground or at the point where it emerges from concrete. Galvanized steel can be safely embedded into concrete. For even greater protection in soils, thicker galvanized coatings can be specified (see Section 7).

In contact with wood

Very acidic woods such as oak, sweet chestnut, western red cedar and douglas fir can be used in conjunction with galvanized steel, provided they are isolated from direct contact.

In contact with other metals

There is only slight additional corrosion of zinc as a result of contact with the majority of metals in most atmospheric conditions. Bimetallic corrosion can occur in immersed conditions or in locations where rainwater is unable to drain easily or dry out at the contact surfaces. Guidance is given in BSI’s PD6484: ‘Commentary on corrosion at bimetallic contacts and its alleviation’.

In contact with chemicals

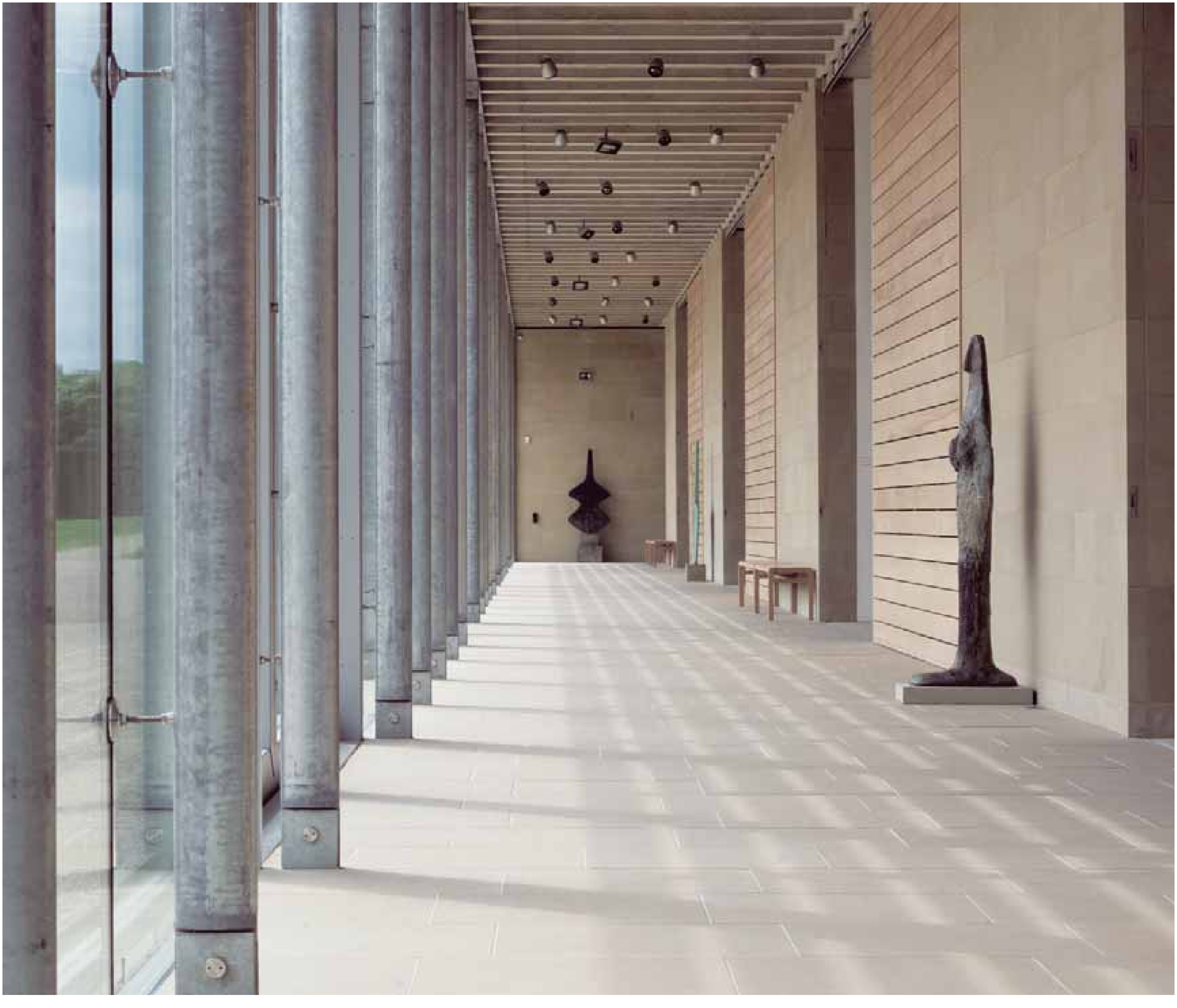
Contact with chemicals requires special consideration. A wide range of chemicals are compatible with galvanized steel. Prolonged or frequent contact with acids and strong alkalis is not advisable.

High temperature

Galvanized coatings will withstand continuous exposure to temperatures of approximately 200°C and occasional excursions up to 275°C without any effect on the coating. Above these temperatures there is a tendency for the outer zinc layer to separate, but the alloy-layer, which comprises the majority of the coating, remains intact. Adequate protection may often, therefore, be provided up to the melting point of the alloy layer (around 530°C).

In contact with building materials

Damp mortar, cement and plaster have a slight etching action upon galvanized coatings whilst drying or setting. This effect ceases once the action has finished.



SECTION
FIVE
–

TITLE
HOW GALVANIZING PROTECTS STEEL
–

GALVANIZING IS UNIQUE - TOUGH, LONG LASTING, SELF HEALING AND COVERS INTERNAL AND EXTERNAL SURFACES.

BARRIER PROTECTION
–

Galvanizing provides a barrier between all internal and external steel surfaces and their environment. Galvanizing is a term often wrongly used to describe zinc coatings in general. Fig. 9. illustrates how the different types of zinc coatings vary in terms of coating thickness. The life expectancy of a zinc coating is largely determined by its thickness. Thicker coatings give longer life. Hot dip galvanizing provides fabricated iron or steel products with maximum protection through a continuous, tough, metallurgically bonded coating of much greater thickness.

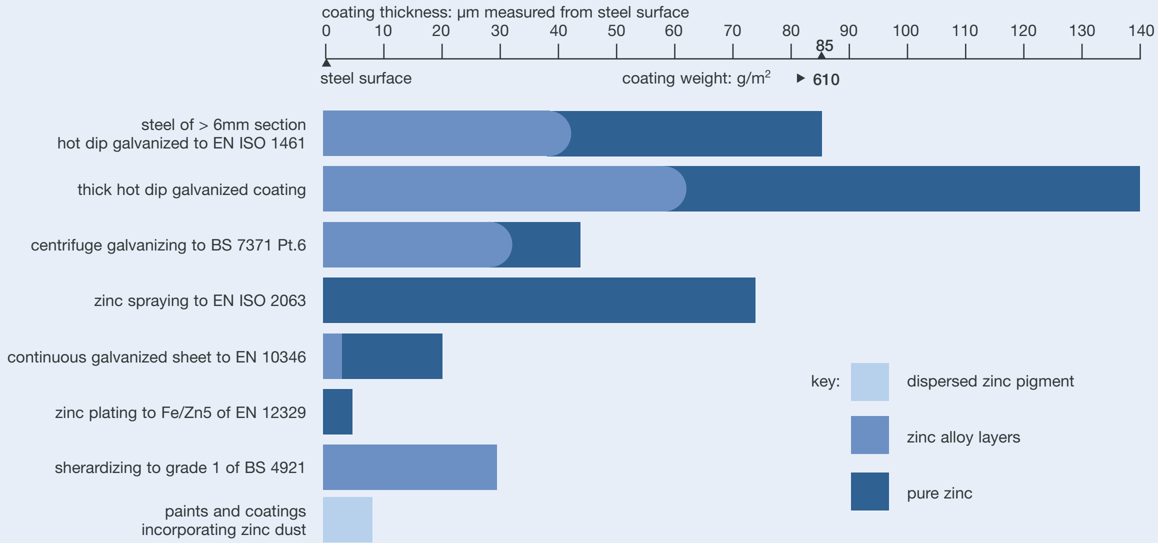


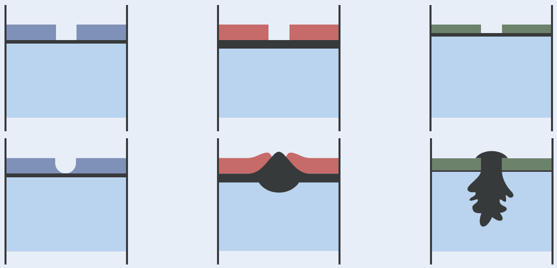
Fig. 9.
Zinc coatings compared in terms of coating thickness

PROTECTION BY SACRIFICIAL ACTION

–

Zinc corrodes in preference to steel and sacrifices itself to protect the steel, hence hot dip galvanizing will provide this sacrifical action Fig 10. The corrosion products from the zinc are deposited on the steel resealing it from the atmosphere and therefore stopping corrosion. With paint coatings, additional protection would have to be applied immediately after the damage occurred or the steel would rust with eventual break down of the whole coating as rust crept underneath the paint film.

Fig. 10.
Schematic to illustrate the consequence of damage to different types of coating offering corrosion protection.



hot dip galvanized coating

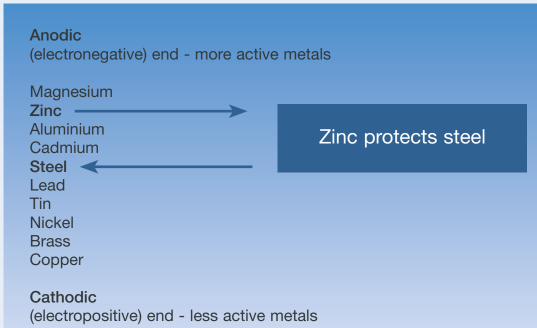
A galvanic cell is formed. The zinc around the point of damage corrodes. Corrosion products precipitate on the steel surface and protect it. The steel is also protected because it is cathodic in relation to the zinc coating.

paint coating

The steel rusts where the paint film has been damaged. Rust creeps under the paint film, which is lifted up from the steel surface. Corrosion continues until the damage has been repaired.

coating of more electro-positive metals than steel

Nickel, chromium, and copper - give rise to more rapid corrosion at the point of damage than if the steel had been uncoated. The corrosion often takes the form of pitting, which can even go through the steel.



Zinc's position in the Galvanic Series

SECTION
SIX
–

TITLE
COST AND ECONOMICS
–

GALVANIZING PROVIDES UNRIVALLED WHOLE LIFE COST BENEFITS FOR STEEL STRUCTURES AND COMPONENTS - AND CAN ALSO BE COMPETITIVE ON AN INITIAL COST BASIS

ECONOMICS
–

The true cost of protecting steelwork from corrosion has to take into consideration two important elements:

- The initial cost of protection
- The lifetime cost, which includes the cost of maintenance. This is the cost of ensuring that steelwork is protected from corrosion throughout its service life.

INITIAL COST
–

Hot dip galvanizing is often perceived to be more expensive than it is. There are two reasons for this: Firstly, that such a high performance coating is automatically assumed to be expensive. Secondly, the initial cost of galvanizing relative to paint has changed significantly over recent years. Painting costs have steadily increased whilst galvanizing costs have remained stable.

Galvanizers Association recently commissioned independent consultants, The Steel Protection Consultancy Ltd (SPC), to investigate the cost competitiveness of galvanizing. SPC in conjunction with consulting engineers, WS Atkins, designed a typical, 240 tonne, steel framed building and sent it out to tender. Two corrosion protection systems were specified; (i) hot dip galvanizing and (ii) a good quality, grit blast and three coat paint system of 250μm dry film thickness. Quotations from eight fabricators in different parts of the UK were obtained and averaged. The paint system was found to be 35% more expensive than hot dip galvanizing.

Fig. 11 illustrates that for many applications the cost of hot dip galvanizing is lower than that of applying alternative coatings. The reason for this is simple: alternatives such as painting are very labour intensive compared with galvanizing, which is a highly mechanised, closely controlled, factory process.

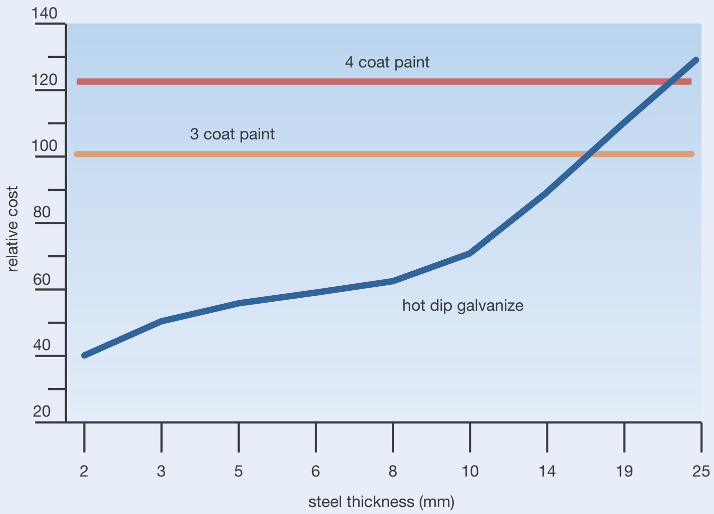


Fig. 11.
Comparison between initial costs

WHOLE-LIFE COST

—

The whole-life cost of a building can be defined as:

“The cost of acquiring, operating and maintaining a building over its whole life through to disposal”

Whole-life costing can be characterised as a system that quantifies financial values for buildings from inception and throughout the building’s life. It is an approach that balances capital with revenue costs to achieve an optimum solution over a building’s whole life.

This technique, whilst not in itself new, has over recent years become accepted best practice in construction procurement. Whole-life costing can be used at any stage of the procurement process and can be used at the levels of facility, function, system and component. This includes everything from initial design to end-of-life.

It is estimated that up to 80% of a building’s whole-life cost can be attributed to running, maintenance and refurbishment costs. Consequently, there are spikes in expenditure at 10 years and every five years after that (see Fig. 12a).

The initial choice of materials and the way that they are protected obviously plays an important role within the maintenance and refurbishment costs of a building over its lifetime. They therefore have a very large influence on the whole-life cost profile of the project.

Design	Build	Operate	Dispose	Total
£ 3%	£ 17%	Run/Maintain £ - 40%	£ ?%	100% Cost of Ownership
		Repair £ - 30%		
		Periodic Replacement/Refurbish £ - 10%		
1 Year	2 Year	25 Years	1 Year	Total

Table 2.
Capturing Whole Life Costs

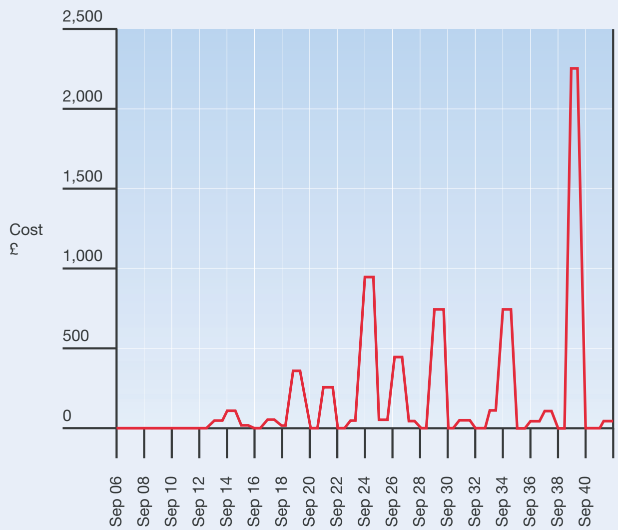


Fig. 12a.
Smoothing the Expenditure

Life cycle expenditure tends to inherently produce “spiky” profiles with large peaks at 10, 15, 20, 25 years.

Above information supplied by Turner and Townsend, Construction and Management Consultants

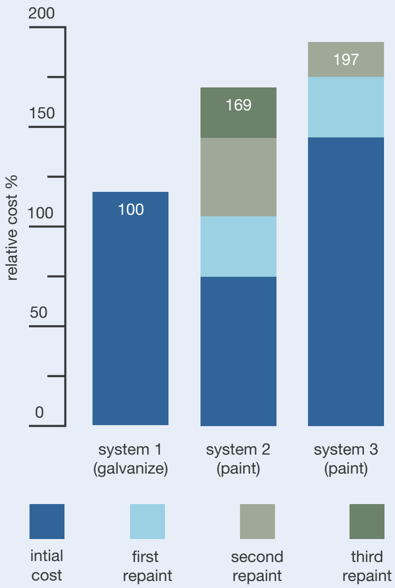


Fig. 12b.
Net Present Value compared

LIFETIME COSTS

–

The overall cost of protecting a steel fabrication throughout its life depends on the cost and durability of the initial coating in the particular environment and, on the costs and frequency of any subsequent treatments where the required life exceeds that of the initial coating.

In the majority of applications, hot dip galvanizing will provide a long, maintenance-free life without any requirement for maintenance painting.

There are ways of calculating the benefits or disadvantages of different methods of corrosion protection. The most common method is to calculate the Net Present Value (NPV) of each method and compare the results. This calculation takes into account the cost of borrowing money, the initial cost of protection, subsequent maintenance costs and the lifetime of the project. It is frequently used by companies to measure the likely outcome of a capital investment project.

$$NPV = I + \frac{M1}{(1+r)^{P_1}} + \frac{M2}{(1+r)^{P_2}} + \text{etc}$$

Where I = Initial cost of protective system
M1 = Cost of maintenance in year P1
M2 = Cost of maintenance in year P2
r = Discount rate

EXAMPLE

–

Take the case of a steel structure that has a projected life of 25 years and for which the discount cost of capital is 5%.

Galvanize: system 1

Hot dip galvanize to BS EN ISO 1461 with a minimum average coating of 85μm on steel of 6mm or more thick. As galvanizing to this standard has an average life expectancy of more than 50 years in the UK (see Section 4), it is very conservative to project a life of 25 years without further maintenance. Let the cost of galvanizing be a base figure of 100 units. There are no further maintenance costs. (NPV = 100)

Paint: system 2

A paint system consisting of cleaning followed by an undercoat and two top coats of paint. This system has a life expectancy of 8 years and so will need to be repainted three times in 25 years. The initial cost is slightly cheaper than hot dip galvanizing at 90 units.
The cost of repainting for the first two occasions is 45 units but goes up to 90 units for the third repaint when the original paint must be removed.
(NPV = 169)

Paint: system 3

A superior paint system consisting of blast cleaning followed by three coats of a higher quality paint. This system has a life expectancy of 11 years and will need to be repainted twice in 25 years. The initial cost is higher than the other paint system at 135 units. The cost of repainting is half this value at 67.5 units. (NPV = 197.5)

Conclusion

It can be seen that over a 25 year project life the cost of a 'cheaper' paint system is almost 70% more than the cost of galvanizing. Likewise the cost of a more 'expensive' paint system is almost double that of galvanizing. In initial, or first, cost terms hot dip galvanizing is comparative with a good quality paint system. However, when looking at lifetime costs, hot dip galvanizing works out to be considerably cheaper than most other systems.

SECTION
SEVEN
–

TITLE
SPECIFYING HOT DIP GALVANIZING
–

STANDARDS
–

The basic specification for hot dip galvanized coatings on iron and steel articles is defined by a single standard, BS EN ISO 1461 ‘Hot dip galvanized coatings on iron and steel articles - specifications and test methods’.

The galvanizer acts as a specialist subcontractor to a steel fabricator and, as such, his contractual relationship is with the fabricator, not with the ultimate user. It is important, therefore, that the user’s requirements for galvanizing are made clear to the fabricator and that all communications concerning galvanizing are channelled through the fabricator. To ensure the best quality and technical back-up service, it should be stated that the work be ‘processed by a member of Galvanizers Association’.

When hot dip galvanizing is specified, the surface of the steel is completely covered with a uniform coating whose thickness is determined principally by the thickness of the steel being galvanized (Tables 3 and 4).

This is an important advantage of the galvanizing process; a standard coating thickness is applied almost automatically. The actual thickness of galvanized coating achieved varies with steel section size, surface profile and surface composition. Actual coating weights are often much more than the minimum specified in the standard. As coating life expectancy figures quoted are based on the minimum coating thickness they are therefore usually very conservative.

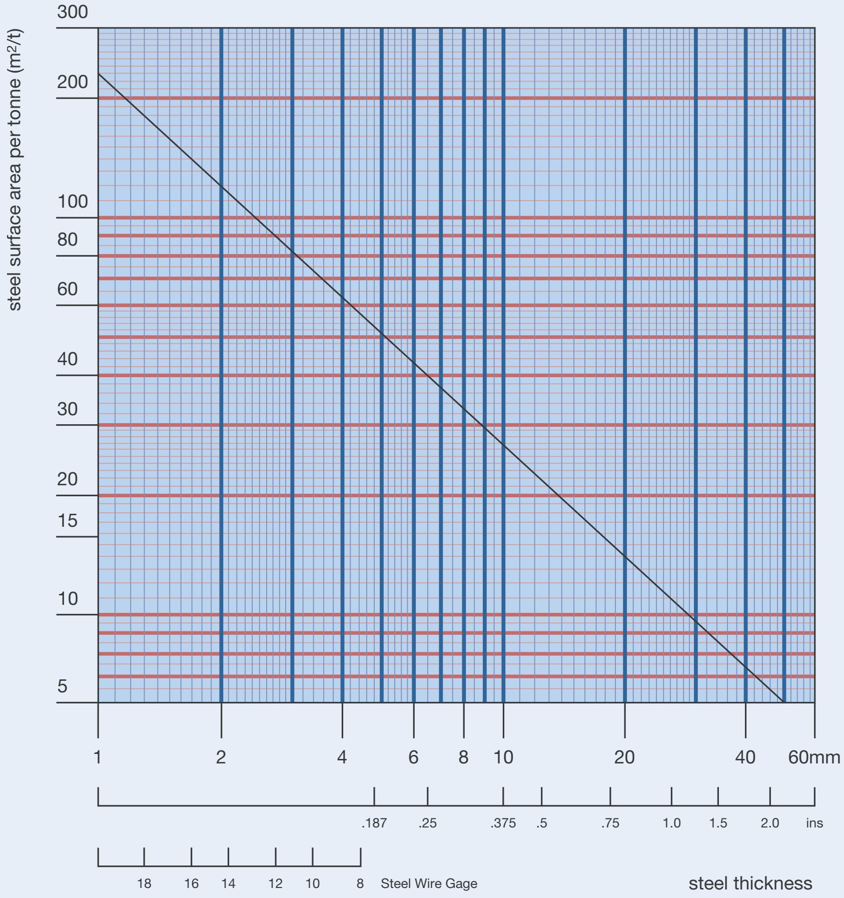


Fig. 13.
Relationship between steel thickness and surface area/tonne

UK National Building Specification (NBS)

There are many references to specifying hot dip galvanizing throughout the National Building Specification (NBS) system, the main location being G10 - Structural steel framing. General guidance on corrosion protection is also given.

In the unlikely event of being unable to identify the correct clause for a particular galvanizing application, please contact Galvanizers Association for specific advice.

Table 3.
EN ISO 1461: coating minimum masses/ thickness on articles that are not centrifuged.

articles & its thickness	local coating (minimum)		mean coating (minimum)	
	g/m²	µm	g/m²	µm
steel > 6mm	505	70	610	85
steel > 3mm to ≤ 6mm	395	55	505	70
steel ≥ 1.5mm to ≤ 3mm	325	45	395	55
steel < 1.5mm	250	35	325	45
castings ≥ 6mm	505	70	575	80
castings < 6mm	430	60	505	70

Table 4.
EN ISO 1461: coating minimum masses/ thickness on articles that are centrifuged.

articles & its thickness	local coating (minimum)		mean coating (minimum)	
	g/m²	µm	g/m²	µm
articles with threads:				
> 6mm ø	285	40	360	50
≤ 6mm ø	145	20	180	25
other articles (incl. castings):				
≥ 3mm	325	45	395	55
< 3mm	250	35	325	45

The requirements of BS EN ISO 1461 include cleaning and preparation of steelwork as well as galvanizing. Guidance on the use and performance of hot dip galvanizing is contained in BS EN ISO 14713 'Protection against corrosion of iron and steel in structures - zinc and aluminium coatings - guidelines' and further guidance is available from Galvanizers Association.

THICKER COATINGS
–

Thicker coatings than those set out in BS EN ISO 1461 can give additional protection for use in particularly aggressive environments and can be specified in conjunction with BS EN ISO 1461.
It should, however, be emphasised that for most applications, thicker coatings are rarely necessary.

The means of achieving thicker coatings are described in Section 2. Grit blasting prior to galvanizing is usually the most appropriate method and a requirement for a nominal coating thickness of 1000 g/m² (140µm) has been successfully specified for steel of ≥ 6mm section thickness. For structural steelwork, it is advisable to ascertain whether thicker coatings could be achieved through their greater section thickness and without grit blasting.

Achieving thicker coatings through specification of a reactive steel is normally only appropriate for specific applications.

Specification of thicker coatings must only be made following consultation with the galvanizer concerning viability and the means by which they will be achieved.

FASTENERS
–

Specifications for fasteners should clearly state 'that the fastener coating should conform to BS 7371: Part 6: 1998'.
Merely to specify 'galvanized' is open to misinterpretation and zinc electroplated, mechanically plated or sherardized components, which provide less protection, may be supplied. More information on fasteners is given in Section 10.

LEAD TIMES
–

Provided reasonable notice is given, most articles can be galvanized and returned to the fabricator within a week. A typical turn-around, depending on size of the order, is three days. Galvanized bolts and nuts are now widely stocked, but it is advisable that orders for galvanized fasteners should be placed as early as possible.

APPEARANCE
–

Galvanizing is primarily used to protect steelwork against corrosion. Acceptable appearance under BS EN ISO 1461 is discussed in Section 9. In cases where appearance and smoothness are particularly important, the galvanizer should be consulted at an early stage.

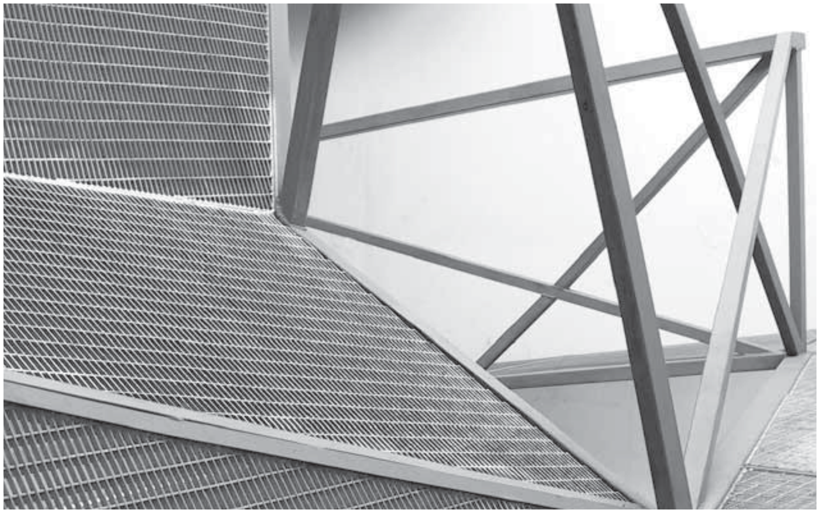
DUPLEX COATINGS
–

The use of paint or powder coatings over a galvanized coating may be used for aesthetics or for additional protection (see Section 11).

SECTION
EIGHT
–

TITLE
DESIGNING ARTICLES FOR GALVANIZING
–

EARLY CONSULTATION BETWEEN GALVANIZER, FABRICATOR AND DESIGNER IS THE KEY TO OBTAINING THE BEST RESULTS FROM THE GALVANIZING PROCESS. DESIGN FEATURES, WHICH AID THE ACCESS AND DRAINAGE OF MOLTEN ZINC, WILL IMPROVE THE QUALITY AND APPERANCE OF THE COATING.



FILLING, VENTING AND DRAINAGE
–

Good design requires:

- means for the access and drainage of molten zinc
- means for escape of gases from internal compartments (venting)

It is important to bear in mind that the steelwork is immersed into a bath of molten zinc at a temperature of 450°C. Thus any features which aid the access and drainage of molten zinc will improve the quality of the coating and reduce costs.

With certain fabrications, holes which are present for other purposes may fulfil the requirements for venting and draining; in other cases it may be necessary to provide extra holes for this purpose.

For complete protection, molten zinc must be able to flow freely to all surfaces of a fabrication. With hollow sections or where there are internal compartments, the galvanizing of the internal surfaces eliminates any danger of hidden corrosion during service.

General principles

1. Holes for venting and draining should be as large as possible. The minimum hole diameters are given in Table 5.

2. Holes for venting and draining should be diagonally opposite to one another at the high point and low point of the fabrication as it is suspended for galvanizing. Very long hollow sections may require additional vent holes to aid drainage and to help produce a better surface finish.

3. With hollow sections sealed at the ends, holes should be provided, again diagonally opposite one another, as near as possible to the ends. In some cases it may be more economical to provide V or U shaped notches in the ends, or to grind corners off rectangular hollow sections - these procedures provide ideal locations for venting and draining.

4. Where holes are provided in end plates or capping pieces, they should be placed diagonally opposite one another, off centre and as near as possible to the wall of the member to which the end plate is connected.

5. Internal and external stiffeners, baffles, diaphragms, gussets etc., should have the corners cropped to aid the flow of molten zinc.

size of hollow section (mm)	minimum diameter of hole (mm)
< 25	10
≥ 25-50	12
> 50 - 100	16
> 100 - 150	20
> 150	consult galvanizer

Table 5.
Suitable sizes of vent holes in tubular structures

Where venting of a hollow section is required, for a longer section (e.g. > 3 m) there may be a need for additional or larger vent holes to help achieve the best possible surface finish and advice should be sought from the galvanizer.

Holes that have been drilled for venting can be plugged, but this is mainly necessary for aesthetic reasons, because a galvanized coating covers all surfaces. If required, tapered aluminium or plastic plugs are available and will prevent undesirable ingress of water.

Detailed design advice is available from Galvanizers Association or directly from the galvanizer. Some points to bear in mind for venting and draining are illustrated in the diagrams on pages 34 - 38.

BASE METAL AND COMBINATIONS

Plain carbon steel, some low-alloy steels and iron and steel castings can all be galvanized.

Soldered or brazed components should not be galvanized.

A fabrication consisting of a variety of materials with different surface conditions should be avoided, as this could affect the uniformity and appearance of the coating. Where differing materials are used, grit blasting the entire assembly can minimise any differences which may arise due to differing effects of pre-treatment. Preferably, the fabrication should be of similar steel type throughout.

Steel fabrications that have been subject to heavy cold work (e.g. bent through a tight radius) may be susceptible to strain age embrittlement and should be stress relieved prior to galvanizing.

When the steel to be galvanized is a high-strength steel with a crack initiator and a high level of residual stress, consideration should be given to reducing potential for steel cracking to occur. Such a combination is very rare but when it does exist, advice should be sought from Galvanizers Association or reference made to Publication No 40/05, 'Galvanizing structural steelwork - An approach to the management of liquid metal assisted cracking', published by the British Constructional Steelwork Association (BCSA)

SIZE AND SHAPE

In recent years, the size and capacity of galvanizing plants has increased significantly. Reference should be made to the Directory of General Galvanizers or www.galvanizing.org.uk for an indication of the bath sizes available in the UK and Republic of Ireland. When the length or depth of the item exceeds the size of the bath, special techniques may be employed to facilitate dipping - in this case advice must be sought from the galvanizer.

FASTENERS

To accommodate the thickness of zinc when galvanizing threaded components, extra clearance must be provided on the female threads. More information on the use of galvanized fasteners is given in Section 10.

OVERLAPPING SURFACES

Overlapping surfaces should be avoided as far as possible. Care must be taken not to specify sealed articles for galvanizing. If overlaps are completely sealed by welding there is a risk of explosion during dipping due to increased pressure of any entrapped air. If overlaps are not completely sealed there is a danger of cleaning fluid entering the cavity and then weeping out and causing localised staining (see page 36).

CASTINGS

Castings must be grit blasted before galvanizing, as embedded sand from the casting process cannot be removed by conventional chemical cleaning. When designing castings to be galvanized, features such as sharp corners and deep recesses should be avoided as these may develop excessive distortion and thermal stresses during hot dip galvanizing. Large fillet radii and uniform section thickness are also desirable.

MOVEABLE PARTS

Adequate clearance on mating surfaces, such as hinges, should be allowed if they are to move freely after galvanizing. An extra clearance of at least 1mm is usually sufficient.

DISTORTION

If steel fabrications distort during galvanizing, this is usually due to 'built-in' stresses being released, as the steel is heated to the galvanizing temperature. Stresses may be inherent in the steel, but they can also be introduced by welding, cold forming, and hole punching.

Efforts can be made at the design stage and elsewhere to minimise residual stresses, for example:

1. Controlling welding procedures during fabrication.
2. Arranging weld seams symmetrically. The size of weld seams should be kept to a minimum.
3. Avoiding large changes in structural cross-section, which may increase distortion and thermal stress in the galvanizing bath.

Where there is an inherent tendency to distort, e.g. in asymmetrically shaped fabrications, the effect can be minimised or possibly eliminated by restricting the fabrication to such a size and design that it can be rapidly immersed in a single dip. The galvanizer should be consulted for advice at an early stage if this is being considered. The size and position of filling and drainage holes in fabricated vessels can have a major effect on distortion, as can the size and position of lifting holes or lugs, particularly on hollow fabrications.

STRENGTH

The tensile properties of structural steels are not affected by galvanizing, as shown in Table 6 (page 32).

				Cold Rolled 10%		Cold Rolled 40%		With Punched Holes		Welded Steel	
		As Received	Galvanized	Not Galvanized	Galvanized	Not Galvanized	Galvanized	Not Galvanized	Galvanized	Not Galvanized	Not Galvanized
EN 10025-2 S275	Tensile strength (Pa)	453	461	563	560	741	706				
	0.5% proof stress (Pa)	294	281	550	502	732	659				
	Elongation (%)	45	46	18	22	8	15	*10	10	28	38
EN 10025-2 S355	Tensile strength (Pa)	531	522	644	635	811	784				
	0.5% proof stress (Pa)	367	362	634	587	807	746				
	Elongation (%)	41	43	16	20	8	15	+15	16	25	33
EN 10028-3 P460	Tensile strength (Pa)	585	597	714	734	905	860				
	0.5% proof stress (Pa)	451	446	692	683	896	842				
	Elongation (%)	36	34	21	21	10	13	^6	5	29	30

key
* As Received
+ 10 % Cold Rolled
^ 40% Cold Rolled

Table 6.
Tensile properties of structural steel tests on plates 12.7mm thick (source: ILZRO, 2006)

POINTS TO CONSIDER WHEN DESIGNING FABRICATIONS FOR HOT DIP GALVANIZING.

WELDING
–

Welding slag is not removed in the cleaning process and may result in black bare spots after hot dip galvanizing. To avoid this problem, efforts should be made to use gas shielded welding processes e.g. M.I.G. and if coated electrodes are used, welds should be thoroughly de-slagged. In order to minimise the incidence of raised weld seams after hot dip galvanizing, the silicon content of the welding rod material should be less than 0.04%. Anti-spatter weld sprays should be water soluble and should be oil and silicone free. Further information on welding is given in Section 10.

LABELLING AND MARKING
–

Water soluble paint or detachable metal labels can be used for temporary identification marks on fabrications. Enamel based paints or oil based markers must not be used. For permanent identification to be legible after galvanizing, large heavily punched or embossed marks are necessary.

MASKING
–

If certain areas of steelwork need to remain uncoated this can be achieved by masking, using high temperature tape, grease or paint and other anti-galvanizing treatments. Again, the galvanizer should be consulted about any areas required to be masked.

CONNECTIONS
–

Galvanized articles can be joined by bolting (including friction grip connections), welding, riveting and adhesive bonding. Bolted joints are best made after galvanizing. Refer to Section 10.

HANDLING OF ARTICLES
–

Depending upon size and shape, articles for galvanizing may require suspension holes or lifting lugs. They may alternatively be handled by chains or, for smaller articles, on racks or in baskets.

In the case of tanks (in particular, open tanks), cross stays may be necessary to ensure the shape of the vessel is maintained during handling.

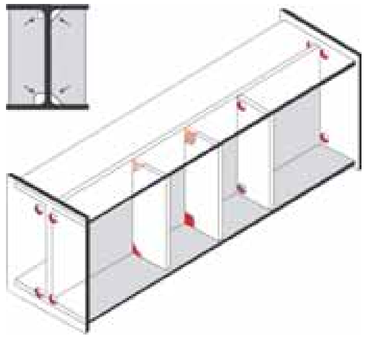
SURFACE CONTAMINATION
–

Clean steel surfaces are an essential requirement for good hot dip galvanizing.

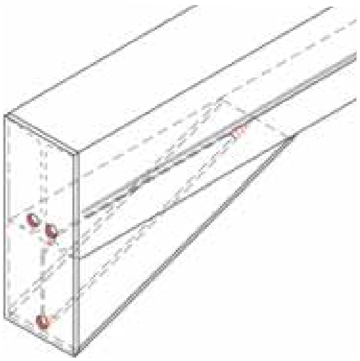
Contamination in the form of grease, tar, paint and weld slag cannot be removed by chemical cleaning and may result in black bare spots after hot dip galvanizing. Specifiers should ensure that the fabricator takes responsibility for articles being delivered free from contamination.

Steel sections, which have been cut or drilled using suds type oil can give similar problems to burnt on anti-spatter sprays. The cutting fluid, which has been burnt or baked onto the steel, should be removed prior to sending the steelwork for galvanizing.

Contamination is sometimes difficult to detect on the steel surface and will only show up after the galvanizing treatment. The article may then have to be regalvanized, at additional cost.

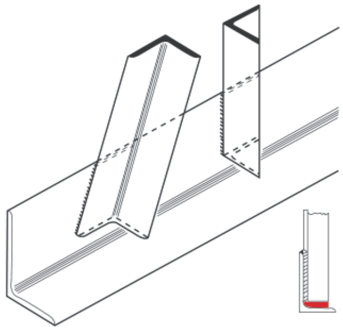


More extensive guidance on design for hot dip galvanizing can be found in BS EN ISO 14713 and other Galvanizers Association publications.

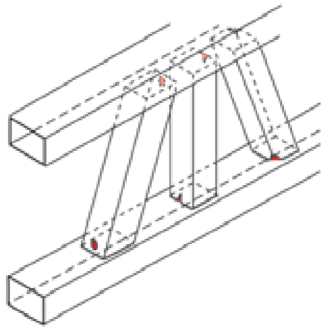


Extenal stiffeners, welded gussets and webs on columns and beams, and gussets in channel sections should have their corners cropped.

Cropping the corners of these brackets will aid access and drainage of molten zinc and a cleaner coating will be obtained.

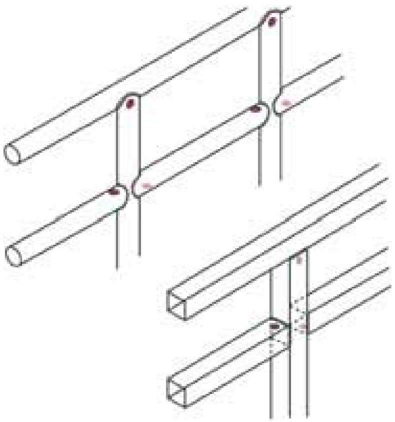


Angle bracings should, if possible, be stopped short of the main boom flange. This will allow the free flow of molten zinc across the surface of the flange, enhancing drainage from the structure. This will assist the development of a smoother galvanized coating, reduce the potential for retention of ash on the surface of the flange and help to avoid air traps within the structure, which could lead to uncoated areas.

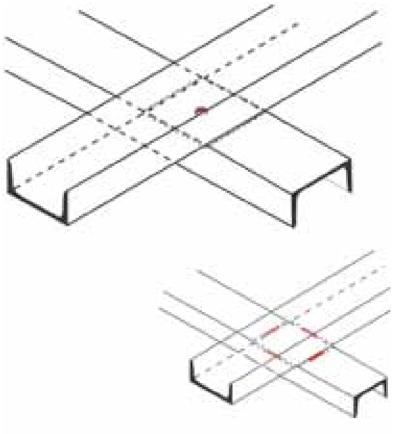


On structural hollow sections, provision must be made for venting and draining. With vertical members, drilled holes or V notches should be provided, diagonally opposite each other, at top and bottom.

Good venting of these sections will aid access and drainage of molten zinc and a cleaner coating will be obtained.

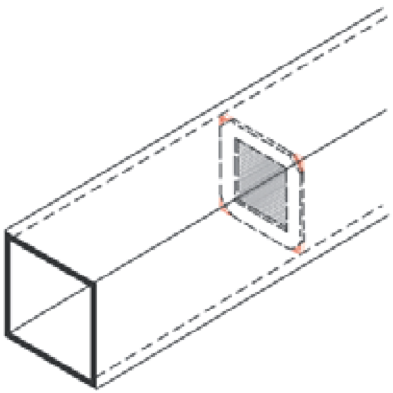


Every sealed section of a fabrication must be vented for reasons of safety and to allow access and drainage of molten zinc.
Holes diagonally opposite each other should be as close as possible to the sealed end.



Overlapping or contacting surfaces are potentially dangerous as pretreatment solutions trapped between surfaces are converted to superheated steam in the galvanizing bath and can lead to an explosion.

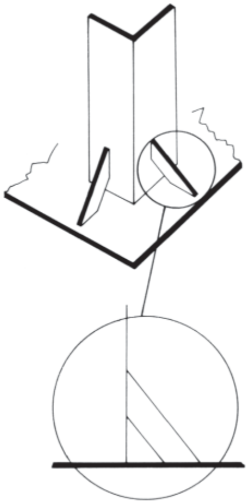
If contacting surfaces can not be avoided, as with these channels, then the edges of the contacting areas should be continuously welded. One hole should be drilled through both members for each 100 cm^2 of overlap, the minimum hole diameter being 10 mm, or the thickness of the section, whichever is greater, in order to eliminate the danger of an explosion in the galvanizing bath.



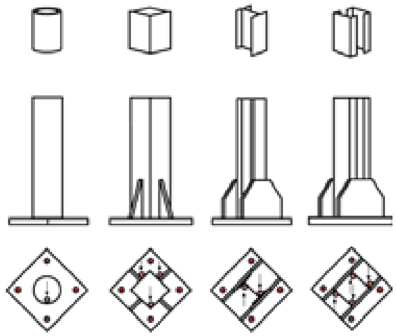
If this is not possible, then welding should be intermittent: in service there may be some weeping of trapped pretreatment solutions from between the plates leading to brown staining, but this will not be detrimental to the protection given by the coating. It will not generally be necessary to make any provision if the enclosed area is less than about 100 cm^2 (e.g.10 cm x 10 cm).

Where designs cannot avoid larger areas of overlapping surfaces (e.g. flange to flange and plate along flange) specialist advice must be sought from the galvanizer or Galvanizers Association.

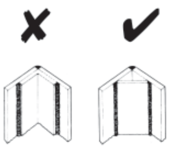
Internal diaphragms in large box sections should have cropped corners and a ‘manhole’. Internal diaphragms on small box sections should have cropped corners. Where any hollow section is vented internally, it is essential for safety reasons, that the galvanizer is able to view such venting.



External stiffeners for beams or channels should have the corners cropped.

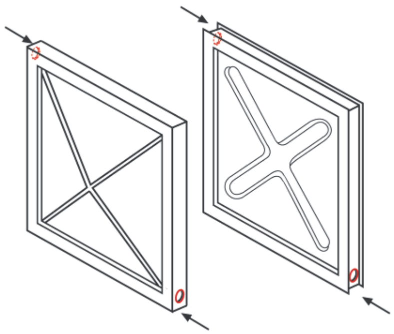


Alternative designs for venting sections fixed to base plates.

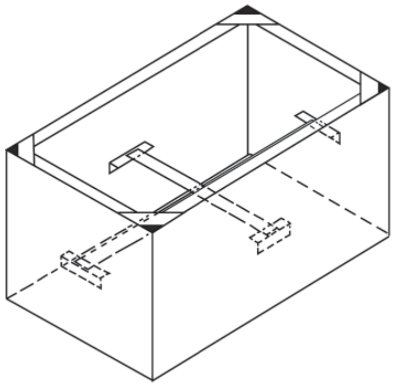


Examples of how weldments should be designed in order to avoid acid traps (narrow crevices).

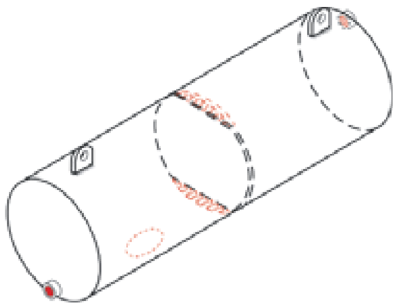
Welded joints should be continuous if they are not enclosing an otherwise unvented surface. Bolted joints are best made after galvanizing.



To minimise the risk of distortion, flat panels should be braced, e.g. dished or ribbed. Openings should be provided in the corners.



Large open top tanks should be stayed to minimise distortion. Where angles are used to rim the tank, appertures must be provided in the corners. Angles or flats used as stays should be as close as possible to the tank wall thickness.



Vents should be diametrically opposite and at least 50mm in diameter. Internal baffles should be cropped top and bottom. Lifting lugs are required as indicated. It should be possible to view the baffles through either the vent holes or an inspection hole - the placement of the inspection hole should be discussed with the galvanizer.

For further guidance please refer to BS EN ISO 14713 and the "Design for Galvanizing" wallchart available from Galvanizers Association.

SECTION
NINE
–

TITLE
QUALITY AND INSPECTION
–

QUALITY ASSURANCE
–

Galvanizers Association always insists upon the highest quality standards from its member companies, who are required to process work to BS EN ISO 1461. The requirements of these standards ensure that the zinc coating is continuous and of the required thickness.

Quality Assurance for industry has been enhanced by the introduction of the BS EN ISO 9000 series of standards - 'Quality Systems'. Already the majority of hot dip galvanizing plants are registered and others will be doing so in the near future.

COATING WEIGHT OR THICKNESS MEASUREMENT
–

The nature of the process ensures that, in most cases, if the coating has formed it will automatically be of sufficient weight to meet the requirements of BS EN ISO 1461. There are a number of inspection techniques which can be used when necessary.

A definitive check of the weight or thickness of a zinc coating can only be made by destructive methods, i.e. a 'strip and weigh' test or by preparing and measuring thickness on a microsection. However, for most purposes, non-destructive instruments are adequate. The magnetic instruments available are of two types - one measures the magnetic attraction between a permanently magnetized needle and the base steel or iron, and the other works on a magnetic induction principle. Non-destructive tests can be carried out at any stage in the life of a galvanized article to establish the thickness of the remaining zinc coating. Magnetic testing of coating thickness is covered in BS EN ISO 2178.

COATING FINISH
–

Table 6 summarises variations in finish which may be observed. The variations are often caused by surface features of the steel itself, and the acceptability of a coating should usually be judged primarily on its long-term performance and corrosion resistance.

appearance	**acceptability of protection (not necessarily of appearance)**
dull grey coating (all alloy, no free zinc)	acceptable
cracking in pooled zinc	acceptable
rust stains	acceptable easily removed by stiff brushing)
general roughness	acceptable unless otherwise agreed
lumpiness and runs	acceptable unless otherwise agreed (uneven drainage)
pimples	acceptable unless dross contamination is heavy
bulky white deposit (wet storage stain)	acceptable (provided coating weight remains in compliance with BS EN ISO 1461)
flux staining	not acceptable
bare spots	generally not acceptable, damaged areas can be repaired following guidance given in the standard

Table 7.
Summary of variations in galvanized finish (illustrated on pages 41- 43).

DULL GREY OR DARK GREY COATING

–

Silicon is sometimes added to steel as a deoxidant during production and this speeds up the reaction between the steel and the molten zinc. When the galvanized article is removed from the bath, but still remains hot, the reaction may continue and convert all or part of the surface zinc layers to zinc-iron alloys. These are dark grey compared with the light grey of pure zinc, although after a period of exposure the difference in grey colour becomes less pronounced.

Zinc-iron alloy coatings on reactive steel are thicker and hence longer lasting, than those on rimmed or aluminium-killed steels. Corrosion resistance, thickness for thickness, is at least as good as unalloyed zinc and may be better in acidic industrial atmospheres. Zinc-iron alloys are more abrasion resistant than zinc, but thick coatings have a greater tendency to flake if handled roughly and appropriate care must be taken.

The dark grey coating surface may develop staining after a relatively short period of exposure, even in mild, damp conditions. This is only a surface effect and does not indicate serious deterioration of the coating: the galvanized coating remains and continues to protect the steel.

Staining and discolouration by rust

Sound galvanized steel with many years of corrosion-free life still remaining, can sometimes be rust stained or discoloured. This may give an incorrect impression that the coating has failed and may occasionally be visually unacceptable. It may be the result of one or more of the following factors:

- Direct contact of galvanized articles with unprotected or inadequately protected steel (e.g., galvanized steel sections fastened with unprotected, electroplated or painted steel bolts).
- Deposits of iron and steel dust and swarf from other operations or sources on the galvanized surface.
- Water draining from unprotected or poorly protected steelwork, e.g. from damaged areas on painted steelwork.
- From cleaning residues in welds. During cleaning, acid may penetrate into the weld area via pin holes or other gaps in the welding.
- Rusting of areas welded after galvanizing and subsequently left unprotected or inadequately protected.
- Water running off other materials, notably metals such as copper and certain hardwoods (e.g. oak). This effect may occur whenever water can dissolve materials from one surface and deposit them on the galvanized steel.

To avoid rust staining, all parts of a structure should receive comparable effective corrosion protection where possible. Nuts and bolts and other fasteners should also be hot dip galvanized (see Section 10). Welds should be continuous wherever possible to minimise the retention of cleaning residues and should also be slag-free. Structures should be designed to avoid run-off water from other metals onto galvanized steel. Where welding after galvanizing is necessary, welded areas should be thoroughly cleaned and the zinc coating restored (see page 43).

Discolouration and staining from most external sources have no effect on the life of the coating. However, affected areas may be cleaned to improve the appearance of the structure. Generally, wire brushing or the use of a scouring powder will remove the stain and leave a sound galvanized coating.

General roughness

BS EN ISO 1461 demands that a galvanized coating shall be 'smooth', but points out that smoothness is a relative term and that coatings on fabricated articles should not be judged by the same standards as those applied to mechanically wiped products, such as galvanized sheet, tube and wire.

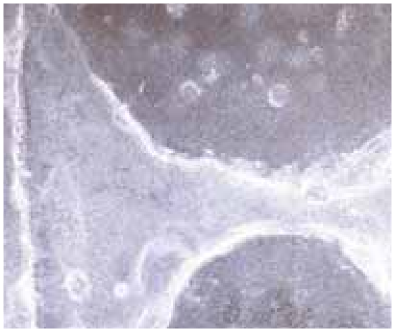
An uneven coating is usually due to excessive or uneven growth of the alloy layers, because of the composition or surface condition of the steel. An uneven coating is often thicker than a conventional coating and therefore, has a longer life, but on rare occasions it may be unsatisfactory or it may interfere with the intended use of the article.

Lumpiness and runs

Lumps and runs caused by uneven drainage of zinc from an article when it is removed from the bath may occur due to shape or thinness of the component and are not harmful to the life of the coating. Sharp points of excess solidified zinc are not acceptable as they may present a hazard during handling. Fabrications with areas where spikes have been knocked off, exposing bare steel, require remedial repair of the coating, which is explained overleaf.

Pimples

Pimples are caused by inclusions of dross (a pasty zinc/iron alloy residual that forms in the galvanizing bath) in the coating. These may arise from iron salts carried over on the work from the cleaning tank and unable to escape from the surface of the coating. Contamination may also arise from agitation of the dross layer at the bottom of the bath. Dross has a similar corrosion rate to that of zinc and its presence in the coating as finely dispersed particles, is not objectionable. But, major dross inclusions tend to embrittle the coating and the galvanizer will avoid this.



Wet storage stain

Wet storage stain is the white corrosion products and dark stains, which may be seen on the surfaces of newly galvanized articles when they have been closely stacked and stored, or transported under damp or wet conditions. Where wet storage stain has formed, the coating beneath may be stained dark grey or black.

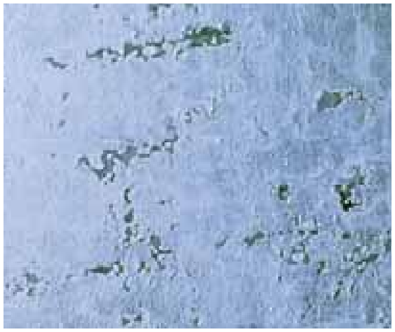
To prevent wet storage stain, zinc coated articles must be transported and stored under dry and well ventilated conditions. If stored outdoors, the surfaces should not be in close contact: free circulation of air is necessary to prevent condensation and retention of moisture. Nesting or close packing must be avoided as capillary action can attract water into closely contacting surfaces. Articles should not be stored in direct contact with the ground.

Barrier coatings, such as clear lacquers, may be used to preserve a bright finish where appearance is paramount. A range of proprietary products are available, some formulated for specific applications. Heavy deposits of wet storage stain should be removed. This can usually be achieved with a stiff bristle brush or light abrasives. Chemical methods should be used as a last resort and require thorough rinsing with fresh water after use.

Flux and dirt staining

Where flux is used during the dipping process, flux residues may adhere to the surface after immersion and pick up moisture to form white corrosion products. Although this is a surface effect, flux stains may be detrimental to the life of the coating and should be removed.

Dirt may be picked up on the surface of the coating from the site, truck beds or from contact with other articles. These are readily washed off to reveal a sound coating underneath and are not, therefore, harmful.



Bare spots

Due to the sacrificial action of zinc, small localised flaws up to 5mm maximum width are usually self-healing and have little effect on the life of coating. Articles with uncoated areas due to faulty processing will be detected by the galvanizer on inspection and retreated but, occasionally bare spots can also be caused by rolling defects in the steel such as laps and folds, laminations and non-metallic impurities rolled into the surface.

RENOVATING DAMAGED COATINGS

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Small areas of the coating may be damaged by operations such as cutting or welding after galvanizing and although a galvanized coating has excellent resistance to rough treatment, small areas of damage may occasionally occur in transport and erection. Due to the sacrificial action of zinc, small localised flaws do not reduce protection. Nevertheless, it is often aesthetically desirable to renew the coating even over such small areas.

Adequate corrosion resistance will be achieved at any damaged area if a weight of zinc is deposited equivalent to the weight of the undamaged coating. The following techniques are acceptable according to BS EN ISO 1461:

- Thoroughly wire brush the affected area and apply sufficient coats of zinc rich paint (by brush or aerosol spray) to give a coating thickness in accordance with the supply standard e.g. EN ISO 1461

- Thoroughly wire brush the affected area, heat it with a blow torch to 300°C and apply a special zinc alloy rod or powder to obtain required repair coating thickness. This may, however, be difficult or too time-consuming to carry out on erected steelwork, or on awkward, or inaccessible areas.
  Care should be taken in applying heat by a blowtorch as excessive heat may damage the surrounding galvanized coating, especially on the heavier coatings resulting from reactive steels.

- Grit blast the affected area and thermal zinc spray. A 100μm thermally sprayed zinc coating confers corrosion protection equivalent to an 85μm galvanized coating.

Zinc rich paint is much the simplest to apply, especially on site. Thermal zinc spraying is usually only economic when applied in the workshop.

BS EN ISO 1461 requires that the coating thickness on renovated areas shall normally be 30μm more than the local coating thickness requirement for the galvanized coating. An exception to this may be when the coating is to be overcoated and the renovated area then requires an equivalent thickness.

Purchasers and applicators of subsequent coatings should ensure that the applied system is compatible with the method and materials used for renovation.

SECTION
TEN
–

TITLE
JOINING GALVANIZED STEEL
–

THERE IS NO REASON WHY STRUCTURES SHOULD HAVE THEIR LIFE EXPECTANCIES REDUCED BY THE SERVICE LIFE OF THE THREADED FASTENERS USED IN ASSEMBLY, SINCE THEY TOO CAN BE HOT DIP GALVANIZED.

HOT DIP GALVANIZED THREADED FASTENERS
–

Sizes

As a general rule, nuts, bolts and washers down to 8mm diameter can be galvanized and a wide range of threaded components can now be processed using special equipment. For ISO metric fasteners, the galvanizing of one thread either internal or external requires an extra clearance of four times the coating thickness. In practice, it is normal for standard bolts from stock to be fully galvanized, but for nuts to be galvanized as blanks and then tapped up to 0.4mm oversize with the threads then lightly oiled. When assembled, the nut thread is protected by contact with the coating on the bolt. Even after many years of service, galvanized nuts can readily be unfastened even though the threads have never been galvanized. Further details of the dimensions, processing and performance of hot dip galvanized nuts and bolts is given in 'The Engineers & Architects' Guide to Hot Dip Galvanized Nuts and Bolts', published by Galvanizers Association.

Coating uniformity.

Whilst there is some tendency for hot dip galvanizing to be thicker in thread roots, a near uniform coating can be obtained with modern equipment. Any thickening that does occur can be accommodated in the normal truncation on the thread of the nut.

Surface finish and appearance

Galvanized fasteners usually have a bright light grey appearance, but with certain grades of high yield and high tensile bolts, the coating may be matt grey, because the higher silicon content of the steel makes them more reactive towards the molten zinc. Fasteners hot dip galvanized at high temperature, (around 550°C) tend to take on a uniform, matt grey appearance due to the structure of the coating formed when the component is cooled.

Storage

Galvanized fasteners should be stored under dry well ventilated conditions to minimise the occurrence of wet storage stain (see Section 9).

Table 8.

type	coating thickness
zinc electroplated	5 - 12 µm (typical)
sherardized class I	30 µm
sherardized class II	15 µm
hot dip galvanized BS 7371: part 6: 1998	43 µm (min)

Specification of hot dip galvanized fasteners

Selected zinc-based protective coatings on threaded fasteners have been listed in Table 8. One difficulty arises because electroplating is often known - misleadingly - as electrogalvanizing. It is not, therefore, enough merely to specify 'galvanizing' if a long life is required. The fastener specification should clearly state 'that the fastener coating should conform to BS 7371: Part 6: 1998' and the addition of a clause 'to be galvanized by a member of the Galvanizers Association' will ensure the high quality provided by its member companies and the technical back-up service of GA.

Relative costs

The initial cost of hot dip galvanizing threaded fasteners is generally a little higher than zinc plating to BS3382: Part 2. However, in terms of cost per year of rust-free life, hot dip galvanizing is by far the most economical coating.

High strength bolts

General grade high strength bolts (ISO grade 8.8) to BS 4395 Part 1, (equivalent to ASTM A325) can be galvanized without difficulty. ISO Grade 10.9 bolts (BS4395: Part 2 or ASTM A490) are galvanized in the UK, Japan, Italy, France and Germany but may require blast-cleaning as an alternative treatment prior to hot dip galvanizing. Grade 12.9 bolts and higher strength fasteners should not be galvanized.

Friction grip connections

Initially, the coefficient of friction with galvanized contact surfaces is low - an average of about 0.19. As slip commences however, friction rapidly builds up and 'lock-up' occurs, due to cold welding between the coated surfaces. If a small amount of slip can be tolerated it is therefore unnecessary to treat the surfaces, but if all slip must be avoided, the coefficient of friction can be raised by roughening the surface of the galvanized coating.
Wire brushing will raise it to 0.35 and a figure of 0.5 can be achieved by a light grit blasting, or by roughening with a pneumatic chisel hammer, or needle gun. In the United States, galvanizing is one of the few coatings permitted on the contact surfaces in the specification for friction grip joints. This is approved by the Research Council for Riveted and Bolted Structural Joints of the Engineering Foundation.

The 'lock-up' effect described above can cause galling in the threads of galvanized fasteners used in friction grip connections and lubrication may be required in order that the required clamping force is developed. Beeswax has been found to be a most effective lubricant and molybdenum disulphide, or tallow, have also been specified for this purpose.

WELDING GALVANIZED STEEL

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Tests at The Welding Institute sponsored by the International Lead Zinc Research Organisation (ILZRO) have established that satisfactory high quality welds can be made on hot dip galvanized steel and that the tensile, bend and fatigue properties of such welds can be virtually identical to those of similar welds made on uncoated steel. Welding speeds are slower and there is more spatter, particularly when CO_2 welding.

All the fusion welding processes can readily be used on galvanized steel, but minor variations in technique may be required, depending on the welding process used, the type of joint and the welding position. For example, with manual metal arc welding:

- A slight ‘whipping’ action moving the electrode forward and backward along the joint.
- line of the joint encourages volatization of the zinc in front of the weld pool.
- Slightly wider gaps are recommended in butt joints to give complete penetration.
- A short arc length gives better control of the weld pool and helps to prevent either intermittent excess penetration, or undercut.
- Both basic and rutile coated electrodes can be used but, simple procedural tests should be made before undertaking production welding.

Detailed recommendations for this and other fusion welding processes are available from Galvanizers Association.

While zinc is a necessary trace element in the human diet and it does not accumulate in the human body, the inhalation of freshly formed zinc oxide fumes can cause a transient ‘metal fume fever’ with symptoms similar to influenza. To maintain fume levels within acceptable levels, extraction should be provided when welding galvanized steel in confined areas, as indeed it should when welding uncoated steel. Wherever welding takes place, due note must be taken of the relevant COSHH regulations.

RUST PREVENTION AT WELDS

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All welds made in galvanized articles should be protected against rust as soon as welding is finished, as the top surface is then free from rust and easy to treat. Treatment can be carried out as described in Section 9.

SECTION
ELEVEN
–

TITLE
PAINTING AND POWDER COATING OF GALVANIZED STEEL
–

HOT DIP GALVANIZING BY ITSELF IS A LONG LASTING AND COST EFFECTIVE MEANS OF CORROSION PROTECTION. WHEN ORGANIC COATINGS SUCH AS PAINT OR POWDER COATINGS ARE APPLIED OVER GALVANIZED STEEL, THE RESULTING COMBINATION IS KNOWN AS A DUPLEX COATING. THESE COATINGS ARE USED TO:

Add colour for aesthetic, camouflage, or safety purposes

Increase the economic life of a structure

Provide additional protection in aggressive environments

Paint coatings may be applied soon after galvanizing, or later in the lifetime of the structure when the galvanized coating has weathered, or later still when further protection is essential to maintain protection.

When paint is to be used to further extend the life of a galvanized structure, it is often most economic to defer painting until a long maintenance-free life has been achieved from the galvanized coating.

PREPARATION OF GALVANIZED STEEL
–

As with all protective treatments of steelwork, it is of great importance that preparation of the galvanized surface is carried out in a thorough and considered manner.
In particular, failure to degrease the galvanized steel surface properly is a common source of failure of duplex coatings.

As with many other substrates, organic coatings can not usually be applied directly onto galvanized steel. However, simple direct application paint systems, designed specifically to adhere to non-ferrous metals such as zinc, are becoming more popular and are available in a full range of colours.

The reasons for the need for effective surface preparation in most cases are quite straight forward. When the steel is withdrawn from the galvanizing bath it has a clean, bright, shiny surface. With time this changes to a dull grey patina as the surface zinc reacts with oxygen, water and carbon dioxide in the atmosphere to form a complex, but tough, stable, protective layer, which is tightly adherent to the zinc. The patina takes time to develop and the exact time depends upon the climate around the galvanizing. Typically, the time can vary from six months to two years or more. During this transition of the zinc outer layer into its final state, simple oxides and carbonates form, which do not adhere strongly to the surface. As most duplex coatings are applied whilst the galvanizing is in this condition, the surface layer must be modified by chemical or mechanical means. Coatings may be applied directly to the initial pure zinc surface, or to the weathered surface, but the results are not always consistent and “taking a chance” is not recommended.

Where the aesthetic requirements for a duplex system are particularly high, a degree of surface finishing or fettling may be required on galvanized coatings, as small surface projections may become more obvious after the application of an organic coating.
This is particularly the case for powder coating systems. Care must be taken when smoothing a galvanized coating, because the zinc coating may be damaged by heavy or excessive grinding.

GUIDELINES: PRE-TREATMENT FOR PAINTING
–

Guidelines for the pre-treatment of galvanized surfaces have been drawn up as a result of (i) a study carried out by an independent research centre and a leading UK paint manufacturer into the performance of commercially available pre-treatment and paint systems and the parameters affecting their performance on hot dip galvanized coatings, and (ii) many years experience with duplex coatings.

Although pre-treatment of galvanized components is best carried out immediately after galvanizing, before the surface has become contaminated in any way, this is not always practical. Pre-treatment can be carried out later, but it is vital that the surface is adequately cleaned to remove all traces of contaminants such as oil, grease and dirt. The cleaning operation must leave no residues on the cleaned surface and any wet storage staining should be removed using a stiff brush. Washing down the coating with water will help to remove soluble salts.

There are four recognised methods of surface pre-treatment that produce a sound substrate for paint coating:

T-Wash (or its proprietary equivalent)

Despite the fact that this preparation process has been available for some considerable time, T-Wash is still generally considered to be the best pre-treatment method for painting galvanized steel. T-Wash is a modified zinc phosphate solution, which contains a small amount of copper salts. When applied, a dark grey or black discolouration of the zinc surface will result. T-Wash must not be allowed to pool on horizontal surfaces, or this will prevent maximum paint adhesion.
Any excess should be removed by water.
T-wash is most suitable for application to new galvanizing and should not be used on weathered galvanizing
(see etch primers below)

The constituents of T-Wash are phosphoric acid (9.0%), ethyl cellusolve (16.5%), methylated spirit (16.5%), water (57.0%) and copper carbonate (1.0%). Variations to this composition may exist and so it is wise to consult the supplier if a successful result is to be achieved.

Sufficient time must be allowed for the T-Wash to react and dry thoroughly before the first coat of paint is applied.
(Suppliers’ information will give recommended time intervals). While research has shown that T-Washed surfaces can be left for up to 30 days before painting and good paint adhesion can still result, it is advisable to minimise the time between pretreatment and paint application. Any white salt formed by the exposure of the T-Washed surface to moisture must be removed before painting using a stiff brush. If the T-Washed surface has become contaminated, it must be cleaned in accordance with the suppliers’ recommendations.

Etch primers

Etch primers have also been used successfully. Their major disadvantage is the absence of any visible colour change in contrast to T-Wash. Therefore, there can never be complete confidence that all surfaces have reacted with the primer. Etch primers are most suited to application on older, weathered galvanizing

Sweep blasting

A mechanical method of pretreatment is sweep blasting using fine copper slag, J blast or carborundum powder with a blast pressure of no greater than 40psi (2.7 bar). This will ensure that only the minimum amount of oxide is removed and the zinc surface is left in a slightly roughened condition. Care should be taken when carrying out sweep blasting on very thick galvanized coatings to avoid damage to the coating. The optimum nozzle-to-work piece distance and angle of blasting needs to be identified for all surfaces on the galvanized steel work, if optimum results are to be achieved. Angular iron blasting grit must not be used under any circumstances. Sweep blasting is often used in addition to the chemical preparation stage.

Weathering

This process only becomes fully effective after a galvanized surface has been exposed to the atmosphere for a period of at least six months. The surface is prepared using either abrasive pads, or a stiff brush, to remove all loose adherent materials and making sure that the bright zinc surface is not restored.

This is followed by a hot detergent wash and rinsing with fresh clean water. The surface must be fully dry before any paint is applied. Weathering should not be used as a method of surface preparation in marine environments with high chloride levels.

GUIDELINES: PAINTING
–

All paint systems should be specifically formulated for use on galvanized steel and applied in accordance with the paint manufacturer's recommendations.

The choice of paint system will depend upon both the application and service environment. With the decline in the use of chlorinated rubber and alkyd paints, high- build epoxy products and vinyl/vinyl co-polymer systems are increasingly utilised with glass reinforced epoxy being an option for more severe environments. In multi-coat systems the use of a micaceous iron oxide (MIO) primer has been shown to give improved adhesion.

Two-pack polyurethane and acrylic urethanes are commonly used as top coats and offer good durability and colour retention. Alternatives include acrylic epoxies and polysiloxanes, the latter offering increased abrasion resistance along with good gloss and colour retention.

At present, high-build epoxies are widely used although water-based products, including polyurethanes, are now being specified. They are less tolerant of poor pre-treatment, but their use could to grow as the Solvent Emissions Directive becomes more stringent.

GUIDELINES: POWDER COATING
–

Powder Coating is a fast growing method of adding colour to metal surfaces. Like galvanizing it is carried out under carefully controlled conditions in a factory. For this reason the maximum size of the steel fabrication to be powder coated will be limited, but powder coatings can be applied successfully to hot dip galvanized surfaces.

The thermal characteristics of galvanized steel are almost identical to those of un-galvanized steel for powder coating purposes and there are many examples of steel which has been galvanized and then powder coated.

However, the pre-treatment of the galvanized surface will depend upon which of the many powder types such as polyester, epoxy, or hybrid is being used. This usually includes a form of chemical pretreatment such as chromating or phosphating, gentle heat treatment, followed by application of the powder. The successful application of a powder coating to any metallic surface requires the multistep instructions provided by the powder manufacturer to be respected in every detail. For this reason an experienced or approved applicator should be asked to do the work. As with wet painting, a full range of colours is available. Powder coating of galvanized steel for architectural applications is covered at present by BS EN 13438.

It is important that the galvanizer is advised that work is to be subsequently powder coated and post-galvanizing treatments agreed with the powder coater.

A limited number of direct application products are now available for use on galvanized steel work. Given adequate preparation work, the use of a direct application paint negates the need for any chemical or mechanical pre-treatment to be conducted. These products are known to have been used in a variety of applications.

SECTION
TWELVE

TITLE
RELEVANT STANDARDS

LISTED BELOW ARE NATIONAL AND INTERNATIONAL STANDARDS ON HOT DIP GALVANIZING AND OTHER ZINC COATINGS. THERE ARE OVER 100 BRITISH STANDARDS AND CODES OF PRACTICE WHERE HOT DIP GALVANIZING IS SPECIFIED AS THE REQUIRED OR OPTIONAL FINISH.

BRITISH AND EUROPEAN STANDARDS

BS EN ISO 1461: 1999
Hot dip galvanized coatings on fabricated iron and steel articles – specifications and test methods.

BS EN ISO 14713: 1999
Protection against corrosion of iron and steel in structures – Zinc and aluminium coatings – Guidelines.

BS 7371: Part 6: 1998
Coatings on metal fasteners – specification for hot dip galvanized coatings.

BS EN 10244: Part 2: 2001
Steel Wire & Wire Products – Non ferrous metallic coatings on steel wire.

BS EN 10326/10327: 2004
Hot dip zinc coatings on steel sheet.

BS 3083: 1988
Hot dip coated corrugated sheet for general purpose.

Other zinc coating standards

BS EN 12329: 2000
Corrosion protection of metals. Electrodeposited coating of zinc with supplementary treatment on iron or steel.

BS EN ISO 2063: 2005
Sprayed aluminium and zinc coatings.

BS 3382: Part 2: 1961
Electroplated zinc on threaded components.

BS 4921: 1988
Sheradized coatings on iron and steel articles.

Other useful British Standards

BS 7361: Part 1: 1991
Cathodic protection.

BS EN 13636: 2004
Cathodic properties of buried metallic tanks and related piping.

BS 7773: 1995
Cleaning and preparation of metal surfaces.

PD 6484: 1979
Corrosion at bimetallic contacts.

BS 7079: 1994
Surface preparation of steel substrates before application of coatings.

BS EN ISO 2178: 1995
Measurement of coating thickness: magnetic method.

BS EN ISO 9001: 2000
Quality management systems.

BS EN ISO 11124: Parts 3 & 4
Chilled iron shot and grit for grit blasting.

BS EN 971-1: 1996
Paints and varnishes terms and definitions for coating materials. General terms.

BS EN 23270: 1991
Specification for temperature and humidities for conditioning and testing paints, varnishes and their raw materials.

BS 4395: Parts 1 & 2: 1969
High strength friction grip bolts.

BS EN 14399: Parts 1-6: 2005
High strength structural bolting assemblies for preloading.

BS EN ISO 1460: 1995
Determination of hot dip galvanizing coating mass: gravimetric method.

BS EN ISO 1463: 2004
Measurement of coating thickness microscopic method.

BS EN ISO 2064: 2000
Definition and convention concerning coating thickness measurement.

BS EN ISO 12944: 1998
Paints and varnises - corrosion protection of steel structures by protective paint systems.

ASTM STANDARDS

—

A 123/A 123M – 02
Hot dip galvanized coatings on fabricated products.

A90/A 90M – 01
Test method for weight of zinc coating on iron and steel articles.

A143 – 03
Safeguarding against embrittlement.

A153/A 153M – 05
Hot dip galvanized coating on iron and steel hardware.

A325 – 06
High strength carbon steel bolts.

A384-02
Safeguarding against distortion.

A385 – 05
Practice for providing high quality galvanized coating.

A653/A 653M – 06
Hot dip galvanized steel sheet.

A767/A 767M – 05
Hot dip galvanized rebar.

A780 – 01
Repair of damaged hot dip galvanizing.

DIN STANDARDS

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DIN 267
Hot dip galvanized fasteners

DIN EN ISO 1461
Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods

DIN 50978
Testing of adhesion of hot dip galvanized coatings

DIN 50933
Measurement of coating thickness using stylus instrument

DIN 51213
Testing of zinc coatings on wire

DIN 59231
Galvanized corrugated sheet

DIN 50961
Electroplating zinc

DIN EN ISO 2063
Sprayed aluminium and zinc coatings

SWEDISH STANDARDS

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SS 3192
Hot dip galvanized threaded components

SS 055900
Blast cleaning steel

SS 3583
Principles and requirements for hot dip galvanizing

SS EN ISO 1461
Hot dip galvanized coatings on fabricated iron and steel - Specifications and test methods

ISO STANDARDS

—

ISO 1459
Protection by hot dip galvanizing: guiding principles

ISO 2063
Metal spraying by zinc and aluminium

ISO 2081
Electroplated zinc coatings

ISO 3575
Continuous hot dip galvanized sheet

AUSTRALIAN STANDARDS

—

AS/NZS 4680
Hot dip galvanized (zinc) coatings on fabricated ferrous articles

AS/NZS 4534
Zinc and zinc/aluminum alloy coatings on wire

AS/NZS 4791
Hot dip galvanized (zinc) coatings on ferrous open sections applied by an in-line process

AS/NZS 4792
Hot dip galvanized (zinc) coatings on ferrous hollow sections, applied by a continuous or a specialised process

SECTION
THIRTEEN
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Galvanizers Association was set up in 1949 and comprises the leading galvanizing companies throughout the British Isles and others throughout the world. In the British Isles more than 90% of work is processed by members and internationally there are over 60 overseas affiliate members in 28 countries.

Galvanizers Association is a non-profit making organisation promoting hot dip galvanized steel and providing a service of technical advice and information to producers and users. This information and advice is generally available free of charge.

LISTED BELOW ARE SOME OF THE SUBJECT AREAS COVERED BY GA PUBLICATIONS.
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- Applications
- Organic coatings on galvanizing
- Fasteners
- Design implications for galvanizing
- Welding
- Performance information
- Sustainability
- Case histories

FOR ADDITIONAL INFORMATION
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- Visit www.galvanizing.org.uk
- Subscribe to “Hot Dip Galvanizing” magazine (quarterly publication highlighting interesting projects across Europe)

  Contact Nicky Smith 0121 355 8838
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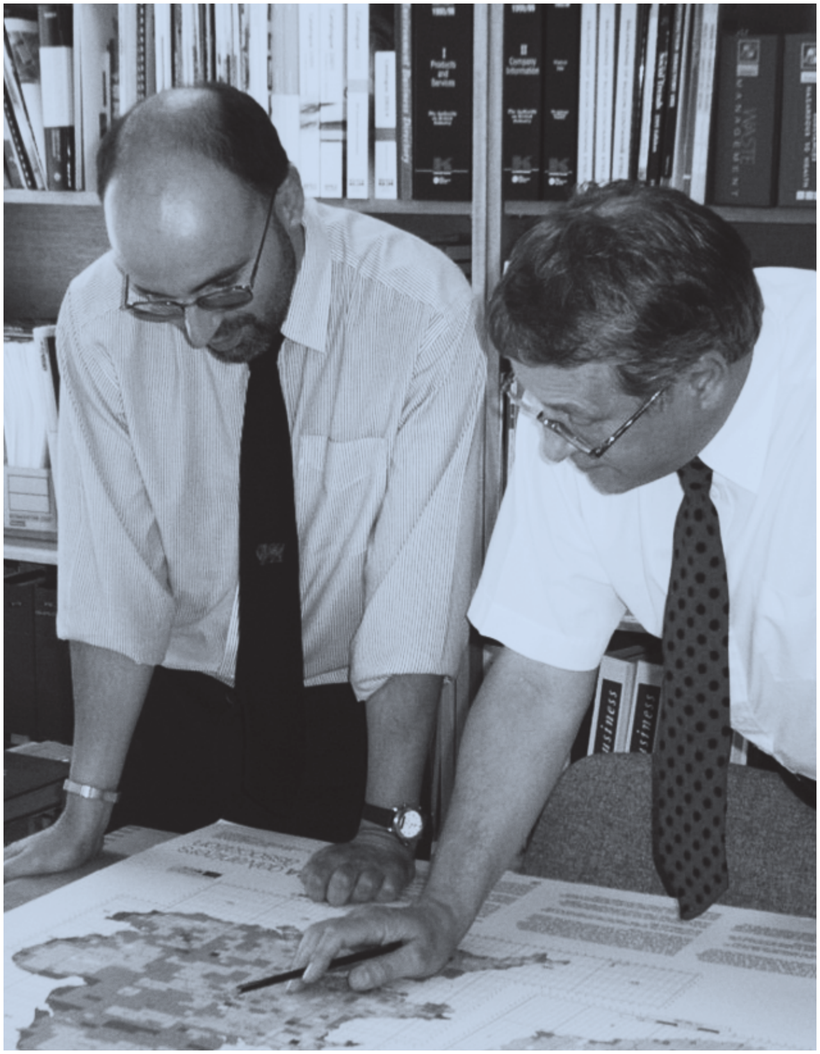

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Please use the space below to tell us your comments and fax to +44 (0) 121 355 8727 or post to our main address.

If you prefer, an online comment form is available at www.hdg.org.uk/feedback

All completed forms will receive a free copy of the *Design for Galvanizing* wall chart.

COMMENTS

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- [ ] Free Subscription to HDG Magazine
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PLEASE NOTE

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Care has been taken to ensure that the contents of this publication are accurate, but Galvanizers Association does not accept responsibility for errors or for information which is found to be misleading. Suggestions for, or the end use or application of, galvanized products are for information only and Galvanizers Association accepts no liability in respect thereof. Before having products hot dip galvanized, the customer should satisfy themselves of their suitability.

ACKNOWLEDGEMENTS
WITH THANKS TO

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