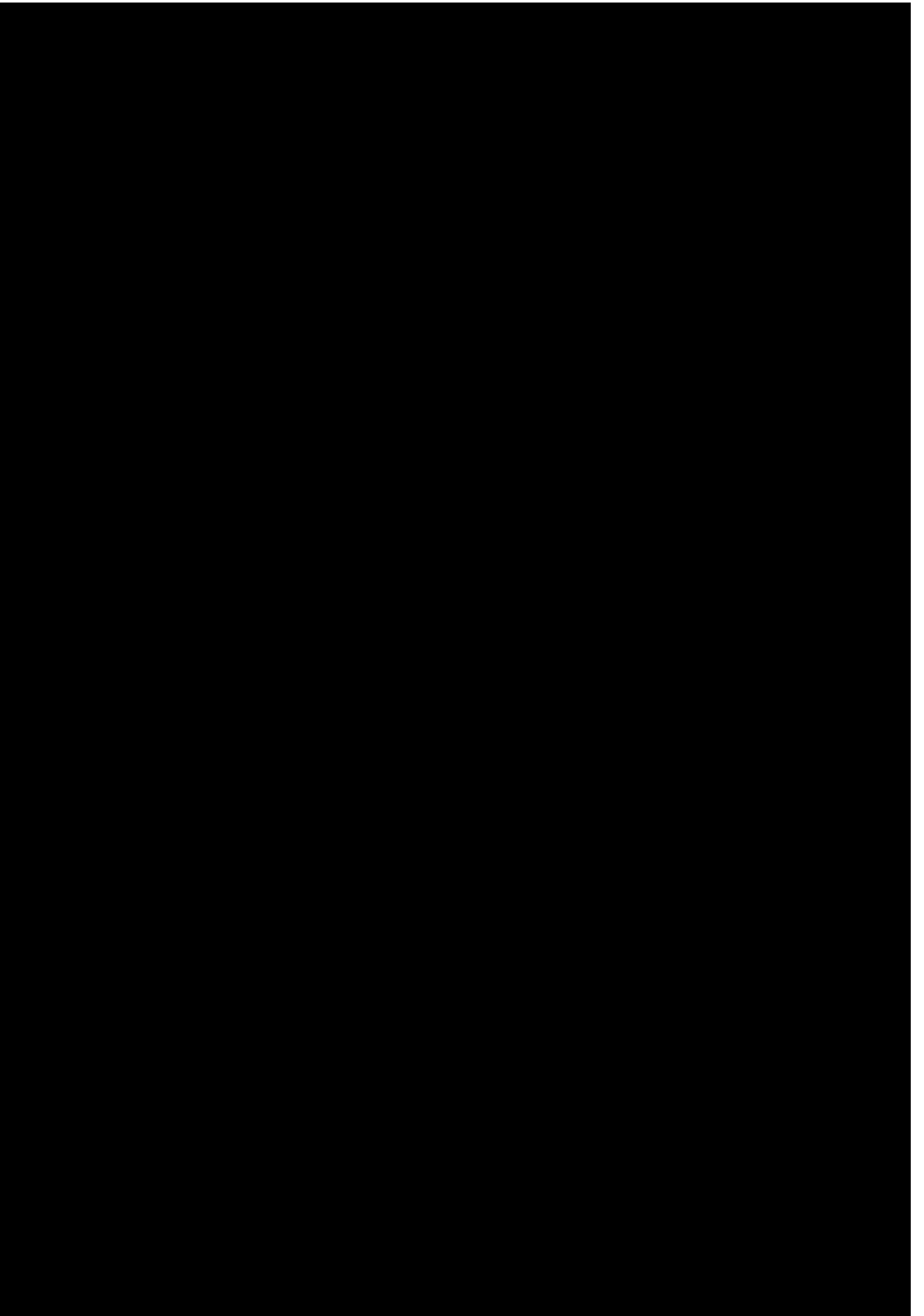Guides to Good Practice
in Corrosion Control

Coating for
the Protection
of Structural
Steelwork

NPL

National Physical Laboratory

Coating for the Protection of Structural Steelwork

Contents page

1.0 Introduction

The purpose of this guide is to explain, in terms of modern concepts, the basic requirements for protecting structural steel with paint and metallic coatings, the systems commonly used and their significance in relation to the protective properties required. The emphasis is on the protection of onshore structures, such as buildings, bridges, factories, and industrial plants in which the process environment contributes to the corrosion hazard.

Reference is made to appropriate standards which deal with alternative protective systems in detail. These documents are a very valuable source of information and it is recommended that they should be consulted freely at an early stage in the selection of a protective coating.

Emphasis is given to the important influence of application methods on the efficiency of the protection achieved, and on the need for strict inspection procedures. Guidance is also given on procedures to be used when drafting specifications, and on the health and safety and environmental protection requirements to be observed.

2.0 Basic requirements for protecting steel

Steel will rust only if water and oxygen are both present and the rusting process is greatly accelerated by pollutants in the atmosphere, such as sulphur dioxide from the burning of oil, coal, or gas and chlorides from de-icing salts or marine atmospheres. Solid pollutants can be hygroscopic and may promote localised attack (e.g. corrosion pitting) at specific points on exposed steel. Protective systems must be resistant to attack by such pollutants and should be applied only to surfaces from which they have been removed.

The importance of surface preparation is paramount to all coating systems and for painted surfaces is dealt with in Guide No. 13 in this series: 'Surface Preparation for Coating'.

To ensure good coating adhesion, it is essential that the surface to be coated is rendered free of dirt, dust and debris that might affect performance. Water-soluble residues, if left on the surface, will cause rapid deterioration at the interface with paint when the coating is exposed to moisture.

Paint is the most commonly used material to protect steel, and in practice the term, 'paint' covers a wide range of materials with different properties. The application of paint is comparatively easy with no limitation on the size of steelwork that can be treated.

Modern paints have been developed to provide improved properties over their predecessors. However, the benefit of these improvements will only be achieved by careful attention to important factors such as surface preparation, the selection of a suitable paint for the specific situation, and correct application.

For structural steelwork the paint film thickness is important for lasting protection since it is difficult to obtain perfect application under construction conditions. Best results are obtained when coatings are applied in heated enclosed workshops; units for bridge structures and building framework can be coated in this manner before erection and additional coats may be applied on site, where required.

Modern coating facilities can automatically blast clean and prime steelwork before departure to site.

Where improved resistance to mechanical damage or better durability in certain environments is required, coatings of non-ferrous metals such as zinc or aluminium can be used instead of paint coatings, although this may incur increased cost. The combination of metallic and paint coatings can provide very long term durability in aggressive environments and an aesthetically pleasing appearance.

3.0 Selecting the protective system

One of the most widely referenced guides to the selection of protective systems for steel has been BS 5493:1977. However, in recent years, new standards for paint and metal coatings have been developed. These are EN ISO 12944 Parts 1 to 8 'Paints and Varnishes - Corrosion Protection of Steel Structures by Protective Paint Systems' and EN ISO 14713 'Protection Against Corrosion of Iron and Steel Structures - Metal Coatings - Guidelines'. These standards classify common types of environments and related corrosivity categories and provide an indication of 'life to first maintenance' of the protective system in each environment. Typical lives to first maintenance are:

Very long:	20 years or more
Long:	10 to 20 years
Medium:	5 to 10 years
Short:	less than 5 years

For 'very long life', the systems are thick hot dip galvanizing or thermal (metal) spraying with an appropriate sealing coat of paint. For long and medium life, selected high performance paint systems are suggested. Paint systems based on drying oils are suitable only for short life to first maintenance in aggressive environments, but are included in the long and medium life in non-polluted exterior and certain interior environments. In dry interior environments, the corrosion risk is insignificant and no protective coating is necessary. Painting may, however, be required for decorative or appearance purposes. The transition from medium to long life to first maintenance is achieved by additional film thickness, provided that the finish maintains the necessary appearance and weathering resistance.

Some systems depart from the conventional primer/undercoat/finish systems. This is possible when a specialised protection can be applied in one or two coats direct to steel that has been blast cleaned to a high standard of cleanliness; elastomeric urethane, solvent free and coal-tar-epoxy systems for long life are typical.

It should be recognised that paint manufacturers compete with each other to offer their products under brand names. However, as most specifications are written against generic paint types, it is difficult for the specifier and the user to be certain what type comparisons are valid. Many standards and guidance documents have gone a long way towards explaining and clarifying the purpose of the constituents of paints and in specifying minimum composition guidelines. More information on these constituents relevant to protective coatings for structural steel is given in the following sections.

4.0   Protective paint systems

4.1   Introduction

Conventionally, protective paint systems consist of primer, undercoat(s) and finish coats. (Figure 1) However, there are now available single coat systems that combine primer and finish coats.

4.2   Primers

The primer is applied directly onto the cleaned steel surface. Its purpose is to wet the surface and to provide good adhesion for subsequently applied coats. In the case of primers for steel surfaces, these are also usually required to provide corrosion inhibition.

There are two basic types of primer:

(i)   **Primers pigmented with metallic elements anodic to steel. When a break in the coating exposes the steel substrate, the anodic metal corrodes sacrificially in preference to the steel. This effectively stifles steel corrosion and under-rusting of the primer until the anodic metal is exhausted. Zinc-rich primers are the most commonly used.**

(ii)   **Primers relying on the high adhesion and chemical resistance properties of the binding media, of which two-pack epoxies are typical. The necessary adhesion is obtained only on a very thoroughly cleaned surface and it is then sufficient to prevent under-rusting at mechanical breaks. These primers may contain inhibitive pigments to interfere with the corrosion process. Zinc phosphate, for example, is a mildly inhibitive pigment and is widely used in modern primer formulations.**

4.3   Undercoats (intermediate coats)

The undercoats (or intermediate coats) are applied to 'build' the total film thickness of the system. Generally, the thicker the coating the longer the life. This may involve the application of several coats.

Undercoats are specially designed to enhance the overall protection and, when highly pigmented, decrease permeability to oxygen and water. The incorporation of laminar pigments, such as micaceous iron oxide, reduces or delays moisture penetration in humid atmospheres and improves tensile strength. Undercoats must remain compatible with finishing coats when there are unavoidable delays in applying them.
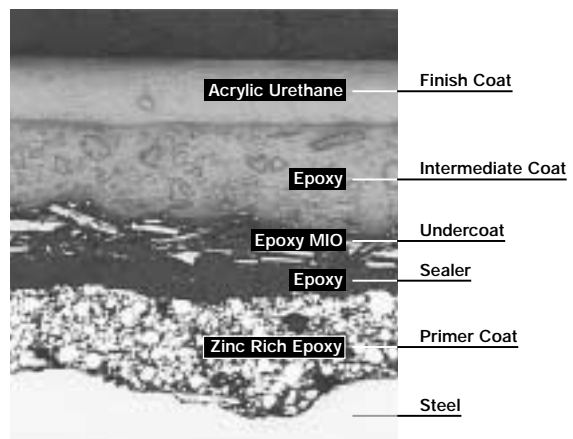

Figure 1. Protective paint system

4.4 Finishes

The finish provides the required appearance and surface resistance of the system. Depending on the conditions of exposure, it must also provide the first line of defence against weather and sunlight, open exposure, condensation (as on the undersides of bridges), highly polluted atmospheres in chemical plant, impact and abrasion at floor or road level, and bacteria and fungi (in food factories and farms).

4.5 The system

The various superimposed coats within a painting system have, of course, to be compatible with one another. They may be all of the same generic type or may be different, e.g. chemical resistant types, such as a recoatable polyurethane finish coat, may be applied onto epoxy primer and intermediate coats. However, as a first precaution, all paints within a system should normally be obtained from the same manufacturer and used in accordance with the manufacturer's recommendations.

With the introduction of the Environmental Protection Act (1990), it is now a statutory requirement that 'shop applied' paints comply with the relevant Process Guidance Notes to minimise the release of harmful volatile organic compounds (voc) into the atmosphere. From 1st April 1998, all shop applied paint coatings must be 'compliant' with the appropriate paint type category in Process Guidance Note PG6/23 (97) Coating of Metal and Plastic. Essentially this means that unless there is a system of solvent recovery or incineration, the following voc limits (g/L) apply under Clause 20(d) of PG6/23:

Etch / wash primer	780
Prefabrication / blast primer	780
Tie coat / sealer	780
General primer / undercoat	250
Top (finish) coats	420

However, an amendment document AQ4(99) of PG6/23 has introduced the following additional voc limits (g/L).

High temperature resistance coatings (>1000°C)	600
Intumescent coatings	420
Top coats for intumescents	600

Also, where a single coat (primer/finish) is specified, the voc limit is 420 g/l. Where a primer is to be subsequently overcoated, the original 250 g/l limit applies.

Other voc limits for coatings applied to ships and marine vessels appear in Clause 20(a) of PG6/23.

It is suggested that reference should be made to the latest amendments of PG6/23 at the time of preparing a coating specification. It is, therefore, important to ensure that the protection specification considers where the different paint types are to be applied and whether they are 'compliant'. At present there are no major restrictions on the types of paints used on site for finishes and maintenance. Specifiers, however, are encouraged to consider paints with low voc values to reduce damage to the atmosphere.

5.0 The main constituents of paint

5.1 Introduction

The main constituents of paint are the binder, pigment and solvent. Each constituent has a specific function and effect on the formation of the film and film properties.

5.2 The pigments

Pigments are finely ground inorganic or organic powders which provide colour, opacity, film cohesion and sometimes corrosion inhibition.

5.3 The binder

Binders are usually resins or oils but can be inorganic compounds such as soluble silicates. The binder is the film-forming component in the paint.

5.4 The solvent

Solvents are used either to dissolve the binder or act as a dispersant to facilitate application of the paint. Solvents are, therefore, usually organic liquids or water.

Paints are applied to steel surfaces by many methods but in all cases this produces a 'wet film'. The thickness of the 'wet film' can be measured, before the solvent evaporates, using a comb-gauge.

As the solvent evaporates, film formation occurs, leaving the binder and pigments on the surface as a 'dry film'. The thickness of the 'dry film' can be measured, usually with an electromagnetic induction gauge.

The relationship between the thickness of the applied 'wet film' and the final 'dry film' thickness (dft) is determined by the percentage by volume of solids of the paint, i.e.:

dft = 'wet film' thickness x % volume solids

In general, the corrosion protection afforded by a paint film is directly proportional to its dry film thickness.

6.0 Main generic types of paint and their properties

6.1 Air drying paints (e.g. alkyds)

These materials dry and form a film by an oxidative process, which involves absorption of oxygen from the atmosphere. They are therefore limited to relatively low film thicknesses (typically 40 μm). Once the film has formed it has limited solvent resistance and usually poor chemical resistance.

6.2 One-pack chemical resistant paints (e.g. acrylated rubbers or vinyls)

For these materials, film formation requires only solvent evaporation and no oxidative process is involved. They can be applied as moderately thick films with film thicknesses of typically 50-75 μm, though retention of solvent in the film can be a problem at the upper end of this range. The formed film remains relatively soft and has poor solvent resistance but good chemical resistance.

Bituminous paints also dry by solvent evaporation. They are essentially solutions of asphaltic bitumen in organic solvents.

6.3 Two-Pack chemical resistant paints (e.g. epoxy or urethane)

These materials are supplied as two separate components, usually referred to as the base and the curing agent. When these two components are mixed (immediately before use) a chemical reaction occurs. These materials therefore have a limited 'pot life' before which the mixed coating must be applied. The polymerisation reaction continues after the paint has been applied and after the solvent has evaporated to produce a densely cross linked film which can be very hard and has good solvent and chemical resistance.

Liquid resins of low viscosity can be used in the formulation thereby avoiding the need for a solvent. Such coatings are referred to as 'solvent less' or 'solvent free' and can be applied as very thick films, with film thicknesses in excess of 1000 μm.

7.0 Classification of paints

Since, in the broadest terms, a paint consists of a particular pigment, dispersed in a particular binder, dissolved in a particular solvent then the number of generic types of paint is limited. The most common methods of classifying paints are either by their pigmentation or by their binder type.

Primers for steels are usually classified according to the main corrosion inhibitive pigments used in their formulation, e.g. zinc phosphate primers, metallic zinc or aluminium primers, etc.

Each of these inhibitive pigments can be incorporated into a range of binder resins giving, for example, zinc phosphate alkyd primers, zinc phosphate epoxy primers, zinc phosphate acrylated rubber primers, etc.

Undercoats (intermediate coats) and finish coats are usually classified according to their binders, e.g. epoxies, vinyls, urethanes, etc.

8.0 Prefabrication primers

8.1 Introduction

Prefabrication primers are also referred to as blast primers, shop primers, temporary primers, holding primers, etc.

These primers are used on structured steelwork, immediately after blast cleaning, to maintain the reactive blast cleaned surface in a rust-free condition until final painting can be undertaken. They are mainly applied to steel plates and sections before fabrication which may involve welding or gas cutting.

The main requirements of a prefabrication primer are as follows:

The primer should be capable of airless spray application to produce a very thin even coating. Dry film thickness is usually limited to 15-20 μm. Below 15 μm the peaks of the blast

profile are not protected and 'rust rashing' occurs on weathering. Above 25 μm the primer affects the quality of the weld and produces excessive weld fume.

The primer must dry very quickly. Priming is often done in-line with automatic blast cleaning plant which may be handling plates or sections at a pass rate of 1-3 metres/minute. The interval between priming and handling is usually of the order of 1-10 minutes and hence the primer film must dry within this time.

Normal fabrication procedures (e.g. welding, gas cutting) must not be significantly impeded by the coating, and the primer should not cause excessive weld porosity (a welding certificate should be available).

Weld fume emitted by the primer must not exceed the appropriate Occupational Exposure Limits. Proprietary primers are tested and certified in the UK by the Newcastle Occupational Health Agency (a Health & Safety certificate should be available).

The primer coating should provide adequate protection. It should be noted that manufacturers may claim extended durability for their prefabrication primers and suggested exposure periods of 6-12 months are not uncommon. In practice, such periods are rarely met except in the least arduous conditions, e.g. indoor storage. In aggressive conditions, durability can often be measured in weeks rather than months.

Zinc-rich and zinc silicate primers provide the highest order of protection of all prefabrication primers.

The primed surface, after weathering, should require the minimum of re-preparation for subsequent painting and must be compatible with the intended paint system.

Many proprietary prefabrication primers are available but they can be classified under the following main generic types: etch primers, epoxy primers, zinc epoxy primers, zinc silicate primers.

8.2   Etch primers

Etch primers are based on polyvinyl butyral resin reinforced with a phenolic resin to increase water resistance.

These primers can be supplied in a single pack or two-pack form, the latter providing better durability.

8.3   Epoxy primers

Epoxy primers are two-pack materials utilising epoxy resins and usually have either polyamide or polyamine curing agents. They are pigmented with a variety of inhibitive and non-inhibitive pigments. Zinc phosphate epoxy primers are the most frequently encountered and give the best durability within the group.

8.4   Zinc epoxy primers

These primers can be either zinc-rich or reduced zinc types. Zinc-rich primers produce films which contain about 82 to 85% by weight of metallic zinc powder while corresponding figures for the reduced zinc type are as low as 55% by weight.

When exposed in either marine or highly industrial environments, zinc epoxy primers are prone to the formation of insoluble white zinc corrosion products which must be removed from the surface before subsequent overcoating. This cleaning process is usually known as 'secondary' surface preparation.

All zinc epoxy primers produce zinc oxide fume during welding and gas cutting and this can cause a health hazard.

8.5   Zinc silicate primers

Zinc silicate primers produce a level of protection which is comparable with that provided by the zinc-rich epoxy types and they suffer from the same drawbacks, e.g. the formation of zinc salts and production of zinc oxide fume during welding. There are currently different categories of zinc silicate primers based upon the binder (organic or inorganic) and the zinc content. Low-zinc primers in this group have been developed to improve their weldability and to minimise weld porosity. However, their durability is also reduced. The organic silicate primers are the most suitable as prefabrication primers.

9.0   The application of paints

9.1   Introduction

The method of application and the conditions under which paints are applied have a significant effect on the quality and durability of the coating. Standard methods used to apply paints to structural steelwork include application by brush, roller, conventional air spray and airless spray. Other methods

such as dip application can also be used, where practicable, e.g. for small items such as brackets.

9.2 Brush application

This is the simplest method but also the slowest and, therefore, most expensive. Nevertheless, it has certain advantages over the other methods, e.g. better wetting of the surface, and can be used in restricted spaces, be useful for small areas, with less wastage and contamination of surroundings.

The traditional method of brush application provides very high shearing forces between the liquid paint and the substrate. This greatly assists the intimate wetting of the steel surface and results in better adhesion of the dry paint film.

Brush application is labour-intensive (i.e. costly) and may be considered too slow when very large areas are being coated. Despite this, and especially where the highest standard of surface cleaning has not been specified, it is recommended that the priming coat, if at all possible, is applied by brush.

9.3 Roller application

This process is much quicker than brushing and is used for large flat areas, but demands suitable rheological properties of the paint. However, structural steel surfaces are never ideally flat, and roller application will ride over high spots and miss edges. It is not suitable for coating awkward corners, bolt heads etc., and is therefore not a recommended application method.

9.4 Spray application

In spray application, the paint is atomised into fine droplets and projected onto the surface to be protected where the droplets join together to form a continuous film. The atomisation can be accomplished in a number of ways.

In air spraying, the paint is atomised by mixing it with a stream of compressed air in a conventional spray gun. The paint can be either sucked into the air stream (as in the simple suction-cup gun used for application to small areas) or fed to the spray gun under pressure from a pressure pot. For ideal application, careful adjustments of the spray nozzle and air pressures must be made by a skilled operator, according to the consistency and composition of the paint product and the film thickness required.

For airless spraying, the paint is hydraulically compressed and, on release through a small orifice in an airless spray gun, it is atomised and projected onto the surface. By changing the orifice size and shape and by varying the hydraulic pressure, atomisation can be accomplished for a wide range of paint consistencies from thin to thick, to give a wide range of rates of deposition. The equipment required is much more expensive than for air-assisted spraying, because it must withstand the much higher pressures involved. For air-assisted spraying, the maximum air pressure will normally not exceed 690 kPa (100 psi); for airless spraying, hydraulic pressures of up to 27,500 kPa (4,000 psi) may be required.

A variant of the above involves heating to reduce the consistency of the paint rather than adding diluents. In this way greater film thickness per application is achieved. This method can be used for the application of solvent-free materials such as two-pack products which can be mixed at the spray gun nozzle at the moment of application. The use of expensive equipment and highly skilled labour is necessary for the achievement of optimum results but is justified for the protection of large and important structures.

10.0 Conditions of application

10.1 Introduction

The principal conditions which affect the application of paint coatings are temperature and humidity. These can be more easily controlled under shop conditions than on site.

10.2 Temperature

Air temperature and steel temperature affect solvent evaporation, brushing and spraying properties, drying and curing times and the pot life of two-pack materials, etc. Where heating is required, this should only be by indirect methods.

10.3 Humidity

Paints should not be applied when there is condensation present on the steel surface or the relative humidity of the atmosphere is such that it will affect the application or drying of the coating. Normal practice is to measure the steel temperature with a contact thermometer and to ensure that it is maintained at least 3 °C above the dew point.

11.0   Metallic coatings

11.1   Introduction

The two most commonly used methods of applying metallic coatings to structural steel are hot-dip galvanizing and thermal (metal) spraying.

In general, the corrosion protection afforded by metallic coatings is largely dependent upon the choice of coating metal and its thickness and is not greatly influenced by the method of application.

11.2   Hot-dip galvanizing

The most common method of applying a zinc coating to structural steel is by hot-dip galvanizing (Figure 2).

The galvanizing process involves the following stages:

(i)   Any surface oil or grease is removed by suitable degreasing agents.

(ii)   The steel is then usually cleaned of all rust and scale by acid pickling. This may be preceded by blast cleaning to remove scale and roughen the surface but such surfaces are always subsequently pickled in inhibited hydrochloric acid.

(iii)   The cleaned steel is then immersed in a fluxing agent to ensure good contact between the steel and zinc during the galvanizing process.

(iv)   The cleaned and fluxed steel is dipped into a bath of molten zinc at a temperature of about 450°C. At this temperature, the steel reacts with the molten zinc to form a series of zinc/iron alloys integral with the steel surface.

(v)   As the steel workpiece is removed from the bath, a layer of relatively pure zinc is deposited on top of the alloy layers.

As the zinc solidifies, it usually assumes a crystalline metallic lustre, often referred to as spangling. The thickness of the galvanized coating is influenced by various factors including the size and thickness of the workpiece and the surface preparation of the steel. Thick steels and steels which have been abrasive blast cleaned tend to produce relatively thick coatings.

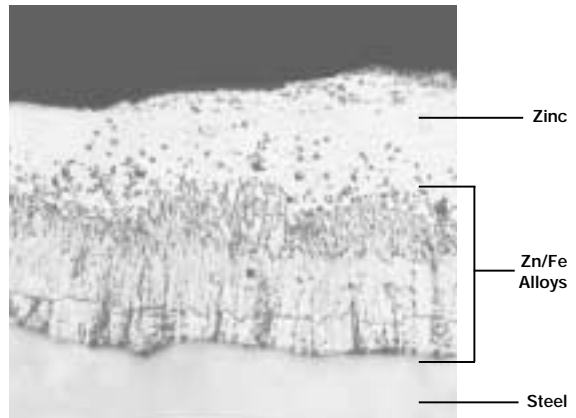Additionally the steel composition has an effect on the coating produced.

Figure 2. Hot-dip galvanizing

Silicon and phosphorus can have a marked effect on the thickness, structure and appearance of galvanized coatings. The thickness of the coating is largely dependent on the silicon content of the steel and the bath immersion time. These thick coatings (circa 200 μm) sometimes have a dull dark grey appearance and can be susceptible to mechanical damage.

Since hot-dip galvanizing is a dipping process, there is obviously some limitation on the size of components which can be galvanized. Double dipping can often be used when the length or width of the workpiece exceeds the size of the bath.

Some aspects of the design of structural steel components need to take the galvanizing process into account, particularly with regard the ease of filling, venting and draining and the likelihood of distortion. To enable a satisfactory coating, suitable holes must be provided in hollow articles (e.g. tubes and rectangular hollow sections) to allow access for the molten zinc, the venting of hot gases to prevent explosions, and the subsequent draining of zinc. Further guidance on the design of articles to be hot dip galvanized can be found in EN ISO 14713.

Distortion of fabricated steelwork can be caused by differential thermal expansion and contraction and by the relief of unbalanced residual stresses during the galvanizing process.

The specification of hot-dip galvanized coatings for structural steelwork was previously covered by BS 729 which was superseded in 1999 by EN ISO 1461. The minimum average coating thickness requirement for steels not less than 6 mm thick remains at 85 μm. This standard was developed in conjunction with a metal coatings Guidance Document, EN ISO 14713.

For many applications, hot-dip galvanizing is used without further protection. However, to provide extra durability, or where there is a decorative requirement, paint coatings are applied. The combination of metal and paint coatings is usually referred to as a 'duplex' coating. When applying paints to galvanized coatings, special surface preparation treatments should be used to ensure good adhesion. These include light blast cleaning to roughen the surface and provide a mechanical key, the application of special etch primers or 'T' wash which is an acidified solution designed to react with the surface and provide a visual indication of effectiveness.

11.3 Thermal spray coatings

An alternative method of applying a metallic coating to structural steelwork is by thermal (metal) spraying. In this case, either zinc or aluminium can be used. The metal, in powder or wire form, is fed through a special spray gun containing a heat source which can be either an oxygas flame or an electric arc (Figure 3).

Molten globules of the metal are blown by a compressed air jet onto the previously grit blast cleaned steel surface. No alloying occurs and the coating which is produced consists of overlapping platelets of metal and is porous.

These pores are subsequently sealed, either by applying a thin organic coating which penetrates into the surface or by corrosion products which form during exposure. Sealers may be un-pigmented, with colouring agents or aluminium flake.

The adhesion of sprayed metal coatings to steel surfaces is considered to be essentially mechanical in nature. It is therefore necessary to apply the coating to a clean
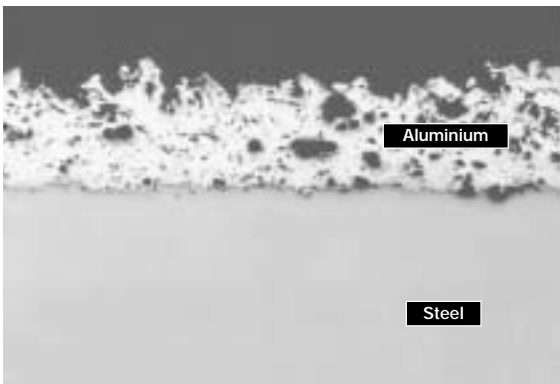

Figure 3. Thermal Spray Coating

roughened surface and blast cleaning with a coarse grit abrasive is normally specified. This would usually be chilled iron grit but for steels with a hardness exceeding 360 HV, alumina or silicon carbide grits may be necessary.

Typically specified coating thicknesses vary between 150-200 μm for aluminium and 100-150 μm for zinc.

Thermal spray coatings can be applied in the shops or at site and there is no limitation on the size of the workpiece, as there is with hot-dip galvanizing. Since the steel surface remains cool, there are no distortion problems. Guidance on the design of articles to be thermally sprayed can be found in BS 4479: Part 7 and EN ISO 14713. Thermal spraying is generally more expensive than hot-dip galvanizing.

For some applications, thermal spray coatings are further protected by the subsequent application of paint coatings. This first requires the application of a sealer which fills the pores in the metal spray coating and provides a smooth surface for application of the paint coating.

The protection of structural steelwork against atmospheric corrosion by thermal sprayed aluminium or zinc coatings is covered in BS EN 22063:1994.

12.0 Specifying the protective system

Before selecting the system to be used, the specifier should consult relevant standards and guidance documents relative to the design, function and life requirements, etc. This exercise is best done at the earliest possible stage of the particular project by the client or his consultant in conjunction with the main contractor, his subcontractor, and the coatings manufacturer(s). It is very important that the client or his consultant has the benefit of advice from a coatings expert on his staff or from outside. Discussion will usually show that alternative systems are suitable and the final decision should not rest first on cost.

13.0 Factors affecting choice

For a given structure the following will be largely predetermined:

- **The expected life of the structure and the feasibility of maintenance.**

- **The environment(s) to which the steelwork will be subjected.**

- **The size and shape of the structural members.**

- **The shop treatment facilities which are available to the fabricator and/or his coatings sub-contractor.**

- **The site conditions, which will determine whether steel work can be treated after erection.**

- **The cost, i.e. the money which is available to provide protection.**

These facts, and possibly others, have to be considered before making decisions on:

- **The types of coating to be used.**

- **The method of surface preparation.**

- **The method(s) of application.**

- **The number of coats and the thickness of each coat.**

In general, each case has to be decided on its own merits. However, the following points may be of assistance in making these decisions:

Protection requirements are minimal inside dry, heated buildings. Hidden steelwork in such situations requires no protection at all.

The durability of painting systems is increased several times over by using abrasive blast cleaning methods rather than manual surface preparation.

Shot blasting is preferred for most painting systems, however, grit blasting is essential for thermal spraying and some primers, e.g. zinc silicates.

If abrasive blast cleaning is to be used, two alternative process routes are available:

(i)   **Blast/prime/fabricate/repair damage.**
(ii)   **Fabricate/blast/prime.**

The former is usually cheaper but requires the use of a weldable, prefabrication primer.

Prefabrication primers have to be applied to blast cleaned surfaces as thin films, usually of 25 μm maximum thickness. Their durability is therefore limited and further shop coating is often desirable.

Manual preparation methods are dependent upon weathering to loosen the mill scale. These methods are, therefore, not usually appropriate for shop treatments. On site an adequate weathering period, usually several months, must be allowed.

Many modern primers based on synthetic resins are not compatible with manually prepared steel surfaces since they have a low tolerance for rust and scale. However, with the phasing out of red lead primers which were very tolerant of poor surfaces, surface tolerant epoxies have been specially developed and are widely used for maintenance jobs.

Many oil and alkyd based primers cannot be overcoated with finishing coats which contain strong solvents, e.g. acrylated rubbers, epoxies, bituminous coatings, etc.

Two-pack epoxies have poor resistance to UV radiation and are highly susceptible to superficial 'chalking' degradation. Overcoating problems can arise with two-pack epoxies unless they are overcoated before the prior coat is fully cured. This is particularly relevant when an epoxy system is to be partly applied in the shop and partly on-site.

Steelwork which is to be encased in concrete does not normally require any protection, given an adequate depth of concrete cover (British Standard BS 8110).

Perimeter steelwork which is hidden in the perimeter (cavity) walls of buildings can be sub-divided into two categories:

(i)   **Where an adequate air gap (40 mm minimum) exists between steel and the outer brick or stone leaf, then adequate protection can be achieved by applying relatively simple painting systems.**

(ii)   **Where the steelwork is in direct contact with the outer leaf, or is embedded in it then the steel should be hot-dip galvanized and painted with a water resistant coating, e.g. bitumen.**

Where fire protection systems are to be applied to the steelwork, consideration must be given to the question of

compatibility between the corrosion protection and the fire protection systems.

New hot-dip galvanized surfaces can be difficult to paint and, unless special treatments are used, adhesion problems can arise. Weathering of the zinc surface before painting reduces this problem.

Thermal spraying produces a porous coating which should be sealed by applying a low viscosity sealant. Further painting is then optional.

Particular attention should be paid to the treatment of weld areas. Flux residues, weld spatter and sharp peaks should be removed before the application of coatings. In general, the objective should be to achieve the same standard of surface preparation and coating on the weld area as on the general surface.

Black bolted joints require protection of the contact surfaces. This is normally restricted to the priming coat, which can be applied either in the shops or on site before the joint is assembled.

For high strength friction grip bolted joints, the contacting surfaces must be free of any contaminant or coating which would reduce the slip factor required on the joint. Some thermal spray coatings and some inorganic zinc silicate primers can be used but virtually all organic coatings adversely affect the slip factor.

Fasteners, such as nuts and bolts, should also be considered in the protection specification to ensure that they are coated to a standard equivalent to the main structural steelwork. Where steelwork is coated in the fabricating shops and then bolted on site, the fasteners may only receive a finish coat unless the specification is written to ensure that the fasteners are adequately protected. For steelwork which is to be treated to a high standard of protection e.g. blast cleaning and a high performance coating system, the fasteners should also be treated accordingly.

For example, metal coated structural steelwork should be connected with fasteners that have equivalent metal coating, where practical, to aim for a similar durability.

Reference to BS 7371:1998 'Coatings on Metal Fasteners', Part 6 and Part 8 relate to specifications for hot dip galvanised

coatings and sherardized coatings respectively and these standards should be included in the protection specifications where appropriate.

14.0 Writing the specification

The specification is intended to provide clear and precise instructions to the contractor on what is to be done and how it is to be done. It should be written in a logical sequence, starting with surface preparation, going through each paint or metal coat to be applied and finally dealing with specific areas, e.g. welds. It should also be as brief as possible, consistent with providing all the necessary information. The most important items of a specification are as follows:

- **The method of surface preparation and the standard required. This can often be specified by reference to an appropriate standard, e.g. BS 7079: Part Al Sa2$\frac{1}{2}$ quality.**

- **The maximum interval between surface preparation and subsequent priming.**

- **The types of paint or metal coatings to be used, supported by standards where these exist.**

- **The method(s) of application to be used.**

- **The number of coats to be applied and the interval between coats.**

- **The wet and dry film thickness for each coat.**

- **Where each coat is to be applied (i.e. shops or site) and the application conditions that are required, in terms of temperature, humidity etc.**

- **Details for treatment of welds, connections etc.**

- **Rectification procedures for damage etc.**

15.0 Inspection

As in most contractual situations, inspection must be carried out to ensure that the requirements of the specification are being met.

Inspection of the processes, procedures and materials required for the protective coating of steel structures is vital, since a major error in even one operation cannot be easily detected after the next operation has been carried out, and if

not rectified immediately can significantly reduce the expected life to first maintenance.

The appointment of a suitably qualified inspector should be regarded as an important part of the job. Those involved with such duties should have been trained in internationally recognised practices and standards and have appropriate certification. Such schemes are available through The Institute of Corrosion in the UK.

16.0 Costs

The cost of protective coatings is not usually a dominant item in the capital cost of any project. However, when capital cost estimates suggest that the budget will be exceeded, planned expenditure on protective coatings often suffers.

It is, however, now well established that when the initial protective coating system is not correctly specified or is not done exactly to the specification, the expected life to first maintenance will not be achieved and subsequent attempts to recover the situation by additional maintenance can be excessively costly.

When the cost of protecting a very-long-life structure is being considered, it is wise to estimate the whole life cost and to consider the specification of durable treatments to maximise performance and minimise total costs.

17.0 Health and safety

The increasing awareness of health and safety requirements in industry has placed restrictions on the operations and materials used for the protective coating of structural steel. In particular, the provisions of the Health and Safety at Work Act 1974 and the Control of Pollution Act 1974 must be observed. For example,

(i) Because of toxicity, there are restrictions on the use of certain materials and components.

(ii) Noise produced by processes such as blast cleaning must be kept below a level that would damage hearing.

(iii) Explosion hazards must be avoided by providing ventilation to remove flammable solvents and/or dust.

(iv) Operators must be protected against such hazards by the provision of protective clothing, fresh air masks, ear muffs, etc.

Where precautions are necessary, paint manufacturers label their products suitably and equipment manufacturers give necessary advice. However, because of the complicated nature of some requirements, it is good policy to enlist the aid of the local Health and Safety Inspectorate in defining the requirements for any particular situation. Training of operators in the procedures required to obtain effective coating protection of steel structures should always include instruction on health and safety requirements.

18.0 Environmental protection

In addition to the requirements for corrosion protection, there is increasing pressure being introduced by legislation to use paints and coatings which are 'environmentally friendly' and thereby minimise damage to the atmosphere. The implications for specifiers are to specify coatings which do not contain high quantities of organic solvents and toxic or harmful substances. Following the introduction of the Environmental Protection Act (1990), the Secretary of State's Process Guidance Note PG6/23 'Coating of Metal and Plastic (97)', referred to previously, should be consulted and the paints in the draft specification checked for compliance with the appropriate category. Compliant coatings generally are those which contain high solids or water as the primary solvent or are solvent free.

Specifiers now have the responsibility of including 'compliant' coatings particularly for shop applications. Most reputable paint manufacturers indicate whether their coatings are 'compliant' with the appropriate categories listed in the Process Guidance Notes.

19.0 Additional reference reading & futher sources of information

Additional reference reading

Steelwork Corrosion Control, Bayliss, D.A. and Chandler K.A. Elisevier Applied Science, 1991.

New Paint Systems for the Protection of Construction Steelwork Report 174, CIRIA, 1997.

The Improving Performance of Hot Dip Galvanizing and Duplex Coatings, Institute of Corrosion WGE5/10 Report, August 1997.

The Engineers and Architects Guide to Hot Dip Galvanizing, Galvanizers Association, 1998.

Sprayed Metal Coatings Protect Steel Structures, Association of Thermal Sprayers.

The Environmental Protection Act, 1990, Part 1 Secretary of State's Guidance - Coating of Metal and Plastic - PG6/23(97) March 1997 - Department of the Environment.

The Environmental Protection Act 1990, Part 1
as above. Amendment AQ4(99), April 1999.

Further Sources of Information

National Corrosion Service
National Physical Laboratory
Queens Road
Teddington
Middlesex TW11 0LW
Tel: 020 8943 6142
Fax: 020 8943 7107

The Institute of Corrosion
Leck House
4 Lake Street
Leighton Buzzard
Bedfordshire LU7 8TQ
Tel : 01525 851771
Fax: 01525 376690

Building Research
Advisory Service
Garston
Watford WD2 7JR
Tel: 01923 664664
Fax: 01923 664098

Paint Research Association
Waldegrave Road
Teddington
Middlesex TW11 8LD
Tel: 020 8977 4427
Fax: 020 8943 4705

Galvanizers Association
Wren's Court
56 Victoria Road
Sutton Coldfield
West Midlands B27 1SY
Tel: 0121 355 8838
Fax: 0121 355 8727

The Thermal Spraying and Surface
Engineering Association
5 Keats Road
Stratford upon Avon
Warwickshire CV37 7JL
Tel: 01789 299661
Fax: 01789 268324

The National Corrosion Service

The National Corrosion Service (NCS) is operated by NPL on behalf of the DTI to provide a gateway to corrosion expertise for UK users. By acting as a focal point for corrosion enquiries, the NCS can make the UK's entire base of experts available to solve problems or can, using in-house expertise or teams, carry out consultancy. The NCS also helps raise awareness of corrosion problems and methods of control.

For more information on NCS services and products please contact us at:

E-mail: ncs@npl.co.uk   Tel: 020 8943 6142   Fax: 020 8943 7107

2295/aaron/IK/0004