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Code of practice for

Protective coating of iron and steel structures against corrosion

(Formerly CP 2008)

UDC 624.014.2:691.71:620.197.6

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Foreword

This code of practice was originally published, under the number CP 2008, in 1966; in accordance with BSI policy whereby codes of practice are now published in the general series of British Standards, this revision is published as BS 5493. The code was originally drawn up to assist those responsible for the choice or application of measures to protect iron and steel from corrosion.

Since that time developments have taken place in both the methods and processes concerned with the protection of steel from corrosion, and this new edition has been prepared to take account of these changes.

The total content of the code has been reduced, the format has been revised, and much of the explanatory matter that appeared in the original code has been omitted but essential background information has been included in the appendices. The section on cathodic protection has been omitted entirely and reference should be made to BS 7361-1. Sections on specifications and inspection have been included and this reflects the importance attached to these matters as a means of achieving the full potential of protective coatings in practice.

A new feature of this code is the inclusion of reference numbers for complete protective systems and also for their component parts. This should be of particular assistance to users where coatings or materials do not comply with the relevant British Standards. Although some compositional requirements of the coating materials are included, these are not sufficiently detailed to provide more than a general indication of the characteristics of the coatings, and are not intended to be used as standards.

The treatments suggested represent the minimum acceptable standard of good practice for important steel structures. In some buildings and structures of less importance lower standards of protection may be acceptable but the reduction of initial costs will generally result in higher maintenance costs. Where steelwork is fully encased, e.g. in concrete, the standard of protection will generally be lower than that recommended here.

Protective processes are constantly being developed and improved, the recommendations in the code cannot, therefore, be final and are not intended to discourage the use of other measures and materials where they can be shown to be equivalent to or better than those recommended here.

BS 5493 has been amended to accord with current UK health and safety legislation, as a holding exercise pending changes in legislation resulting from EC Directives. References in BS 5493 to other British Standards have also been updated.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to viii, pages 1 to 130, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This code classifies recommended methods of protection against corrosion of iron and steel structures exposed to environments commonly encountered. It describes the various methods in detail and gives guidance on how to specify a chosen protective system, how to ensure its correct application, and how it should be maintained.

The code does not include specific recommendations for ships, vehicles, offshore platforms, specialized chemical equipment, or cladding materials; nor does it include detailed recommendations for plastics coatings or cement-mortar linings.

For some situations, weathering steel may be an alternative to ordinary structural steel with applied coatings. No detailed recommendations on the use of weathering steels are given in this code and when their use is contemplated, advice should be sought from the steel industry.

2 References

The code makes frequent reference to Swedish Standard SIS 05 59 00 "Pictorial surface preparation standards for painting steel surfaces", which may be purchased through the British Standards Institution.

The titles of the other standards publications referred to in this code are listed on the inside back cover.

Bibliographical references are listed in appendix J.

3 Use of the code

3.1 General. The most frequent use of this code is likely to be made when choosing and specifying a protective system for a new or proposed structure. For such a use the basic procedures are as follows.

a) Identify the environment with the help of Table 1.

b) Decide on the life requirement and select suitable systems (from the relevant part of Table 3).

c) Compare these systems (with the assistance of the detailed information in Table 4) and select the preferred system.

d) Define the system as completely as possible using Table 4 and specify with the assistance of section 3.

These four fundamental procedures may be subdivided into more precise steps according to:

1) the severity of the environment, its local variations and any special conditions;

2) the size and nature of the structural contract; and

3) the experience and technical expertise of the user of the code (see **3.2** and **3.3**).

The code allocates key reference letters to the principal groups of protective systems (see Table 2 and Table 3). Some users of the code may be tempted to specify a protective system by quoting only the system reference (third column of Table 3) and on rare occasions this minimum reference may suffice for a specification, but in most cases it would leave a very wide choice of components and combinations to be selected. It would therefore usually be wiser to select more exactly (from the relevant part of Table 4) the products to be used and to ensure that they are agreed by all parties concerned (see note following Table 4F, part 4).

Although the correct selection of a protective system and the correct specification of materials and methods are both essential, they do not, by themselves, ensure the adequate performance of the chosen system. The recommendations given in sections 4, 5 and 6 are equally important to the full realization of a successful corrosion protection scheme.

3.2 Use by the experienced specifier. A specifier who is experienced in the technology of protection against corrosion will need little guidance on how to find the information required in the code. Nevertheless, the list of questions given in clause **4** may be a useful guide.

Attention is drawn especially to section 3 because it is very important that decisions and requirements in a complex specification be stated clearly and completely.

3.3 Use by the non-technical specifier. A specifier with limited knowledge or experience of corrosion protection will probably seek expert advice on any but the simplest of projects, but may and should study the code carefully with a view to using it in one of the following ways.

a) To distinguish between the problems that do and do not have simple solutions.

b) To consider factors (see clause **4**) that will provide evidence of the advantage of one type of system over another for specific requirements.

c) To check that a protective system or specification offered by a supplier fulfils the requirements of the code.

d) To select, in accordance with **3.1** a) and b) above, a number of systems that meet the assessed environmental conditions and the life requirements and then to use clauses **10** to **13** to narrow the choice before seeking quotations.

Attention is drawn to the step-by-step approach in appendix H.

The non-technical specifier may find in the code some unfamiliar terminology. Most of the technical terms used are defined in BS 2015.

3.4 Specification requirements. Attention is drawn particularly to clause **15** covering the need to specify, fully and coherently, all the required operations. The lives to first maintenance indicated in Table 3 will be achieved only by ensuring that the materials conform to the specification and that the application, handling and inspection procedures given in sections 3 and 4 are followed. Nevertheless, the details given in this code (or in any standard) are often insufficient to set a quality standard and when a specifier finds this to be the case he should require the suppliers of coatings and other materials to provide appropriate performance data.

Section 2. Factors influencing the choice of protective systems

4 General

4.1 Recognition of the problem. The design of structures is based largely on data and functional requirements which can be quantified. On the other hand the selection of a protective system involves qualitative judgement on the relative importance of many factors that can vary widely according to the type of structure, its function, its general location, its immediate environment, and any changes (natural or otherwise) that may occur in its environment. There are other factors affecting the selection (such as required life to first maintenance, thickness of coatings, etc.) which may appear to be quantitative, but should be viewed with caution, because in practice, the degree of variation may differ between one coating system and another, and between one proprietary material and another within an individual system.

Costs may vary considerably even for the same coating system, and great care is necessary to ensure that quotations for apparently identical products or services do in fact cover the same materials or application with the same degree of consistency and control. Appendix E deals with the overall economic assessment of costs.

Some of the critical conditions and circumstances that have to be taken into account before selecting a protective system are listed below in question form. Not every question will be relevant for a particular application and the importance of each relevant question may vary. The order of relevant questions may have to be changed because some answers might be modified in the light of answers to later questions. The list should therefore be studied as a whole before the questions are considered in detail.

4.2 Questions related to design, use and site requirements	**Sources of information**
4.2.1 *Function*	
a) What is the main function of the structure?	
b) What are the secondary functions of the structure?	Design remit
4.2.2 *Life*	
a) For how long is it required to fulfil this function?	Design remit
b) What is the life to first maintenance? (It may not be possible to decide this until further questions have been answered.)	Design remit, clauses **6** and **7**, Table 3
4.2.3 *Environment*	
a) What is the general (atmospheric) environment at the site of the structure?	Considerations of use and geography, clause **5**, Table 3
b) What localized effects exist or are to be expected (e.g. fumes from chimneys)?	Table 1
c) What other factors may affect the structure (e.g. surface temperature and abrasion)?	Table 1
4.2.4 *Appearance*	
a) What is the structure required to look like (colour and finish)?	Design remit
b) Is the final coat to be applied on site?	Depends on coating system selected, **24.1** and consideration of (a) above
4.2.5 *Special properties*	
a) What special properties are required of the coating (e.g. coefficient of friction)?	Design remit, clauses **7** and **8**
4.2.6 *Maintenance*	
a) What access is there going to be for effective maintenance?	Consider design remit and site, **47.2** and **A.3.6.6**.
b) What is the possibility of effective maintenance?	
4.2.7 *Health and safety*	
a) Are any problems to be taken into account during initial treatment?	
b) Are any problems to be taken into account during maintenance treatment?	Section 6. Consider design and site
4.2.8 *Tolerance*	
Does the coating need to be tolerant of:	
a) indifferent surface preparation	Clauses **9** and **17**
b) indifferent application techniques	Discretion and experience
c) departures from specification?	Clause **17**, discretion and experience

4.3 Questions relating to coating systems	**Source of information**
4.3.1 *Coating systems*	
a) What coating systems are suitable?	Clauses **10**, **11**, **12** and **24.1**
b) Are these systems readily available?	Consult supliers, **21.1**
c) Are the system elements mutually compatible?	**12.1.4**
d) Can the coats be applied by:	
brush	**22.2**
roller	
airless spray	
other? (describe)	
4.3.2 *Coating facilities*	
a) Are the coating facilities readily available:	
1) for factory application	Clauses **9** and **10.4**
2) for site application?	
b) Do they cover all sizes and shapes of fabrication?	Consult suppliers, **11.1.2**
c) Do they permit speedy application?	Clause **22**
d) Do the facilities permit work to adequate standards?	Experience
4.3.3 *Compatibility with engineering and metallurgical features*	
a) Is the design and jointing of the structure compatible with the preferred coating technique?	Clauses **7** and **8**
b) Does surface preparation (blasting, pickling) or application of coating affect the mechanical properties of the steel in any way that matters?	**10.2**, **11.2.1** and **16.2.3**
c) Is the system compatible with cathodic protection?	Consult specialist
4.3.4 *Delays*	
What delays should be allowed between:	**10.4** and **22.2.6**, consult specialist
a) fabrication and first protective coating;	
b) application of primer and undercoat;	
c) application of undercoat and finishing coat;	
d) final shop coat and erection;	
e) erection and final treatment?	
4.3.5 *Transport, storage, and handling*	
How well does the coating withstand:	
a) excessive or careless handling;	Clauses **12.1.6** and **24**
b) abrasion and impact;	
c) early stacking;	
d) exposure to sea water during transit?	
4.3.6 *Experience*	
a) What is known of the consistent performance of the coating?	Case histories
4.3.7 *Export*	
a) What special precautions should be taken when the steelwork is exported?	Full consideration of environment during transport, storage, and use
4.3.8 *Maintenance*	
a) Is the deterioration of the coating rapid and serious if maintenance is delayed?	Section 5
4.3.9 *Costs*	
a) What are the approximate costs of:	
1) the basic system;	Cost analysis of previous contracts; appendix E; consult suppliers and contractors
2) any additional items;	
3) transport;	
4) access?	
b) What are the approximate costs of maintenance?	Cost analysis of previous maintenance; appendix E; consult suppliers and contractors

The manner in which this list of questions can assist in choosing a protective system is demonstrated in appendix H.

5 Environment

5.1 Classification of types. Table 1 gives details of the most common types of environment (exterior atmospheres, including the problems of sheltered conditions, building interiors, sea water, fresh water, soil) and of special situations requiring additional or priority treatment (high temperatures, refrigerated surfaces, fungal and bacterial growth, chemicals, abrasion or impact, local mining and encasement in concrete).

The definitions of environment and recommendations for coatings are primarily related to conditions in the United Kingdom. However, much oversea construction is supplied by and controlled from the United Kingdom.

It should be noted therefore, that subtropical and especially tropical environments can be much more corrosive than those in Britain, because of the much higher and wider range of temperature, rainfall and humidity. The surface temperature of a structure can, after heavy rain, quickly reach 70 °C or 80 °C, and humidities at or close to 100 % can persist for long periods. The salinities of both fresh and salt waters can be much higher because of the high evaporation rates of ground water; and high water temperature promotes rapid growth of corrosive bacteria. It should also be borne in mind that when coated or uncoated goods are shipped from a temperate climate into or through a tropical climate, the environmental conditions during transport may be much more aggressive than those in which the coatings are intended to serve. For all these reasons, specialist advice should be sought when considering protective schemes in such environments.

5.2 Identification of relevant types. When selecting a protective system, identification of the environment should be allowed for by answering the following questions.

a) What is the nature of the general environment?

b) Will the environment change markedly after completion of the structure or in the foreseeable future?

c) Is there local pollution, e.g. sulphur dioxide, which could make the environment more corrosive than is at first apparent?

d) Should the worst environment be allowed for when determining protective systems or should the project be divided into different parts from an environmental standpoint?

e) What special situations apply, e.g. watersplash and residual pools, vulnerability of posts to traffic near ground level or floor levels?

6 Life required of coating

6.1 Definition. Most structures are designed for a specific functional life. In the rare cases where access for repair or maintenance of the coatings is impossible, the initial protective coating will be required to have the same life as the structure. More usually, however, the life requirement of the initial protective coating is based on the time which can elapse before major or general maintenance of the coating becomes necessary. That time is known as the "life to first maintenance" and its values, related to types of environment and coating systems, are given in Table 3, which also indicates which systems have special maintenance requirements.

Section 5 of the code gives details of conditions of coating which indicate that maintenance is due.

6.2 Categories

6.2.1 *Life to first maintenance.* The following ranges of life are used in Table 3.

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

It should be noted however, that there may be wide variability in the environment and in the application of the coating system which may shorten or lengthen the expected maintenance-free life. However, when maintenance is due after 20 years or more on "very long life" systems in the more unfavourable combinations of circumstances, the coating may have deteriorated to such an extent that it may be necessary to blast-clean and recoat the steelwork (see clause **55**). On structures with a design life of more than 50 years it is advisable to inspect the coatings earlier than the date scheduled for maintenance. It can then be decided if maintenance work should be put in hand earlier than the scheduled date in order to preserve the integrity of the coating that was applied initially.

Mechanical damage to coatings during handling, transport and erection is not considered in Table 3 but is discussed in clause **24** and Table 8 (section 4).

6.2.2 *Life between subsequent maintenances.* After galvanized or metal-sprayed structures have been painted, subsequent maintenance will be of the paint scheme. Well maintained painted structures may have longer lives between maintenance operations as the total intact paint film becomes thicker.

6.3 Assessment of life requirement. It may be necessary to assess the life of each part of a structure separately (see **5.2** d) and e) and **15.6**). For each assessment (whether or not more than one is required) the following points should be taken into account.

a) Required life of structure.

b) Decorative aspects; the decorative life of a coating is not usually as long as the protective life.

c) Irreversible deterioration if scheduled maintenance is delayed.

d) Difficulty or ease of access for maintenance (see clause **7**).

e) Technical and engineering problems in maintenance.

f) Minimum acceptable period between maintenances.

g) Total maintenance costs, including shut-down of plant, closure of roads, access costs, etc.

7 Design of the structure

The design of the structure may influence the choice of protective system. It may be appropriate and economic to modify the design (see BS 4479) to suit the preferred protective system. The following points should be borne in mind when designing.

a) Easy access for protection and maintenance should be provided and, wherever possible, pockets and recesses in which water and dirt may collect should be avoided. Corrosive chemicals, including de-icing salts, should be directed away from structural components, e.g. by drainage tubes.

Table 1 — Environments and special situations

Environment		
Category	**Description**	**Relevant part of Table 3**
Exterior exposed	Rain washed surfaces	
Non-polluted inland	Most rural and suburban areas with low sulphur dioxide, acid, alkali and salt pollution. NOTE Some apparently non-industrial areas may be polluted from distant sources, according to prevailing wind and topography	Part 1
Polluted inland	Airborne sulphur dioxide, or other pollution from industrial or domestic sources	Part 2
Non-polluted coastal	As non-polluted inland with salt detectable. Typically nearer to coast than a distance which may be as little as 0.25 km or as much as 3 km, according to prevailing wind and topography (but with frequent salt spray, treat as sea water splash zone)	Part 4
Polluted coastal	As polluted inland with salt detectable. Typically nearer to coast than a distance which may be as little as 0.25 km or as much as 3 km, according to prevailing wind and topography (but with frequent visual salt spray, treat as sea water splash zone)	Part 3
Exterior sheltered	As above except not washed by rain, badly ventilated, and normally subject to condensation, e.g. undersides of bridges	Part 5
Interior	Inside buildings which may or may not be heated	

Category	Description	Relevant part of Table 3
Normally dry	Allows for some condensation and for exterior conditions during erection, e.g. warehouses	Part 6
Frequently damp and wet	Substantial condensation, e.g. swimming baths	Part 7
Non-saline water	Potable and non-potable water. Applicable to river installations, sewage-treatment tanks, water tanks, and domestic water systems	Part 8
Sea water	Sea and other saline waters and estuary water	
Immersed	Permanent immersion, e.g. submerged structures, offshore drilling rigs	Part 10
Splash zone	Wind and water area of floating and tidal structures, e.g. wharfs, piers, sea walls or frequent salt spray	Part 9
Soil	Earth, sand, rock, etc. Mainly buried structures, e.g. pipelines and exteriors of tunnels and underground storage tanks	Part 13
Special situations requiring priority consideration[a]		
Mines	Typically coal mines. Warm humid conditions. Water present (pH 2.5 to 11) and sometimes saline	Part 12
Encasement in concrete	Alkaline concrete away from atmosphere, but carbonation occurs close to surface and in cracks	Part 14
Refrigerated surfaces	Surfaces near to refrigeration systems subject to ice formation and condensation	Part 15
High-temperature surfaces	The temperature aspect is usually of greater importance than the general atmosphere. Thermal shock may need to be considered	Part 11
Chemicals		
Acids and alkalis	Specific corrosion hazards from both liquid and vapour	Part 16
Neither acidic nor alkaline	Usually solvents and petroleum products with dissolution effect on many organic coatings	
Road (de-icing) salts	Salts containing chlorides used to suppress ice formation, particularly on highways	Part 17
Abrasion and impact	Additional consideration in some applications	Part 18
Fungi and bacteria	Additional consideration in some applications	Part 19

[a] Some environments are so highly corrosive that special high duty coatings not detailed in this code may be required.

b) Certain areas may, after erection, be inaccessible for maintenance and so may require a coating system designed to last for the total life of the structure.

c) Some structural sections may be more suited to some coating systems than others; e.g. hollow sections can be more easily wrapped than structural shapes.

d) The method or size of fabrication may preclude or limit some coating systems.

e) The absence of sharp edges facilitates the even application of paints which might recede from arrises.

f) If materials are chosen which may give serious bimetallic corrosion problems additional measures are necessary. (See PD 6484.) The effect of contact with other building materials should be considered (see clause **28**).

g) Electrical continuity in some exposed steel structures can be important. If continuity is not otherwise provided, copper tapes may have to be bonded to the steel parts to bridge the discontinuity (e.g. lightning conductors) but this creates a risk of bimetallic corrosion. Metal coatings retain electrical continuity and most paint coatings provide electrical resistance.

8 Fabrication

8.1 General. Full protection applied in the shop immediately after fabrication normally results in a longer life of the protective system. However, damage during transportation and erection may subsequently necessitate widespread repair or touch-up of coatings, so specifiers may prefer to leave a final coat or coats of a multi-coat system for application on site. This may, however, delay site work, e.g. removal of scaffolding. When the final cost of paint is applied on site the specifier should choose a system that is tolerant of delay (with possible contamination) at this stage. The specification should state clearly who is to be responsible for quality control at each stage in the fabrication and processing.

8.2 Faying surfaces of friction-grip joints.[1] The faying surfaces of friction-grip bolted joints (see BS 3294 and BS 4604) require special attention. If left bare, all points where moisture could gain access should be effectively sealed. The alternative is to protect the faying surfaces, but in this case the effect of the protective schemes on the slip factor has to be closely investigated, and their behaviour under static, dynamic and sustained loading should be considered. If adequate test results are not available they should be obtained. Consideration should also be given to possible losses of pre-tension arising from the behaviour of protective coatings on fasteners and in friction-grip joints. Sprayed aluminium or zinc, hot-dip galvanizing, paints of the zinc silicate type, or special paints with abrasive additions may be considered. Most organic-based protective coatings, including strippable coatings, oils, and waxes, would greatly reduce the slip factor below the acceptable values for properly prepared steel.

8.3 Fasteners. Fasteners which are exposed after assembly, such as steel pipe-and cable-hangers, are zinc- or aluminium-coated, or blast-cleaned and primed before welding-on (if not blast-cleaned with the structure). Fixing nuts and bolts may be galvanized (see BS 729), sherardized (see BS 4921), or electroplated (see BS 3382 and Table 4). An adequate thickness of zinc should be specified, and when the zinc coating on fasteners (applied by galvanizing, electroplating or sherardizing) is too thin for the life requirement, further coatings should be applied on surfaces exposed after assembly as follows.

a) Zinc-dust paints: to total thickness suggested by Figure 1 for appropriate environment and life to first maintenance.

b) Other coatings: to thickness that will offer protection equivalent to that given to the main structure.

8.4 Procedure for welds. As-rolled steel may be blast-cleaned and protected with blast-primers before fabrication and welding (see Table 4A). This prevents the serious development of rust, which would be difficult to remove after fabrication. The use of steel that has rusted heavily during storage is best avoided for the same reason. When welding metal-coated or zinc-dust-painted steel, it is sound practice first to remove the coating near the weld area, or mask-off the weld area before coating. Most painted steel can be cut and welded satisfactorily provided that the coating thickness is less than 25 µm, but welds that are likely to be heavily stressed should be examined by the engineer for porosity.

After welding, scale and heat-damaged coatings should be removed by local blast-cleaning and the areas renovated by re-applying the original coating (if possible). Galvanized or metal-sprayed surfaces may be made good by:

a) metal-spraying on site;

b) application of zinc-rich paints to reinstate the original dry-film thickness; or

c) application of low-melting-point zinc alloys heated by torch to a pasty condition[2].

To avoid the need for early maintenance of site welds on painted structures they should be blast-cleaned before protection.

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[1] The term "faying surfaces of a friction-grip joint" means surfaces which, when in contact with one another, transmit a load across the interface by friction.

[2] These contain fluxes which should be removed.

9 Facilities for application of coatings

Surface preparation (see clause **14**) is normally done by the contractor applying the coating. If blast-cleaning is not available and it is necessary to use a surface-preparation method that is inferior to blast-cleaning, it is advisable to choose a paint which is compatible with that surface preparation; the advantages of some chemical resistant paints are lost if they are applied over inadequately prepared surfaces.

When programming the work, factors to be considered include the following.

a) The sequence of operations (e.g. blast-cleaning before fabrication is normally cheaper than blast-cleaning after fabrication).

b) The application time (e.g. length of a drying or curing time for coating).

c) Methods of application (e.g. airless spray, air spray, or brush). (See clause **22**.)

d) The possible advantage or disadvantage of applying the final coat(s) on site (see clauses **8.1**, **12** and **24**). Some coatings (e.g. galvanizing[3]) cannot be applied on site.

10 Classification and characteristics of protective coatings

10.1 Classification. The first stage of classification separates all protective coatings into “metallic” and “non-metallic”. (Metallic zinc-rich coating materials are treated as paints in this code (see **12.1**).) The next stage of classification groups the principal types of coatings in the manner shown in Table 2. Each group is given a key reference letter (from the sequence B to M) which will be used for identification throughout the code, especially in Table 3 and Table 4. The letter A is not used in Table 2 but is used as the key reference letter for blast primers in Table 3 and Table 4.

Throughout the remainder of the code, the key reference letter is prefixed by the letter S when a complete protection system is the subject of the reference.

To identify the components within a system the key reference letter is amplified by one of the following suffix letters:

P to denote first treatment or primer (AP to denote blast primer);

U to denote undercoat(s); and

F to denote finishing or top coat.

Numbers following the alphabetical reference indicate more specific alternatives within the general type.

For example:

SB3 denotes a complete system (S) of zinc coating (B), being the third (3) alternative of the four systems listed in Table 4B.

FF4A denotes a drying-oil-type (F) finishing coat (second F), in the fourth (4) group of alternatives listed in the last part of Table 4F, and sub-group A for white and tints. It is not itself a system.

The further alphabetical suffix that appears after some of the numbers indicates still further sub-classification, as in the example FF4A above. Use of the designation FF4 would imply any or all of the referenced products in the relevant product section.

For some of the applications there are several systems that offer acceptable protection, so choice has to be guided by other characteristics. These include availability, convenience of application, ease of inspection and control, ease of maintenance, and economy in use for the specific structures and situations involved. The following general considerations are supplemented by more specific information in Table 3 and Table 4 and clauses **11** and **12**.

Metallic coatings are usually supplied under technical names which are generally related to the techniques of application, such as galvanizing, sprayed-metal (frequently known as metal spray), etc. On the other hand, non-metallic coatings are usually supplied as proprietary products. The products within each sub-classification group may have slightly different compositions and properties

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[3] Galvanizing facilities are listed in the Galvanizers Directory, issued by the Galvanizers Association, 34 Berkeley Square, London, W1X 6AJ.

Table 2 — Principal types of coating systems (see **10.1**)

Key reference letter	Type	Characteristic constituents	Reference to Table 4	Clause reference
B	Zinc coating (except sprayed-metal): bare or painted	Zinc and/or zinc-iron alloy	4B	**11.1**
C	Sprayed-metal: bare, sealed or painted	Zinc or aluminium metal	4C	**11.2**
D	Organic zinc-rich	Zinc and organic binder	4D	**12.2**
E	Inorganic zinc-rich	Zinc and silicate binder	4E	**12.2**
F	Drying-oil type	Drying oil, urethane oil, alkyd, modified alkyd, phenolic varnish, or epoxy ester plus pigment	4F	**12.3**
G	Silicone alkyd	Silicone-modified alkyd plus pigment	4G	**12.3**
H	One-pack chemical-resistant	Chlorinated rubber or vinyl copolymer resin plus pigment	4H	**12.4**
J	One-pack chemical-resistant and type F primer	Epoxy ester or alkyd primer with chlorinated-rubber finish[a]	4J, 4F	**12.4** **12.3**
K	Two-pack chemical-resistant	Epoxy or polyurethane resin (including modification with coal tar) plus pigment	4K	**12.5**
L	Two-pack chemical-resistant overcoated with type H travel coat and finish	Epoxy resin overcoated with chlorinated rubber plus pigment	4L	**12.5**
M	Bitumens	Coal tar or mineral bitumen with or without pigment, coal tar enamel	4M	**12.6**

[a] Moisture-curing polyurethanes and high-molecular-weight linear epoxy resins (see appendix B), which are both one-pack chemical-resistant materials, are not included in the product sections of Table 4 because of limited experience in their use. Where these materials are considered the specifier should, as with all newer materials, refer to suppliers for recommended systems and conditions of use.

Table 3 — Recommendations for protective coating systems for specific environments

Introduction

The following lists of systems, classified by environment and typical time to first maintenance, indicate the options open to the specifier. The recommended treatments listed for longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives. The recommendations indicate minimum requirements to ensure protection; thus combinations of metallic zinc or aluminium with paint are limited to sealed, sprayed-metal or metal with relatively thin paint coatings, although it is recognized that, for decorative purposes, additional paint coatings will often be specified.

It is impossible to achieve an exactly uniform thickness of any type of coating. The term “nominal thickness” is used in the heading to the fourth column of this table and elsewhere throughout the code to indicate an *aim* in such a manner that the permissible variation from that aim can be usefully specified. The manner of specifying the permissible variation is described in clause **19**.

Table 3 — Part 1: Exterior exposed non-polluted inland atmosphere

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (μm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize	SB1	(85 min.)	a, b, c, d
	Unsealed sprayed aluminium	SC2A	150	d, f
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
Long (10 to 20)	Galvanize plus paint	SB8	(85 min. + 30 min.)	h, i
	Unsealed sprayed aluminium	SC1A	100	d, f
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Sealed sprayed zinc	SC5Z	100	d, e, f
	Sprayed aluminium plus paint	SC9A	100 + (30 to 100)	e, i
	Sprayed zinc plus paint	SC9Z	100 + (30 to 100)	e, i
	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	Silicone alkyd over two-pack chemical-resistant	SG1	245	
	One-pack chemical-resistant	SH6	270	
	One-pack chemical-resistant over two-pack chemical-resistant	SL3	295	
Medium (5 to 10)	Organic zinc-rich	SD2	75	g
	Drying-oil type	SF7	165 to 190	
	One-pack chemical-resistant	SH3	150	
Short (less than 5)	Drying-oil type	SF2	120 to 150	j
	Drying-oil type	SF5	85 to 105	j

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 2: Exterior exposed polluted inland

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize (silicon in steel)	SB3	210	a, b, c, d
	Unsealed sprayed aluminium	SC2A	150	d, f
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
Long (10 to 20)	Galvanize	SB2	140	a, b, c, d
	Galvanize plus paint	SB9	(85 min. + 60 min.)	h, i
	Unsealed sprayed aluminium	SC1A	100	d, f
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC5Z	100	d, e, f
	Sprayed aluminium plus paint	SC10A	100 + (60 to 100)	e, i
	Sprayed zinc plus paint	SC10Z	100 + (60 to 100)	e, i
	Organic zinc-rich	SD5	150	
	Inorganic zinc-rich	SE3	150	
	Silicone alkyd over two-pack chemical-resistant	SG2	345	
	One-pack chemical-resistant	SH7	300	
	Two-pack chemical-resistant	SK3	270	
	One-pack chemical-resistant over two-pack chemical-resistant	SL6	335	
Medium (5 to 10)	Galvanize	SB1	(85 min.)	a, b, c, d
	Galvanize plus paint	SB8	(85 min. + 30 min.)	h, i
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	Drying-oil type	SF8	190 to 230	
	One-pack chemical-resistant	SH4	200	
	Two-pack chemical-resistant	SK2	240	
	One-pack chemical-resistant over two-pack chemical-resistant	SL2	235	
Short (less than 5)	Drying-oil type	SF3	170 to 190	j
	Drying-oil type	SF6	130 to 150	
	One-pack chemical-resistant	SH2	220	j

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 3: Exterior exposed polluted coastal atmosphere

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize (silicon in steel)	SB3	210	a, b, c, d
	Unsealed sprayed aluminium	SC3A	250	d, f
	Unsealed sprayed zinc	SC4Z	350	a, c, d, f
	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC7Z	250	d, e, f
Long (10 to 20)	Galvanize	SB2	140	a, b, c, d
	Galvanize plus paint	SB9	(85 min. + 60 min)	h, i
	Unsealed sprayed aluminium	SC2A	150	d, f
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
	Sprayed aluminium plus paint	SC10A	100 + (60 to 100)	e, i
	Sprayed zinc plus paint	SC10Z	100 + (60 to 100)	e, i
	Silicone alkyd over two-pack chemical-resistant	SG2	345	
	Two-pack chemical-resistant over zinc silicate	SE4	275	
	One-pack chemical-resistant	SH7	300	
	Two-pack chemical-resistant	SK3	270	
	One-pack chemical-resistant over two-pack chemical-resistant	SL6	335	
Medium (5 to 10)	Galvanize	SB1	(85 min.)	a, b, c, d
	Galvanize plus paint	SB8	(85 min. + 30 min.)	h, i
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed zinc	SC5Z	100	d, e, f
	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	Drying-oil type	SF8	190 to 230	
	One-pack chemical-resistant	SH4	200	
	Two-pack chemical-resistant	SK2	240	
	One-pack chemical-resistant over two-pack chemical-resistant	SL2	235	
Short (less than 5)	Drying-oil type	SF3	170 to 190	j
	Drying-oil type	SF6	130 to 150	
	One-pack chemical-resistant	SH2	220	j

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 4: Exterior exposed non-polluted coastal atmosphere

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize	SB2	140	a, b, c, d
	Unsealed sprayed aluminium	SC2A	150	d, f
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
Long (10 to 20)	Galvanize	SB1	(85 min.)	a, b, c, d
	Galvanize plus paint	SB9	(85 min. + 60 min.)	h, i
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC5Z	100	d, e, f
	Sprayed aluminium plus paint	SC9A	100 + (30 to 100)	e, i
	Sprayed zinc plus paint	SC9Z	100 + (30 to 100)	e, i
	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	Drying-oil type	SF8	190 to 230	
	Silicone alkyd over two-pack chemical-resistant	SG1	245	
	One-pack chemical-resistant	SH6	270	
	One-pack chemical-resistant over two-pack chemical-resistant	SL3	295	
Medium (5 to 10)	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Organic zinc-rich	SD2	75	g
	Inorganic zinc-rich	SE1	75	g
	Drying-oil type	SF7	165 to 190	
	One-pack chemical-resistant	SH3	150	
Short (less than 5)	Organic zinc-rich	SD1	50	g
	Drying-oil type	SF2	120 to 150	j
	Drying-oil type	SF5	85 to 105	
	One-pack chemical-resistant	SH1	160	j

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 5: Exterior sheltered atmosphere

For galvanizing, sprayed-metal (preferably sealed), and zinc-rich coatings the recommendations are the same as for the relevant fully exposed condition, but when "dead" pockets of air occur, the thickness of bare or sealed metallic zinc coatings should be increased by about 25 %. Combinations of metal and paint are not usually to be recommended [see note i)].

Paint systems should be at least as good as for the relevant fully exposed conditions with preference for the more water-resistant systems, e.g. system types H, J, K, L, and, where fully protected from sunlight, M.

Table 3 — Part 6: Interior (of buildings) normally dry

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (μm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize	SB1	(85 min.)	a, b, c, d
	Unsealed sprayed aluminium	SC1A	100	d, f
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
Long (10 to 20)	Galvanize plus paint	SB8	(85 min. + 30 min.)	h, i
	Sprayed aluminium plus paint	SC9A	100 + (30 to 100)	e, i
	Sprayed zinc plus paint	SC9Z	100 + (30 to 100)	e, i
	Organic zinc-rich	SD2	75	g
	Inorganic zinc-rich	SE1	75	g
	Drying-oil type or coal tar epoxy	SF7 + SK6	(165 to 190) + 250	
	One pack chemical-resistant over two pack chemical-resistant	SL2	235	
Medium (5 to 10)	Organic zinc-rich	SD1	50	g
	Drying-oil type	SF2	120 to 150	j
	Drying-oil type	SF5	85 to 105	
Short (less than 5)	Drying-oil type	SF1	100	j
	Drying-oil type	SF4	70	

NOTE 1 Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

NOTE 2 The above recommendations take into account situations where the steelwork, although fully enclosed inside a building, may be subject to conditions of external exposure during construction, e.g. where the erection of cladding is unduly delayed. Furthermore, these recommendations indicate typical lives to first maintenance under such conditions, and provided that signs of corrosion are not apparent during the delay period no further serious corrosion is likely to occur that could result in a shortening of the typical life to first maintenance.

When it can be assured that there will be no delay between coating the steelwork and its enclosure within the building, and when the design is such as to ensure dry conditions without local or general condensation or ingress of water, then the above-mentioned recommendations are likely to be conservative and the time to first maintenance can be extended.

Under dry conditions, the loss of steel by corrosion is slight, so provided that the steelwork inside a building remains dry and no breakdown of the coating is likely to occur prior to enclosure of the steelwork within the building, the coating requirement may be determined by experience of the conditions and by the nature of the construction.

Under these conditions, the above treatments would generally result in times to first maintenance being longer than those quoted. See also clause **8**.

Table 3 — Part 7: Interior of building, frequently damp or wet

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Galvanized	SB1	(85 min.)	a, b, c, d
	Unsealed sprayed aluminium	SC1A	150	d, f
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	sealed sprayed zinc	SC5Z	100	d, e, f
Long (10 to 20)	Galvanize plus paint	SB8	(85 min. + 30 min.)	h, i
	Unsealed sprayed aluminium	SC2A	100	d, f
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Sprayed aluminium plus paint	SC9A	100 + (30 to 100)	e, i
	Sprayed zinc plus paint	SC9Z	100 + (30 to 100)	e, i
	Organic zinc-rich	SD5	150	g
	Inorganic zinc-rich	SE3	150	g
	Two-pack chemical-resistant over zinc silicate	SE6	275	
	One-pack chemical-resistant	SH7	300	
	Two-pack chemical-resistant	SK3	270	
	Coal tar epoxy	SK6	250	
	One-pack chemical-resistant over two-pack chemical-resistant	SL3	295	
Medium (5 to 10)	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	One-pack chemical-resistant	SH5	220	
	Two-pack chemical-resistant	SK2	240	
	Coal tar epoxy	SK6	250	
	One-pack chemical-resistant over two-pack chemical-resistant	SL2	235	
Short (less than 5)	One-pack chemical-resistant	SH2	220	j
	One-pack chemical-resistant over drying-oil type primer	SJ1	170	j
	Two-pack chemical-resistant	SK1	170 to 180	
	Coal tar epoxy	SK5	150	

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 8: Non-saline water [for potable water see note n)]

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long	Galvanize	SB2	140	b, c, d, m
(20 or more)	Sealed sprayed aluminium	SC6A	150	e, l, m
	Sealed sprayed zinc	SC6Z	150	e, l, m
Long	Galvanize	SB1	(85 min.)	m
(10 to 20)	Galvanize plus bitumen (BS 3416)	SB9	(85 min. + 40)	See Table 4M
	Sealed sprayed aluminium	SC5A	100	e, l, m
	Sealed sprayed zinc	SC6Z	150	e, l, m
	Sprayed aluminium plus paint	SC9A	100 + (30 to 100)	e, l, m
	Sprayed zinc plus paint	SC9Z	100 + (30 to 100)	e, l, m
	Organic zinc-rich	SD5	150	
	Inorganic zinc-rich	SE3	150	
	One-pack chemical-resistant over two-pack chemical-resistant over zinc silicate	SE6	275	
	Two-pack chemical-resistant	SK4	320	
	Coal tar epoxy	SK8	450	
	Hot-applied bitumen	BS 4147	Various	See Table 4M
	Coal tars	BS 4164	Various	See Table 4M
Medium	Organic zinc-rich	SD3	100	
(5 to 10)	Inorganic zinc-rich	SE2	100	
	One-pack chemical-resistant	SH7	300	
	Two-pack chemical-resistant	SK2	240	
	Coal tar epoxy	SK7	350	
	Bitumen	BS 3416	Various	See Table 4M

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 9: Sea water splash zone, or frequent salt spray

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC7Z	250	d, e, f
Long (10 to 20)	Galvanize plus coal tar epoxy	SB1 + SK5	(85 min. + 150)	i
	Galvanize (silicon in steel)	SB3	210	a, b, c, d
	Galvanize plus paint	SB9	(85 min. + 60 min.)	i
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
	Sprayed aluminium plus paint	SC10A	100 + (60 to 100)	e, i
	Sprayed zinc plus paint	SC10Z	100 + (60 to 100)	e, i
	One-pack chemical-resistant over two-pack chemical-resistant over zinc silicate	SE7	475	
	Coal tar epoxy	SK8	450	
	One-pack chemical-resistant over two-pack chemical-resistant	SL5	440	
Medium (5 to 10)	Galvanize	SB2	140	a, b, c, d
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC5Z	150	d, e, f
	One-pack chemical-resistant over two-pack chemical-resistant over zinc silicate	SE6	275	
	One-pack chemical-resistant	SH6	270	
	Coal tar epoxy	SK7	350	
	One-pack chemical-resistant over two-pack chemical-resistant	SL4	345	
Short (less than 5)	Galvanize	SB1	(85 min.)	a, b, c, d
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Two-pack chemical-resistant	SK2	240	
	One-pack chemical-resistant over two-pack chemical-resistant	SL2	235	

NOTE Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 10: Sea water, immersed

Typical time to first maintenance (years)	General description	System reference (Table 4)	Total nominal thickness (µm)	Notes (see the end of this table)
Very long (20 or more)	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC7Z	250	d, e, f
Long (10 to 20)	Galvanize plus coal tar epoxy	SB1 + SK5	(85 min. + 150)	
	Galvanize (silicon in steel)	SB3	210	a, b, c, d
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
	Sprayed aluminium plus paint	SC10A	100 + (60 to 100)	e, i
	Sprayed zinc plus paint	SC10Z	100 + (60 to 100)	e, i
	One-pack chemical-resistant over two-pack chemical-resistant over zinc silicate	SE7	475	
	Coal tar epoxy	SK8	450	
Medium (5 to 10)	Galvanize	SB2	140	a, b, c, d
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC5Z	100	a, c, d, f
	One-pack chemical-resistant over two-pack chemical-resistant over zinc silicate	SE6	275	
	One-pack chemical-resistant	SH7	300	
	Coal tar epoxy	SK7	350	
Short (less than 5)	Galvanize	SB1	(85 min.)	a, b, c, d
	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	One-pack chemical-resistant	SH5	220	
	Coal tar epoxy	SK6	250	

NOTE 1 Note k), at the end of Table 3, refers to anti-fouling paints.

NOTE 2 Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

Table 3 — Part 11: High temperature surfaces

The coatings that protect structural steel against corrosion may also need to be heat-resistant. Resistance to heat is influenced mainly by the nature of the temperature cycle, the maximum service temperature and its duration.

Furthermore, the behaviour of the coating will vary considerably according to whether or not the surface remains dry (even when cold). When warm, the presence of hot gases will have specific effects.

Only general recommendations can be given and specialist advice should always be sought.

For temperatures up to 200 °C, sealed sprayed aluminium (SC6A) or sealed sprayed zinc (SC6Z) may be considered for long or even very long life to first maintenance, depending on the circumstances. A special silicone alkyd over a zinc silicate primer system (SG1 type but thinner) may be considered for medium lives. The paint coating should be less than 100 µm for radiators, etc. Colours are usually satisfactory but for higher temperatures the aluminium version is recommended (see Table 4F, part 4, product section F5). Where silicones cannot be tolerated, a silicone-free aluminium paint may be specified; advice should be sought from paint suppliers. The maintenance period is related to the operating temperature. Certain drying-oil types of coating (e.g. SF1 or SF4) will give short-term protection but selection of the paint requires specialist advice.

For temperatures up to about 550 °C aluminium (175 µm nominal thickness) is suitable as sprayed. Arc-sprayed aluminium should preferably be specified where there may be cyclical temperature fluctuations. The sprayed aluminium may also be silicone-sealed (SC6AH) and, for temperatures typically about 250 °C, silicone-sealed sprayed aluminium SC6AH can have a very long life (20 or more years).

The zinc silicate systems are also recommended; system SE1, for example, may, in some circumstances, last for up to 10 years before maintenance is needed. The zinc silicate/aluminium silicone treatment SE8 is to be preferred for the more severe conditions and in favourable circumstances may have long life to first maintenance.

For temperatures up to 900 °C aluminium (175 µm nominal thickness) applied by electric arc under controlled conditions may be considered for some uses; the current edition of BS 2569-2, gives some alternatives.

For components to be used at service temperatures up to 1 000 °C the current edition of BS 2569-2, specifies a nickel-chromium alloy; with sulphurous gases present the nickel-chromium is followed by aluminium and in each case there is a subsequent heat treatment.

The life to first maintenance of coatings recommended for temperatures up to 550 °C, up to 900 °C, and up to 1 000 °C will depend on the exact combination of conditions in service but will usually be less than 10 years, although the sprayed aluminium coating may last longer if maximum temperature and other conditions are not too severe.

Table 3 — Part 12: Mines

Specialist advice should be sought because conditions differ considerably in different mines.

Advice should also be sought from H.M. Inspector of Mines and Quarries regarding the special restrictions which apply to materials taken down into mines (e.g. low-flash-point paints) and the processes which may be used in mines (e.g. blast-cleaning).

Zinc coatings (but not aluminium coatings or paint in coal mines) should be considered provided that the water has pH > 5. For sprayed zinc or aluminium a sealed coating is preferred. Data on the coatings and likely performance, given in parts 8, 9 and 10 of this table, can be used for guidance but the time spans to first maintenance may vary widely according to local conditions.

Table 3 — Part 13: Soil

Many specialist coatings exist, e.g. wrapping tapes, bituminous coatings (BS 3416, BS 4147, BS 4164 as appropriate), powder coatings and polythene sleeves, often in conjunction with cathodic protection. The choice is greatly influenced by the nature of the structure, i.e. pipe, pile, or column. Suitable coal tar epoxy systems are SK8 for 10 to 20 years, SK7 for 5 to 10 years and SK6 for 2 to 5 years.	The suitability of metallic coatings and other paint systems (which may be desired because they form the preferred protective scheme of the part of the structure above ground) may vary according to the nature of the soil, and specialist advice is required. Clinker and ashes contain soluble sulphates and unburnt coke, which shorten coating life. In inorganic moderately reducing soils and highly reducing organic soils, zinc coatings usually have paint or plastic finishes, sprayed zinc is preferably sealed. Aluminium coatings are not recommended for direct contact with alkaline clays.

Table 3 — Part 14: Encasement in concrete [see note f)]

Steel requires no protection when fully encased in alkaline (uncarbonated) concrete. Protection by sprayed zinc, by galvanizing, or by zinc-rich coatings to BS 4652, type 3, is beneficial in the zone which may become carbonated (see **13.4** and **A.3.5.3**). Where the coated steel enters the concrete, a bituminous coating may subsequently be applied usefully at any interface where water may tend to remain (see Figure 6).	

Table 3 — Part 15: Refrigerated surfaces (down to – 30 °C)

The low temperature reduces the corrosion rates but facilitates condensation conditions. Where water is present an effective barrier layer is required on the steel. Sealed or unsealed sprayed-metal coatings and bare galvanizing are generally suitable (e.g. SB1, SC1A, SC1Z, SC5A, SC5Z of Table 4).	Typical coating systems include zinc silicate SE1 or two-pack zinc epoxy SD2 for 5 to 10 years; one-pack chemical-resistant paint systems SH4 for 5 to 10 years and SH3 for less than 5 years; and two-pack chemical-resistant systems SK2 for 5 to 10 years and SK1 for less than 5 years. For temperatures below – 30 °C specialist advice should be sought.

Table 3 — Part 16: Chemicals

For storage or transport of chemicals specialist advice should be sought. The effect of the coating on the chemical should be considered as well as the protection of the steel. When subject to splashes of acid or alkaline chemicals, painting recommendations are similar to those given in part 7 of this table, except that oil-type paints (systems F and G) should not be used and zinc silicates are not recommended for acid conditions.	Metallic zinc is generally suitable for Chemicals when the pH-value is in the range 5 to 12; metallic aluminium is generally suitable when the pH-value is in the range 4 to 9. Only specially formulated two-pack chemical-resistant paints and silicates are suitable for solvents and petroleum products. In splash conditions coal tar epoxy (SK7 for 10 to 20 years, SK6 for 5 to 10 years, SK5 for less than 5 years) or zinc silicate (SE2 for 10 to 20 years) may be suitable.

Table 3 — Part 17: Road (de-icing) salts

Highway authorities recognize that special protection is required for bridge steelwork such as parapets and railings exposed to de-icing salts. For example, galvanizing plus paint is advised in the Department of Transport's Notes for Guidance on the Specification for Road and Bridge Works, published by HMSO London, 1976 (see pages 96 to 107). On the other hand, no provision is made for the special protection of the undersides of bridges against road salts. When, occasionally, de-icing salt can attack such steelwork it is usually the result of accidental blockage of a drain or failure of a deck joint.

Table 3 — Part 18: Abrasion and impact

Galvanized steel is recommended for resistance to abrasion, rough handling, or impact. The thickness of coating should be determined by the surrounding environment and the degree of wear expected. Sprayed metal (sealed or unsealed) also has good resistance and the coating polishes by friction.	For the longest life of paints, an abrasive should be incorporated in the finish, e.g. in SK4 two-pack chemical-resistant. Zinc silicate systems, SE1 for less than 5 years or SE3 or SE4 for 5 to 10 years may also be recommended.

Table 3 — Part 19: Fungi and bacteria

As for the appropriate environment (see parts 1 to 10 of this table) with suitable fungicidal or bactericidal additives to the undercoat and finish of paint systems.

Table 3 — Part 20: Notes to Table 3

a) *Life of zinc coatings.* The life of metallic zinc coatings in typical atmospheres and sea water is shown in Figure 1. Life in the atmosphere decreases with increase in sulphur dioxide pollution.

b) *Thickness of galvanizing.* BS 729 specifies the standard galvanized coating at the equivalent of 85 µm minimum for steel 5 mm thick or more. Thinner steel, automatically galvanized tubes and centrifugal work (usually threaded work and fittings) have thinner coatings. Galvanized coatings thinner than 85 µm minimum are not included in Table 3, but where it is desired to use such thinner coatings their lives can be ascertained by reference to Figure 1. Thicker galvanized coatings (see **11.1.2**) are not specified in BS 729 but the general provisions of that standard apply; the galvanizer should be consulted before specifying.

c) *Build-up or repair of zinc coatings.* Inadequate thickness e.g. on small components, may be made-up by applying zinc-dust paint to give the total thickness of zinc for the life requirement. Discontinuities and damaged areas may be made good by zinc-spraying, special zinc-alloy solder-sticks or zinc-rich paint.

d) *Maintenance intervals for metal coatings which are to be painted.* When bare galvanized surfaces or sealed sprayed-metal surfaces are maintained by the use of paint, the future maintenance intervals will be those of the metal-plus-paint system, which is often less than that for the bare metal coating but longer than for a similar paint system applied directly to steel. Unsealed sprayed-metal coatings are usually designed to protect the structure for its required life. Maintenance operations for such coatings are usually more elaborate than for sealed coatings. The systems recommended in Table 3 in the "very long" life category will in general meet the life requirements when maintenance is effected after 20 years. Where there is scope for maintenance of very-long-life coatings before the 20-year period has elapsed, it may be advantageous to undertake such maintenance, especially if the structure is required to last indefinitely. In the more unfavourable combinations of circumstances in one category it may be necessary to blast-clean and recoat the steel (see Table 10).

e) *Sealed and painted metal coatings.* The appearance and life of sprayed-metal coatings is improved by sealing (see **11.2.2**). There is no requirement for a measurable overlay of sealer but sealers should be applied until absorption is complete. Sealing is particularly desirable when it is desired to retain the sprayed coating when the surface is eventually to be maintained, and such maintenance requires only the renewal of the sealer. Painting of sprayed-metal coatings is seldom the preferred treatment except when colour, an inert barrier or abrasion resistance is required.

f) *Contact of metal coatings with concrete.* The alkalinity of concrete makes it unsuitable for direct contact with aluminium and an inert barrier layer should be present. Such a layer is not needed with zinc coatings which react sufficiently with concrete to form only a useful mechanical bond. In the atmosphere an interface of either aluminium or zinc with concrete, soil, etc. benefits from application of an inert layer.

g) *Sealed zinc-rich coatings.* The appearance of a zinc-rich coating is improved by the application of a suitable sealer coat. Guidance on type of top coat to be used should be obtained from the supplier of the zinc-rich coating.

h) *Painted galvanized coatings.*

1) For the less aggressive environments (or for shorter lives than indicated) a single coat of paint (30 µm or more), over pretreatment if specified, is sufficient.

2) For more aggressive and wet environments two coats of paint (60 µm or more) are used to minimize through-pores.

i) *Maintenance of painted metal coatings.* The "life to first maintenance" given in the first column of the table is calculated to allow substantial retention of the metal coating and is suitable for maintenance work designed to retain a metal-plus-paint protective coating. The apparent anomaly in some parts of the table (that metal coatings are recommended "for very long" life to first maintenance, whilst the same thickness of metal coating plus paint is recommended for "long" life only) arises from the normal practice of maintaining metal-plus-paint coatings before significant degradation of paint or loss of metal has occurred. (It should be noted that an area of degraded paint can hasten the corrosion of metal by acting as a poultice, particularly on a surface not subjected to washing by rain.) Where it is desired to retain a reasonably intact layer of paint as the basis for maintenance after the recommended life to first maintenance, the initial paint coating should be thicker (typically more than 75 µm). The extra thickness should be in finishing paints rather than in primers or undercoats.

j) *Painting of surfaces which have not been blast cleaned.* It is recognized that blast-cleaning is not always possible, but schemes based on lower standards of preparation require maintenance more frequently than do comparable paint coatings over blast-cleaned surfaces.

k) *Anti-fouling paints.* Special formulations of paints are available to prevent formation of marine deposits on structures. Most anti-fouling paints need to be re-applied every year or two. Zinc and aluminium should not normally be overcoated with copper or mercury compounds.

l) *Sealers for metal coatings for potable water.* Vinyl or epoxy co-polymer sealers (see Table 4C, part 2) are usually used.

m) *Zinc and aluminium coatings in non-saline water.* The maintenance-free lives given for zinc are for cold scale-forming waters. The maintenance period in non-scale-forming waters will be one category less (Langelier's index is used to calculate whether the water is scale-forming). Choice of aluminium or zinc is often on the basis of pH-value, aluminium for pH < 5 or 6; zinc for pH > 5 or 6. Since the composition of these waters may vary greatly, previous experience or expert advice should be sought. For hot water, specialist advice should be sought.

n) *Structures for potable water.*

1) *General.* Coatings used for all structures, including pipes, fittings, tanks and tank covers in contact with potable water, must be non-toxic and must not impart any taste or odour, colour or turbidity to the water, and must not foster microbial growth. The National Water Council maintains a list of approved coatings.

2) *Tanks.* Small tanks should be galvanized and, if further protection is necessary, high-build bitumen paint should be applied in sufficient coats to give a dry-film thickness of 500 µm.

Tanks too large for galvanizing may be protected as follows.

i) Prepare the steel surface by blast-cleaning or manual cleaning and apply high-build bitumen paint to give 500 µm dry-film thickness. Alternatively, a hot-applied bitumen coating may be used, although some coatings of this type can support microbial growth.

ii) Blast-clean and apply an approved high-build chlorinated rubber or cold-cured epoxy resin coating that complies with the potable water requirements above to give a dry-film thickness of 250 µm.

3) *Tank covers.* The undersides of tank covers should also receive a protective coating.

o) *Table 3, Parts 7, 8, 9 and 10.* Electrochemical attack can occur in a wet environment if parts of a structure coated with zinc or aluminium are in contact with bare steel or more cathodic metals such as copper. In immersion conditions such as sea-water the anodic zinc or aluminium can be rapidly destroyed. This action can be avoided by electrically insulating the differing parts from each other.

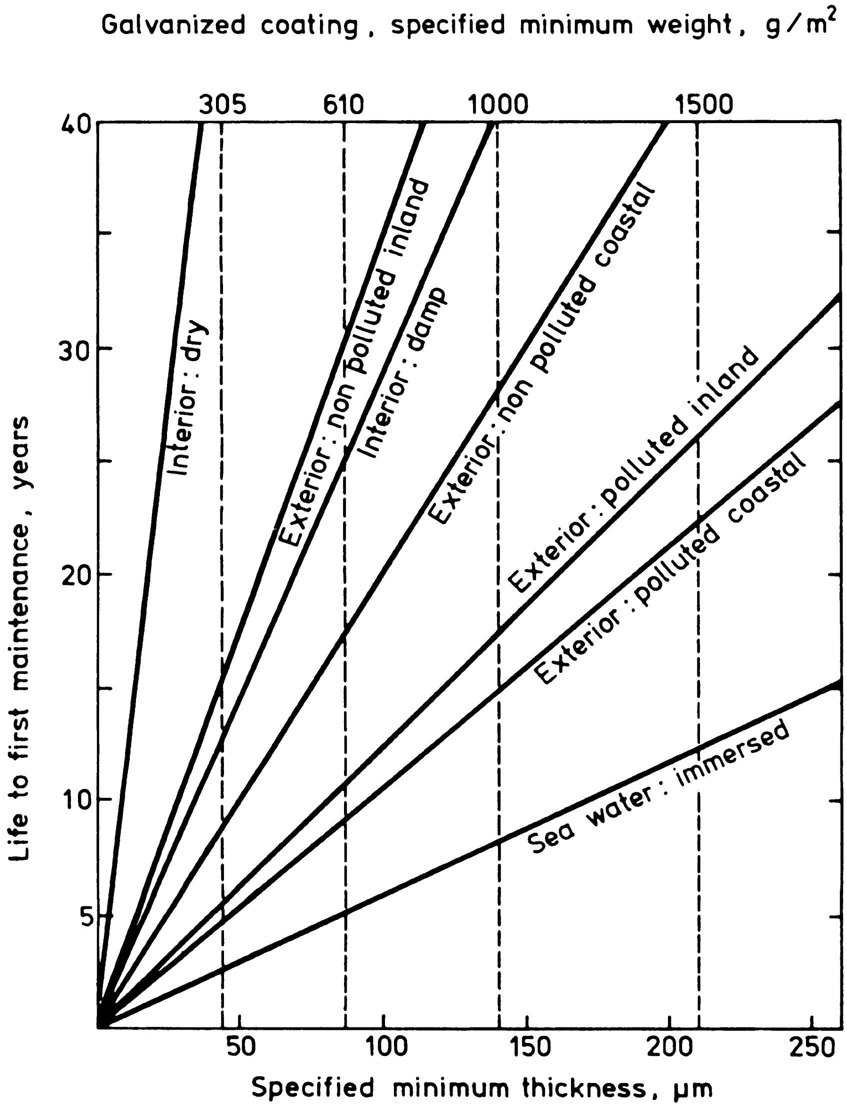

Figure 1 — Typical lives of zinc coatings in selected environments

Table 4 — Typical coating systems and their components[a]
(see **12.1.4** regarding compatibility)

This table is presented in twelve principal sections, identified as Table 4A, Table 4B etc., to Table 4M according to the group key reference letters (see Table 2). These main sections are, where applicable, further divided into sub-parts according to the following list.

Table 4A	Product section AP	Blast primers
Table 4B	Group B systems	Zinc coatings other than sprayed-metal
Table 4C		
Part 1	Group C systems	Sprayed-metal coatings
Part 2	Product section CP	Pretreatments and sealers for sprayed-metal coatings
Table 4D		
Part 1	Group D systems	Organic zinc-rich systems
Part 2	Product section DF	Organic zinc-rich paints
Table 4E		
Part 1	Group E systems	Inorganic zinc-rich paints
Part 2	Product section EF	Zinc silicate paints
Table 4F		
Part 1	Group F systems	Drying-oil-type paints
Part 2	Product section FP	Drying-oil-type primers
Part 3	Product section FU	Drying-oil-type undercoats
Part 4	Product section FF	Drying-oil-type finishes
Table 4G	Group G systems	Silicone alkyd paint over two-pack chemical-resistant primer and undercoat
Table 4H		
Part 1	Group H systems	One-pack chemical-resistant paints
Part 2	Product section HP	One-pack chemical-resistant primers
Part 3	Product section HU	One-pack chemical-resistant undercoats
Part 4	Product section HF	One-pack chemical-resistant finishes
Table 4J	Group J system	Drying-oil-type primer with one-pack chemical-resistant undercoat and finish
Table 4K		
Part 1	Group K systems	Two-pack chemical-resistant paints
Part 2	Product section KP	Two-pack chemical-resistant primers
Part 3	Product section KU	Two-pack chemical-resistant undercoats
Part 4	Product section KF	Two-pack chemical-resistant finishes
Table 4L	Group L systems	Two-pack primer and undercoat, overcoated with one-pack chemical-resistant finish
Table 4M	Product section MF	Bitumen and coal tar products

[a] Notes to Table 4 are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4A — Product section AP. Blast primers [note c)[a]]

For airless spray, products AP2A to AP4A may have 2 % less (volume) solids

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness; (μm per coat) (advised)	Additional information (see note c)[a] for application method)
AP1A	Two-pack epoxy	Zinc phosphate	25	40	20	See BS 4652 Essential to avoid settlement of pigment
AP1B		Zinc dust	30	95	20	
AP2A	Two-pack polyvinyl butyral	Zinc tetroxychromate	10	85	15	Also has uses other than as a blast primer (see Table 4C and Table 4D)
AP3A	Two-pack polyvinyl butyral/phenolic	Zinc tetroxychromate	10	85	15	Suspect with cathodic protection if there is any discontinuity in covering system. See also AP2A
AP4A	One-pack polyvinyl butyral/phenolic	Zinc phosphate	22	40	20	Slightly inferior to AP3A
AP4B		Zinc chromate	22	20	20	Slightly inferior to AP3A

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4B — Group B systems. Zinc coatings other than sprayed

Reference number	Surface preparation	Coating				Remarks
		Zinc coating coating	Number of coats		Nominal system thickness, (µm)	
			Pre-treatment	Paint		
SB1	See BS 729	Galvanize	—	—	85 min.	Factory-applied after fabrication or semi-fabrication. This thickness is applicable to steel 5 mm (or more) thick (see **11.1.2**)
SB2	Grit-blast and/or pickle	Galvanize	—	—	140	See **11.1.2**. Consult galvanizer before specifying
SB3	Pickle	Galvanize (silicon in steel)	—	—	210	See **11.1.2**. Consult galvanizer before specifying
SB4	See BS 729	Galvanize and centrifuge	—	—	43	Centrifuged after galvanizing. Mainly small parts, particularly threaded work. Consult galvanizer if greater thickness desired
SB5	See BS 4921	Sherardize	—	—	15	Factory-applied. Mainly small parts, particularly threaded work. SB5 is BS 4921 class 2 and SB6 is BS 4921 class 1
SB6	See BS 4921	Sherardize	—	—	30	
SB7	See BS 1706 or BS 3382	Zinc plate ZN10	—	—	25	BS 1706 class ZN10. Factory-applied. Small parts. Threaded parts plated to BS 3382-2 have 4 µm to 9 µm; are not recommended for general use: they would be satisfactory only in dry interiors
SB8	See BS 729	Galvanize (85 µm min.)	(1)	1	85 min. + 30 min.	See note e) and **11.3** for advice on painting zinc coatings. Pretreatment not necessary for some paints
SB9	See BS 729	Galvanize (85 µm min.)	(1)	2	85 min + 60 min.	See note e) and **11.3** for advice on painting zinc coatings. Pretreatment not necessary for some paints

NOTE 1 SB1, SB4, SB5, SB6 and SB7 usually have average thickness up to 50 % higher than the minimum.

NOTE 2 *Paint systems for galvanized steel.* Galvanized steel should be degreased prior to applying paints. When galvanizing or zinc plating is supplemented by painting with some specially selected primers, in particular products FP1D, FP1E, FP2C, KP1C, KP1D, no pretreatment other than degreasing is necessary. Before applying most other paints it is necessary to degrease and apply one of the pretreatments listed in the Table 4C, part 2. Finishes for use over these pretreatments include those listed in Table 4K, part 4 and Table 4H, part 4 or (for immersed conditions only) Table 4M. Most drying-oil-type paints other than the primers listed above are unsuitable for use over zinc coatings because of possible development of adhesion failure (see **11.3**).

Table 4C — Part 1: Group C systems. Sprayed-metal coatings

Applied to components in factory or to complete structures on site

Reference number	Surface preparation	Coating					Remarks
		Metal type	Number of coats			Nominal system thickness[a] µm	
			Pre-treatment	Sealer [see note d)]	Paint		
SC1A	See BS 2569	Aluminium	—	—	—	100	See note a)[b]
SC1Z		Zinc	—	—	—	100	
SC2A		Aluminium	—	—	—	150	Also for use up to 550 °C [see note b)]
SC2Z		Zinc	—	—	—	150	See note a)
SC3A		Aluminium	—	—	—	250	See note b)
SC3Z		Zinc	—	—	—	250	See note a)
SC4Z		Zinc	—	—	—	350	See note a)
SC5A	See BS 2569	Aluminium	(1)	1	—	100	Pretreatment optional Choice of sealed versus unsealed: see **11.2.2** Choice of sealer: see Table 4, part 2. Seal until absorption complete. NOTE polyurethane sealer should be compatible with metallic zinc.
SC5Z		Zinc	(1)	1	—	100	
SC6A		Aluminium	(1)	1	—	150	
SC6Z		Zinc	(1)	1	—	150	
SC7A		Aluminium	(1)	1	—	250	
SC7Z		Zinc	(1)	1	—	250	
SC8Z		Zinc	(1)	1	—	400	
SC6AH	See BS 2569	Aluminium	—	1	—	175	For use up to 550 °C.
SC9A	See BS 2569	Aluminium	1	—	See **11.3.1**	100 + (30 to 100)	See note b).
SC9Z	See BS 2569	Zinc	1	—	See **11.3.1**	100 + (30 to 100)	Inert paint coatings preferred: dry film thickness < 100 µm (see **11.3**)
SC10A	See BS 2569	Aluminium	2	—	See **11.3.1**	100 + (60 to 100)	
SC10Z	See BS 2569	Zinc	2	—	See **11.3.1**	100 + (60 to 100)	

[a] Nominal thickness for metals given as in BS 2569. Minimum local thicknesses are also given in BS 2569. Zinc coatings thinner than 100 µm and sealed or painted may be specified for short and medium lives in some environments but are not incorporated in Table 3.

[b] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4C — Part 2: Product section CP. Pretreatments and sealers for sprayed-metal coatings

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Additional information (see note c)[a] for application method)
CP1	Two-pack polyvinyl butyral	Zinc tetroxychromate	10	85	Pretreatment materials, i.e. first treatment before sealing. For airless spray, minimum percentage volume solids may be 8 %
CP2	Two-pack polyvinyl butyral/phenolic	Zinc tetroxychromate	10	85	
CP3A	Blend of vinyl chloride/acetate copolymers with or without non-saponifiable plasticizers	Clear	10	—	Products CP3 and CP4 recoatable at all time intervals. Vinyls for atmospheric or immersed conditions; phenolic or epoxy for chemical resistance except extremely alkaline conditions; polyurethane for severe atmospheric conditions. Pigments used should preferably be fine powder, non-flaking; chemical-resistant, with high UV-light resistance and low water-absorption
CP3B		Aluminium	15	95	
CP3C		Coloured	15	—	
CP4A	Two-pack phenolic	Clear	10	—	
CP4B		Aluminium	15	95	
CP4C		Coloured	15	—	
CP5A	Two-pack epoxy	Clear	10	—	
CP5B		Aluminium	15	95	
CP5C		Coloured	15	—	
CP6A	Two-pack polyurethane	Clear	10	—	
CP6B		Aluminium	15	95	
CP6C		Coloured	15	—	
CP7	Silicone resin	Aluminium	15	95	For service up to 550 °C (see BS 2569-2)

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4D — Part 1: Group D systems. Organic zinc-rich systems

Reference	Surface preparation (Swedish standard[a])	Coating system	Nominal system thickness, µm
SD1	Sa2½	Product reference DF see below	50
SD2	Sa2½		75
SD3	Sa2½		100
SD5[b]	Sa2½		150

NOTE No products other than epoxy zinc-rich have been included in this table, BS 4652 covers other media.

[a] see **14.3.1.5**.

[b] Designation SD4 is not used.

Table 4D — Part 2: Product section DF. Organic zinc-rich paints

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information
DF	Two-pack epoxy	Zinc dust	35	95	50	Quality covered by BS 4652, type 3. Maximum of 75 µm recommended by spray for each layer. An initial prefabrication primer may be only 25 µm

Table 4E — Part 1: Group E systems. Inorganic zinc-rich systems

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness, µm
		Primer EP1, EP2	Undercoat KU1, KU2 (see Table 4K)	Finish KF1, KF2 (see Table 4K)	
SE1	Sa2½	75			75
SE2	Sa2½	100			100
SE3	Sa2½	150			150
SE4	Sa2½	75	100	100	275
SE5	Sa2½	75	200	100	375
				HF1, HF2 (see Table 4H)	
SE6	Sa2½	75	100	100	275
SE7	Sa2½	75	200	200	475
				CP7 (see Table 4C)	
SE8	Sa2½	75		25	100

Table 4E — Part 2: Product section EP. Zinc silicate paints

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
EP1A	Alkali silicate	Zinc dust	40	80	75	Normal spray or pressure pot. Not normally recommended for airless spray (consult manufacturer). High-build
EP2A	Organic silicate	Zinc dust	40	80	50	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4F — Part 1: Group F systems. Drying-oil-type paints

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness, µm
		Primer FP1 to FP5	Undercoat FU1 to FU4	Finish FF1 to FF4	
SF1	St2	35	35	35	105
SF2	St2	70	25 to 40	25 to 40	120 to 150
SF3	St2	70	50 to 80	50 to 80	170 to 230
SF4	Sa2½	35	—	35	70
SF5	Sa2½	35	25 to 35	25 to 35	85 to 105
SF6	Sa2½	70	35 to 40	25 to 40	130 to 150
SF7	Sa2½	70	70 to 80	25 to 40	165 to 190
SF8	Sa2½	70	70 to 80	50 to 80	190 to 230

Table 4F — Part 2: Product section FP. Drying-oil-type primers

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
FP1A	Blend of raw and process drying oils	Red lead see BS 2523 Type A	75	98	40	Brush application recommended (see note c)[a]) Slow drying
FP1B		Red lead see BS 2523 Type B	83.5	92	40	
FP1C		Red lead/white lead see BS 2523 Type C	72	92	40	
FP1D		Calcium plumbate see BS 3698 Type A	64	75	40	
FP1E		Calcium plumbate see BS 3698 Type B	70	50	40	
FP2A	Drying oil modified with phenolic or phenolic-modified resin	Zinc phosphate	45	40	35	
FP2B		Zinc chromate	45	40	35	
FP2C		Metallic lead	45	50	30	Brush application recommended [see note c)]
FP3A	Alkyd or modified alkyd	Zinc phosphate	45	40	35	
FP3B		Zinc chromate	45	40	35	
FP3C		Red lead	50	60	40	Quick drying red lead. Brush application recommended [see note c)]
FP4	Drying-oil epoxy ester (one-pack epoxy)	Zinc phosphate	45	40	35	
		Zinc chromate	45	40	35	
FP5A	Urethane oil (one-pack polyurethane)	Zinc phosphate	45	40	35	
FP5B		Zinc chromate	45	40	35	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that the notes are immediately visible when required.

Table 4F — Part 3: Product section FU. Drying-oil-type undercoats

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (μm per cost) (minimum advised)	Additional information (see note c)[a] for application method)
FU1A	Drying oil modified with phenolic or phenolic-modified resin	Titanium dioxide (white and tints) and coloured pigments (full colours). Suitably extended	45	—	35	Note f)
FU1B		Micaceous iron oxide[b]	50	80	40	Note g)
FU1C			45	80	75	High-build in excess of 75 μm per coat may present through-drying problems. Note g)
FU1D		Aluminium	45	95	25	Non-leafing aluminium pigment recommended
FU2A	Alkyd or modified alkyd	Titanium dioxide (white and tints) and coloured pigments (full colours). Suitably extended	45	—	35	Note f)
FU2B		Micaceous iron oxide	50	80	40	Note g) FU2C is high-build airless spray
FU2C			45	80	75	
FU2D		Aluminium	45	95	25	As for FU1D
FU3A	Chlorinated rubber modified with alkyd in the ratio 2 (min.) to 1 (CR to alkyd)	Titanium dioxide (white and tints) and coloured pigments (full colours). Suitably extended	40	—	35	Note h)
FU3B		Micaceous iron oxide	40	80	35	
FU4A	Drying-oil epoxy ester (one-pack epoxy)	Titanium dioxide (white and tints) and coloured pigments (full colours). Suitably extended	45	—	35	Note f)
FU4B		Micaceous iron oxide	50	80	40	Note g) FU4C is high-build airless spray
FU4C			45	80	75	
FU4D		Aluminium	45	95	25	As for FU1D

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

[b] Usually known as MIO

Table 4F — Part 4. Product section FF. Drying-oil-type finishes

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
FF1A	Drying oil modified with phenolic or phenolic-modified resin	Fade-resistant coloured pigments and carbon black	45	—	35	Mixture of suitable pigments may be required, depending on shade and opacity specified
FF1B		Micaceous iron oxide	50	80	40	High-build of FF1C over 75 µm per coat has through-drying problems [note g)]
FF1C			45	80	75	
FF2	Drying oil modified with phenolic or phenolic-modified resin	Aluminium	45	95	25	Non-leafing aluminium pigment recommended to improve shelf life or finish. For very high lustre and if leafing aluminium pigment is used, two-pack may be permissible
FF3A	Alkyd or modified alkyd	Rutile titanium dioxide: white and tints	45	90	35	For reduced gloss, suitable matting agents or extender pigments may be added
FF3B		Fade-resistant coloured pigments and carbon black	45	—	35	As for FF1A and note g)
FF3C		Micaceous iron oxide	50	80	40	Note g)
FF3D			45	80	75	As for FF1C
FF3E		Aluminium	45	95	25	As for FF2
FF4A	Drying-oil epoxy ester	Rutile titanium dioxide: white and tints	45	90	35	As for FF3A
FF4B		Fade-resistant coloured pigments and carbon black	45	—	35	As for FF1A and note g)
FF4C		Micaceous iron oxide	50	80	40	Note g). FF4D is for high build airless spray
FF4D			45	80	75	
FF4E		Aluminium	45	95	35	As for FF2
FF5A	Silicone alkyd (at least 30 % silicone)	Rutile titanium dioxide: white and tints	45	90	35	Reduced gloss levels not recommended
FF5B		Fade-resistant coloured pigments and carbon black	45	—	35	As FF1A. Reduced gloss levels not recommended
FF5C		Aluminium	45	95	25	As for FF2

NOTE Table 4F (parts 1 to 4) especially, and other sections of Table 4 to a less extent, show groups of systems in each of which the alternative combinations of products offer about equal performance. A specification will, therefore, normally need to detail the requirements more closely e.g., under SF7 a choice could be made as follows:

Surface preparation. Blast-clean to Sa2½ and apply blast primer (AP2A or AP3A) (10 µm to 15 µm).
Primer FP2A. Zinc phosphate/modified phenolic, two coats 70 µm.
Undercoat FU1C. MIO/modified phenolic, high-build 80 µm.
Finish FF1B. MIO/modified phenolic 40 µm.

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[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4G — Group G systems. Silicone alkyd paint over two-pack primer and undercoat

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness, µm
		Primer KP1 (see Table 4K)	Undercoat KU1, KU2 (see Table 4K)	Finish FF5 (see Table 4F)	
SG1	Sa2½	70	125	50	245
SG2	Sa2½	70	220	50	345

Table 4H — Part 1: Group H systems. One-pack chemical-resistant paints

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness, µm
		Primer HP1, HP2	Undercoat HU1, HU2	Finish HF1, HF2	
SH1	St2	35	100	25 to 30	160
SH2	St2	70	100	50 to 60	220
SH3	Sa2½	35	60	50 to 60	150
SH4	Sa2½	70	100	25 to 30	200
SH5	Sa2½	70	100	50 to 60	220
SH6	Sa2½	70	100	100	270
SH7	Sa2½	100	100	100	300

Table 4H — Part 2: Product section HP. One-pack chemical-resistant primer

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
HP1A	Blend of chlorinated rubbers and non-saponifiable plasticizers	Zinc phosphate	35	40	35	Recoatable at all time intervals. Tends to stick if stacked early
HP1B		Zinc chromate	35	40	35	
HP1C		Zinc dust (BS 4652 Type 1)	40	95	40	Solvent added just before use. Pigment tends to settle during application. Recoatable at all time intervals
HP1D		Zinc dust (BS 4652 Type 2)	40	95	40	Pigment tends to settle and harden in container. Should be homogenized prior to application. Recoatable at all time intervals
HP1E		Metallic lead	45	50	35	Should be homogenized before application. Brush application recommended [see note c)]. Recoatable at all time intervals
HP2A	Blend of vinyl chloride/acetate copolymers (maleic modified) with or without non-saponifiable plasticizers	Zinc phosphate	35	40	35	Similar to Type HP1 above, but better surface preparation is required for good adhesion. Recoatable at all time intervals HP2C is BS 4652 Type 1 HP2D is BS 4652 Type 2
HP2B		Zinc chromate	35	40	35	
HP2C		Zinc dust	40	95	40	
HP2D		Zinc dust	40	95	40	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4H — Part 3: Product section HU. One-pack chemical-resistant undercoats

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
HU1A	Blend of chlorinated rubbers and non-saponifiable plasticizers	Titanium dioxide (white and tints) and chemical resistant coloured pigments (full colours). Suitably extended	35	—	25	Note f). HU1B is high-build
HU1B			30	—	100	
HU1C		Micaceous iron oxide	40	80	30	Note g). HU1D is high-build
HU1D			35	80	100	
HU2A	Blend of vinyl chloride/acetate copolymers with or without non-saponifiable plasticizers	Titanium dioxide (white and tints) and chemical resistant coloured pigments (full colours). Suitably extended	35	—	25	Note f). HU2B is high-build
HU2B			30	—	100	
HU2C		Micaceous iron oxide	40	80	30	Note g). HU2D is high-build
HU2D			35	80	100	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4H — Part 4. Product section HF. One-pack chemical-resistant finishes

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
HF1A	Blend of chlorinated rubbers and non-saponifiable plasticizers	Rutile titanium dioxide: white and tints	35	90	25	HF1B is for high-build airless spray
HF1B			30	90	100	
HF1C		Fade-resistant chemical-resistant coloured pigments and carbon black	35	—	25	HF1D is for high-build airless spray
HF1D			30	—	100	
HF1E		Micaceous iron oxide	40	80	30	Note g). HF1F is for high-build airless spray
HF1F			35	80	100	
HF2A	Blend of vinyl chloride/acetate copolymers with or without non-saponifiable plasticizers	Rutile titanium dioxide: white and tints	35	90	25	HF2B is for high-build airless spray
HF2B			30	90	100	
HF2C		Fade-resistant chemical-resistant coloured pigments and carbon black	35	—	25	HF2D is for high-build airless spray
HF2D			30	—	100	
HF2E		Micaceous iron oxide	40	80	30	HF2F is for high-build airless spray
HF2F			35	80	100	
HF2G		Aluminium	35	95	25	HF2H is for high-build airless spray
HF2H			30	95	100	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4J — Group J system. Drying-oil-type primer with one-pack chemical-resistant undercoat and finish

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness µm
		Primer FP3, FP4 (see Table 4F)	Undercoat HU1 (see Table 4H)	Finish HF1, HF2 (see Table 4H)	
SJ1	St2	35	100	35	170

Table 4K — Part 1: Group K systems. Two-pack chemical-resistant paint

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness µm
		Primer KP1	Undercoat KU1, KU2	Finish KF1, KF2	
SK1	Sa2½	35	100	35 – 45	170 – 180
SK2	Sa2½	70	100	70	240
SK3	Sa2½	70	100	100	270
SK4	Sa2½	70	150	100	320
				KF3: coal tar epoxy	
Sk5	Sa2½			150	150
SK6	Sa2½			250	250
SK7	Sa2½			350	350
SK8	Sa2½			450	450

Table 4K — Part 2: Product section KP. Two-pack chemical-resistant primers

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
KP1A	Two-pack epoxy	Zinc phosphate	35	40	35	
KP1B		Zinc dust	35	95	35	
KP1C		Zinc dust/zinc oxide	35	50	35	
KP1D		Metallic lead	45	50	35	Brush application recommended [see note c)]

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4K — Part 3: Product section KU. Two-pack chemical-resistant undercoats

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (μm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
KU1A	Two-pack epoxy	Titanium dioxide (white and tints) or chemical-resistant coloured pigments (full colours). Suitably extended	45	—	40	Note f). For airless spray 40 % min. volume solids
KU1B			45	—	100	High-build airless spray [Note f)]
KU1C		Micaceous iron oxide	45	80	40	Note g). For airless spray KU1C advised dry-film thickness 50 μm. KU1D is for high-build airless spray
KU1D			45	80	100	
KU2A	Two-pack polyurethane	Titanium dioxide (white and tints) or chemical-resistant coloured pigments (full colours). Suitably extended	45	—	40	Note f), KU2B is for high-build airless spray
KU2B			40	—	100	
KU2C		Micaceous iron oxide	45	80	40	Note g). KU2D is for high-build airless spray
KU2D			45	80	100	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4K — Part 4: Product section KF. Two-pack chemical-resistant finishes

Reference	Binder	Main pigment	Volume solids (nominal %)	Main pigment in total pigment (weight % min.)	Dry-film thickness (µm per coat) (minimum advised)	Additional information (see note c)[a] for application method)
KF1A	Two-pack epoxy [see note i)]	Rutile titanium dioxide: white and tints	45	90	40	For reduced gloss minimum additions of suitable matting agents or extender pigments may be permitted. KF1B is for high-build airless spray
KF1B			40	90	100	
KF1C		Fade-resistant chemical-resistant coloured pigments and carbon black	45	—	40	As KF1A. KF1D is for high-build airless spray
KF1D			40	—	100	
KF1E		Micaceous iron oxide	45	80	40	Note g). For airless spray of KF1E, 50 µm dry-film thickness advised, KF1F for high-build airless spray
KF1F			45	80	100	
KF1G		Aluminium	45	95	35	Not recommended where chemical resistance is involved
KF2A	Two-pack polyurethane [see note i)]	Rutile titanium dioxide: white and tints	45	90	40	As for KF1A. KF2B is for high-build airless spray
KF2B			40	90	75	
KF2C		Fade-resistant chemical-resistant coloured pigments and carbon black	45	—	40	As for KF1A. KF2D is for high-build airless spray
KF2D			40	—	75	
KF2E	Two-pack polyurethane [see note i)]	Micaceous iron oxide	45	80	40	As for KF1E. KF2F is for high-build airless spray
KF2F			45	80	75	
KF3A	Two-pack epoxy or modified epoxy coal tar	Silicate extender	60	100	60	The two pigmentations enable the material to be supplied in two colours, black and chocolate, to identify succeeding coating. KF3B and KF3D are for high-build airless spray
KF3B			55	100	100	
KF3C		Micaceous iron oxide	60	100	60	
KF3D			55	100	100	

[a] Notes to this table are on a pull-out folder following Table 4M. The folder should be extended whilst using any part of Table 4 so that all notes are immediately visible when required.

Table 4L — Group L systems. Two-pack primer and undercoat overcoated with one-pack chemical-resistant finish [or travel coat[a] (tie coat)] and site finish

Reference	Surface preparation	Nominal coating thicknesses, µm			Nominal system thickness, µm
		Primer KP1 (see Table 4K)	Undercoat KU1, KU2 (see Table 4K)	Finish HF1, HF2 (see Table 4H)	
SL1	Sa2½	35	100	50	185
SL2	Sa2½	35	100	100	235
SL3	Sa2½	70	125	100	295
SL4	Sa2½	70	175	100	345
SL5	Sa2½	140	200	100	440
SL6	Sa2½	50	150	Travel coat (FU3) 35 Finish(HF1) 100	335

[a] The travel coat should be applied before the epoxy coating is completely cured (usually within 2 to 7 days, depending on shop conditions).

Table 4M — Product section MF. Bitumen and coal tar products

These products and their fields of use are described in the British Standards listed in the table. Except when used as an isolating coat over galvanizing (at a thickness of approximately 60 μm) heavy coatings (at least 300 μm) are advised.

Specification and description		**Additional information**
BS 1070	Type A	Normally dry 8 hours. Called black paint (tar-based)
	Type B	Normally dry 4 hours. Called black paint (tar-based)
BS 3416	Type I	Normally dry 24 hours. Black bitumen coating: general use
	Type II	Normally dry 24 hours. Black bitumen coating: suitable for drinking water containers
BS 4147	Class A grade (a) primers	Cold-applied bitumen-based. S/P 50-100 °C; F/P 23 °C min.
	Class A grade (b) primers	Cold-applied bitumen-based. S/P 100-125 °C; F/P 23 °C min.
	Class B synthetic primers	Cold-applied chlorinated-rubber-based. F/P 23 °C min.
	Class C grade (a) primers	Hot-applied bitumen-based. S/P 80-100 °C; F/P 200 °C
	Class C grade (b) primers	Hot-applied bitumen-based. S/P 100-120 °C; F/P 200 °C min.
	Type 1 grade (a) coating	Hot-applied unfilled bitumen. S/P 80-100 °C; F/P 200 °C
	Type 1 grade (b) coating	Hot-applied unfilled bitumen. S/P 100-120 °C; F/P 200 °C min.
	Type 1 grade (c) coating	Hot-applied unfilled bitumen. S/P 120-140 °C; F/P 200 °C min.
	Type 1 grade (d) coating	Hot-applied unfilled bitumen 40 °C F/P 200 °C min. For hot dipping and as a primer
	Type 2 grade (a) coating	Hot-applied bitumen/asphalt/inert non-fibrous filler (23-35 %). S/P 100-120 °C; F/P 200 °C min.
	Type 2 grade (b) coating	Hot-applied bitumen/asphalt/inert non-fibrous filler (25-35 %). S/P 115-130 °C; F/P 200 °C min.
	Type 2 grade (c) coating	Hot-applied bitumen/asphalt/inert non-fibrous filler (45-55 %). S/P 120-150 °C; F/P 200 °C min.
	Type 3 grade (a) coating	Hot-applied bitumen/asphalt/inert fibrous/inert non-fibrous filler (20-40 %). F/P 200 °C min.
	Type 3 grade (b) coating	Hot-applied bitumen/asphalt/inert fibrous/inert non-fibrous filler (40-60 %). F/P 200 °C min.
BS 4164	Type A coal tar primer	Coal-tar-based primer for Types II and IV coatings
	Type B synthetic primer	Chlorinated-rubber-based primer for Types II and IV coatings
	Type 1 refined coal tar	For dipping. Viscosity Grade 38
	Type 1 refined coal tar	For dipping. Viscosity Grade 25
	Type 2 filled coal tar pitch	Softening grade 70. Service temperature 0-35 °C
		Softening grade 85. Service temperature 0-50 °C
	Type III modified coal tar	For dipping. Softening point 30-45 °C
	Type IV filled modified coal tar	Grade 95/25 maximum application temperature 250 °C
		Grade 105/15 maximum application temperature 250 °C
		Grade 105/8 maximum application temperature 250 °C
		Grade 120/5 maximum application temperature 260 °C
		Grade 90/1 maximum application temperature 230 °C

NOTE S/P is the softening point. F/P is the flash point.

Table 4N — Notes to Table 4A to Table 4M

a) *Zinc coatings.* The desirable thickness of bare zinc for atmospheric or sea water use is indicated in Figure 1. Where necessary zinc-dust paint may be applied to small parts after erection to bring the total zinc thickness to the required level. For sprayed-zinc coatings BS 2569 specifies the minimum thickness as 75 % of the nominal thickness. For galvanized coatings (see BS 729) only minimum thickness is specified. Zinc coatings may be safely used up to at least 200 °C; beyond that temperature specialist advice should be obtained on the types of zinc coating to be used.

b) *Aluminium coatings*. There is rarely any gain in applying coatings thicker than 150 µm.

c) *Application method.* Paints and sealers are most frequently applied by airless spray but brushing is recommended for inhibitive primers. For airless-spray application the percentage volume of solids is usually slightly lower and the recommended dry-film thickness is slightly higher; details are given in the notes for each section. Where no figures are given the same composition may be used for brush, normal spray or airless spray.

d) *Sealers for sprayed-metal coatings.* Sealers should be applied immediately after spraying, preferably by brush. Pretreatment primer, product CP1 or CP2, should preferably be applied to sprayed coatings before sealing. Seal with products CP3, CP4, CP5 or CP6 until absorption is complete.

e) *British Rail "T wash".* 9.0 % phosphoric acid s.g. 1.70; 16.5 % ethyl cellusolve, 16.5 % methylated spirit, 57 % water, 1 % copper carbonate (all percentages are by weight) A blue solution which turns the bright zinc surfaces black when properly applied. (If such discoloration does not occur, it is a sign that the pretreatment has not been effective.) Proprietary materials are available for the manufacture of the "T wash".

f) The weight of the principal pigment present is dependent on the shade and opacity specified. The extender should be chemically resistant.

g) Where special colour is not required MIO (micaceous iron oxide) pigment enhances protection.

h) Used mainly in conjunction with chlorinated rubber systems as:

1) a key between the primer and the chlorinated rubber top coating;

2) as a "travel coat" to avoid excessive damage during transit.

Not recommended with cathodic protection.

i) Two-pack epoxy and polyurethane: adhesion when refurbishing

1) Not more than 3 days after applying the two-pack epoxy or polyurethane finish, apply a further coating of suitable finish (product reference HF1, HF2 or FF1 to FF4). Refurbish every 10 years.

2) Alternatively at time of refurbishing use controlled wet blasting with entrained abrasive to roughen surface. Dry thoroughly. Note need for initial design to provide for easy access for blasting.

10.2 Characteristic advantages of metal and paint coatings. The general advantages of metallic coatings that should be initially considered when choosing a protective system are as follows.

a) Predictable life.

b) Single application system.

c) No drying time is needed.

d) Protection of damaged areas by cathodic protection.

e) Good abrasion resistance.

Hot-dip coatings have the following additional advantages.

f) Good adhesion because of metallurgical bond to substrate.

g) Coating thickness is unaffected by contours.

h) Major faults are easily visible.

Sprayed-metal coatings have the following additional advantages over hot-dip coatings

i) They can be applied on site.

j) Structures of any size can be coated.

k) Thickness of coating can be built up as desired.

The general advantages of paint coatings that should be considered when choosing a protective system are.

a) Ease of application in shop or on site.

b) Wide availability of painting facilities.

c) No effect on the mechanical properties of the steel substrate.

d) Easy repair of damage to coatings.

e) Wide range of colours available for aesthetic purposes.

Zinc-dust-containing coatings have some of the application advantages of paints and (in the dry-film form) some of the advantages of other zinc coatings, but, in common with sophisticated paint systems, they are critically dependent upon good surface preparation.

10.3 Other coatings. The coatings listed in clause **13** have only specific applications, to which their special individual properties are well suited.

10.4 Application facilities. Most fabricators have regular facilities for applying paint in works or on site. Facilities for spraying metal are not so common, and facilities for galvanizing are comparatively rare (about a hundred plants exist in the United Kingdom). Such facts may affect the choice of a protective system (see clauses **4** and **9**).

10.5 Effects of delays during application. For many protective systems the timing of operations is critically important, particularly when the work has to be done under adverse atmospheric conditions. In some situations it is important to allow sufficient time for coatings to cure or for residual solvent to evaporate, but more often failure to achieve the expected performance is caused by unforeseen delays between operations. If delays are likely, because of uncertain weather, hold-up in building operations, or other factors, a system tolerant of changes in periods between coats should be selected or provision should be made for appropriate remedial treatment if necessary. For example a zinc-rich primer that has been exposed for several months before overcoating should be washed down thoroughly to remove soluble zinc salts and in similar circumstances the surface of a paint based on epoxy resin should be abraded or lightly blast-cleaned to ensure adhesion of the next coat.

10.6 Costs. Cost is a major factor in determining the choice of a protective system. Quotations should be sought from several sources for each system that meets all other requirements. Appendix E gives guidance on the principles involved in assessing real costs.

11 Characteristics of metallic coatings

11.1 Zinc coatings (other than zinc-rich paints)

11.1.1 *General.* Four methods for applying metallic coatings are in general use.

a) Hot-dip galvanizing: for structures, fittings and claddings.

b) Sherardizing: mainly for fittings, fasteners and small items.

c) Electroplating: mainly for fittings, fasteners and small items.

d) Metal-spraying: for structures and fittings (including fasteners when done after fabrication).

The desirable weight or thickness of bare zinc for use in different environments can be derived from Figure 1. The metal corrodes at a predictable and uniform rate, which increases as sulphur dioxide pollution of the environment increases.

Areas of discontinuity or insufficient thickness of a metallic zinc coating, however caused, may be rectified at any stage by the application of sprayed zinc, special zinc-alloy solder-sticks or zinc-rich paints.

11.1.2 *Galvanizing.* Cleaned steel is immersed in a bath of molten zinc; a partial alloying action results in a metallurgically bonded coating: As soon as the steel is cool (after withdrawal from the bath) it may be stacked and transported or it can be primed for overcoating.

The size of structural assembly that can be galvanized is limited by the size of the largest bath in each galvanizer's works[4]. The largest sizes that can be galvanized in the United Kingdom are (at the time of preparation of this code):

a) sections up to 27.4 m long;

b) assemblies 16.8 m × 3.6 m × 1.5 m;

c) assemblies 5.2 m × 3.6 m × 1.8 m.

The code does not refer to the galvanizing of steel thinner than 5 mm. Thinner components have thinner galvanized coatings (see BS 729); coatings on continuously galvanized sheet are specified in BS 2989. The coating weight specified for sheet is the total weight on both sides of the metal; for components the rate of coating on one side only is specified.

For sections not less than 5 mm thick reference should be made to BS 729, where a minimum specified weight of zinc, 610 g/m^2, is equivalent to a thickness of 86 μm (shown as "85 μm minimum" in the tables) on each face. The thickness of coating varies with the thickness of steel, surface preparation and conditions of immersion. It may be increased to 140 μm (1 000 g/m^2) if either the steel is grit-blasted before coating or the steel contains silicon (typically more than 0.3 %). The coating thickness may be increased to 210 μm (1 500 g/m^2) by using silicon (typically more than 0.3 %) or silicon-killed steels and consultation with the steel supplier and galvanizer is essential if these thick coatings are required. Brown staining may occur early in the life of steel containing silicon. This is a surface phenomenon and does not affect the protective value of the coating.

Because the recommendations in Table 3 for galvanizing are based on products made of steel more than 5 mm thick, the minimum thickness recommended is 85 μm, i.e. the minimum permitted for such products in BS 729. Some galvanized steel (see above) will have thinner coatings. By reference to Figure 1, the different lives of such thinner galvanized coatings can be estimated and the appropriate life requirement to first maintenance may be assessed.

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[4] Listed in a directory issued by the Galvanizers Association, 34 Berkeley Square, London W1X 6AJ.

11.1.3 *Sherardizing.* This process is used mainly for small parts and fasteners, particularly for threaded work where only small change of dimension is acceptable. After suitable surface preparation, the items are tumbled in hot zinc dust. The thickness of the coating varies with the processing conditions; two grades (15 µm and 30 µm) are specified in BS 4921, and the lives of those thicknesses are compared in Figure 1.

11.1.4 *Electroplating.* Zinc-plating of small parts by the electrolytic deposition of zinc from zinc-salt solutions is done only by specialist firms.

It is rarely economic to electroplate thicker than 25 µm. Cadmium plating is an alternative used for special purposes.

BS 1706 specifies coating techniques for threaded parts.

11.2 Sprayed-metal coatings

11.2.1 *General.* The metals commonly used for spraying structural steel are zinc and aluminium.

The technique of spraying metal is applicable to structures and fittings either in the shop or on site. An atomized stream of molten metal is projected from a special gun (fed by either wire or powder) on to a surface prepared in accordance with BS 2569. There is no size limit (cf. galvanizing, see **11.1.2**) and the process is especially economical when the area/weight ratio is low.

All grades of steel can be sprayed. The steel surface remains cool and there is no distortion, nor is there any effect on the metallurgical properties of the steel.

Coating thicknesses less than 100 µm are not usually specified unless the sprayed metal is to be sealed or painted immediately.

For most atmospheric environments, there is no advantage in spraying aluminium to a thickness greater than 150 µm (nominal).

11.2.2 *Sprayed-metal-plus-sealer systems.* A sealer (Table 4C, part 2) which fills the metal pores and smooths the sprayed surface, improves the appearance and life of a sprayed-metal coating. it also simplifies maintenance, which then requires only the renewal of the sealer.

Sealers should be applied immediately after spraying the metal coating. Pretreatment primer CP1 or CP2 may be applied before sealing. Sealing itself is done with types CP3, CP4, CP5 or CP6 until absorption is complete. (There is no requirement for a measurable overlay of sealer.) Type CP7 is used for sealing when surface temperatures up to 550 °C are envisaged.

Metal-spraying and sealing are normally done by specialist contractors[5] who are equipped to apply the full protective system in shop or on site.

11.3 Metal-plus-paint systems

11.3.1 *General.* Metal-coated steel is painted only when:

a) the environment is very acid or very alkaline (i.e. when pH-value is outside the range 5 to 12 for zinc or 4 to 9 for aluminium); or

b) the metal is subject to direct attack by specific chemicals (see Table 3); or

c) the required decorative finish can be obtained only by paint; or

d) when additional abrasion resistance is required.

Generally one or two coats of paint may be sufficient except in abnormally aggressive environments. Sealed sprayed metal is usually preferable to painted sprayed metal.

Appropriate paints usually have a longer life on metal coatings than on bare steel, and rusting and pitting of the steel is reduced or prevented.

11.3.2 *Zinc coatings plus paint.* The paints used should be compatible with the sprayed or galvanized surfaces. Most paints, other than those containing drying oils, are suitable for application to zinc-coated steel that has been pretreated as described below. Some paints may be applied without pretreatment (see note 2 under Table 4B for some that have been successfully used over a long period of time; more recent developments are not included). Zinc-coated steel is a suitable base for paint but the first treatment may be different from that of uncoated steel. Acceptable treatments include the following.

a) Pretreatment primers that have been specially formulated for the treatment of zinc-coated steel before painting (see Table 4C, part 2).

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[5] Listed in a directory issued by the Association of Metal Sprayers, Heathcote House, 136 Hagley Road, Edgbaston, Birmingham B16 9PN.

b) Many proprietary chemical conversion processes (chromate, phosphate or oxide types) are available for spray, brush or dip application in the shop before shop-painting of galvanized steel in controlled process plants. Manual application can lead to misuse, and some procedures are not suitable for structural steel.

c) A non-proprietary material, known as British Rail "T Wash"; comprises 9.0 % by weight of phosphoric acid ($d = 1.70$), 16.5 % ethyl cellusolve; 16.5 % methylated spirit; 57 % water; 1 % copper carbonate. This is designed for use on galvanized surfaces and is a blue solution which turns the zinc surfaces black when properly applied. If a surface does not turn black the pretreatment has not been effective.

12 Characteristics of paint systems (including metallic zinc-rich paints).

12.1 General. Paint systems usually consist of primer, undercoat(s) and finish coat. Each component normally contains pigment (solid particles) suspended in a solution of binder (resin solution). Choice of pigment and ratio of pigment to binder depends on the function of the paint; e.g. more binder will be used in a penetrating primer for sprayed metal and more pigment in a high-build undercoat.

12.1.1 *Binders*[6]. The binder more clearly defines the essential characteristics of the coating (see appendix B). Drying-oil-type paints dry in the presence of atmospheric oxygen; the action is catalytically promoted by metallic soaps. One-pack chemical-resistant coatings usually dry by evaporation of solvent but the moisture-cured polyurethanes are also in this group. Two-pack chemical-resistant coatings form by chemical reaction; the two components have to be mixed just before use.

12.1.2 *Pigments.* The pigments may inhibit corrosion, reinforce the dry film, provide colour, and/or absorb or reflect ultra-violet radiation, thus improving the durability and stability of the coating (see appendix C).

12.1.3 *High-build coatings.* High-build formulations permit much greater film thicknesses per coat. They are usually applied by airless spray but can be applied by roller or brush.

12.1.4 *Compatibility.* All paints within a system should have compatibility between coats and with the metal substrate (i.e. there should be adequate adhesion to the substrate and between coats over the operating temperature range and there should be no under-softening to cause lifting, wrinkling or bleeding-through of stains). For this and other reasons it is generally advisable to obtain all the components of a paint system from the same source; otherwise, assurance of such compatibility should be obtained. If cathodic protection is applied to the structure, the paint system should be compatible with it (see **13.5** and BS 7361-1).

12.1.5 *Solvents.* Solvent modification of paint composition is frequently necessary to allow for the characteristics of different methods of application.

12.1.6 *Handling, stacking and repair.* Two-pack chemical-resistant paints withstand reasonable handling and can be readily stacked when fully cured, but most other paints are relatively easily removed down to primer. One-pack chemical-resistant paints tend to stick on stacking, but drying-oil-containing paints can be stacked, with care. Touching-up on site is easy for most paints but initial abrasion may be needed to provide adequate adhesion of touching-up treatments over two-pack chemical-resistant paints.

12.2 Zinc-rich paints[7]. Metallic zinc-rich paints may be organic (Type 3 as specified in BS 4652:1971) or inorganic.

With 90 % or more of zinc-dust (which may contain up to 4 % zinc oxide) in the dry film the coating will afford cathodic protection but will be slightly permeable. The formation of zinc salts will gradually render the coating impermeable and it will then be a barrier coating. If damage to the coating exposes the steel the zinc will again become cathodically sacrificial to prevent rust spreading.

Suitable sealer coats improve the appearance of zinc-rich paint coatings. The advice of the coating supplier should be sought regarding the type of sealer to be used, especially if the surface is exposed between applications. The various uses of zinc-rich paints, as shop-primer, fabrication-primer or main coating, are indicated in Table 3 and Table 4. Members and assemblies coated with zinc-rich paints may be handled or stacked as soon as the coating is dry, but exposure of freshly applied zinc silicate paints to moisture within a stack can result in deleterious changes.

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[6] For the correct use of the terms "binder", "vehicle" and "medium" see BS 2015.

[7] Commonly called zinc-rich coatings.

12.3 Drying-oil-type paints. Drying-oil-type paints, F, cover a wide range of materials, ranging from largely obsolescent simple oil paints, which were slow-drying but tolerant of less than perfect surface preparation, to phenolic varnishes and epoxy ester paints, which dry well even at low temperatures. Recoating usually presents no problem but chemical resistance is poor to moderate and weather resistance is moderate to good.

Silicone alkyds, G, are more expensive than other drying-oil-type paints, but keep cleaner and retain colour and gloss better than most other coatings.

12.4 One-pack chemical-resistant paints. One-pack chemical-resistant paints, H, dry under any well ventilated conditions but, where coatings are built up thickly, retained solvent may keep films soft and prone to damage for days or even weeks. Recoating is easy, unless the surface has become heavily contaminated, because the films remain soluble in suitable hydrocarbon solvents. Where the highest chemical resistance is not required a system, J, of anticorrosive, drying-oil-type primer, carefully selected for compatibility with a type-H chemical-resistant finishing system, allows some relaxation of the steel preparation standards.

12.5 Two-pack chemical-resistant paints. Two-pack chemical-resistant paints, K, are resistant to acids, alkalis, oils and solvents, but should not be used unless the highest quality of surface preparation and application can be assured. Cured films are hard and solvent-resistant so that intercoat adhesion may be doubtful, particularly where surface contamination may occur. Coal tar epoxy and urethane/tar coatings are rather cheaper and may be easier to apply, but are restricted to darker colours and have lower solvent resistance.

Hot-applied, solvent-free epoxies have a particular usefulness for tank linings where flammable solvents could be a hazard.

Where the greater part of a two-pack chemical-resistant system is to be applied in the shop and where travel or erection damage may have to be touched-up on site it may be advantageous to choose the system, L, incorporating a chlorinated-rubber travel coat, which will readily accept a further chlorinated-rubber coat after erection.

12.6 Bituminous coatings

12.6.1 *General.* Bituminous coatings are low-cost coatings whose protective properties depend on film thickness. There is a wide range of materials based on either mineral bitumen or coal tar fractions applied as unheated solutions, hot solutions, or hot melts; bituminous emulsions are little used for the protection of steel. Specially developed materials, based on powdered coal dispersed in pitch, are widely used for the protection of underground pipes.

Blast-cleaning before coating gives the best performance but is not essential for many uses.

Bituminous coatings have good resistance to dilute acids and alkalis, salt solutions and water, but are not resistant to vegetable oils, hydrocarbons and other solvents. They may become brittle in cold weather and soften in hot weather. Bitumen-coated articles should not be stacked.

The relevant British Standards are shown in Table 4M, which also lists the available types.

Bitumen solutions and emulsions are readily applied by brush or spray and are often used as priming coats for the heavy-duty materials which can be applied hot or cold at the works or on site. The specifier should consider inhibitive oleo-resin-based primers for heavy-duty bitumen provided that sufficient drying time (several weeks) can be allowed to pass before overcoating.

12.6.2 *Coal tar pitches and bitumens.* Coal tar pitches have high resistance to moisture and good adhesion to steel, so they are very suitable for structures that are immersed in water (especially foul water) or buried in the ground. The appropriate water supply authority should be consulted before coal-tar-based material is used in conjunction with potable water. Coal tar pitch is less readily softened by hydrocarbon oils.

Prolonged exposure to weather and sunlight causes surface chalking because of oxidation and loss of plasticizing components, so coal-tar pitches and bitumens should never be specified for such conditions (unless they are overcoated with asphaltic material in solution or emulsion form), nor should they be used in very hot conditions (such as may arise in a pipeline downstream of a compressor).

The coatings may be reinforced with glass fibre or asbestos wrapping, especially for the protection of pipelines. Wrappings made from vegetable fibres such as cotton or hessian are liable to microbiological attack.

12.6.3 *Asphaltic coatings.* Asphaltic coatings have much better resistance than coal tar pitches to sunlight, weather and exposure to the direct heat of the sun. Resistance to breakdown under sunlight can be improved with flake aluminium. Asphaltic coatings are recommended for buried or submerged conditions and they are best used with inhibitive primers.

12.6.4 *Application of coal tar pitches and asphalts.* The materials are heated as needed in boilers near the application site. For vertical surfaces the material is daubed on with a stiff brush, covering small rectangular areas with short strokes and overlapping to form a continuous coating. In weld areas the brush strokes should be in the direction of the weld; a second coat should then be applied in the opposite direction. For horizontal surfaces the material can be poured on and then trowelled-out and if unevenness occurs where a smooth surface is required, it may be permissible to play a blow-lamp on to the surface and finish by trowelling. Considerable skill is required in all these operations (see BS 534).

12.6.5 *Overcoating.* In general, only bituminous material should be used for overcoating bituminous materials. It is, however, possible to overcoat with some emulsion paints or cement paints and these may be desirable to reduce surface heating under sunlight.

13 Characteristics of some other protective systems

13.1 Powder coatings. Coatings formed from pigmented resins, applied as dry powders and fused by heat, have been developed for protection of lightweight steel components. Some types of powder coatings also find applications on pipes and hollow sections, e.g. lighting columns, where simple shapes facilitate coating and heat curing. They are unlikely to be economical for use on heavy sections because of the high temperatures required for fusing or curing.

Powder coatings are of two main types:

a) thermoplastic powders, based on e.g. polyethylene, polypropylene, vinyl copolymers, or nylon-II, which fuse to form films without any chemical change;

b) thermosetting powders, based on e.g. epoxy, polyester, acrylic or polyurethane resins, which cure to chemically cross-linked films after being fused by heating.

Theremoplastic powders are frequently applied by a fluidized-bed technique in components that have been preheated so that the powder will stick readily. Coatings can be built up to a thickness of 200 µm to 300 µm in one operation and are highly protective where a complete wrap-round can be achieved.

Thermosetting powders are usually applied by electrostatic spraying to a film thickness usually between 50 µm and 100 µm. Epoxy powders are easily applied and form tough coatings. Polyester and polyurethane powders give better resistance to weather. Selected polyurethane and nylon powders are particularly useful where impact and abrasion resistance is important, as on certain types of fastener. Unless anticorrosive pretreatments or solvent-borne primers are first used, powder coatings often have indifferent adhesion so that protection may fail rapidly once the coating has been broken.

13.2 Grease paints. Coatings based on greases have two uses:

a) as permanent non-curing coatings for application to the inside of box sections, and

b) as temporary protectives (see BS 1133:1966, section 6, 1966) for components in store or for machined surfaces before assembly.

Thick grease films form effective barriers to moisture but inhibitors are added to increase, the effectiveness. Grease-based coatings should be used in conjunction with tapes or other wrappings on components that are to be stacked or are liable to rough handling.

13.3 Wrapping tapes and sleeves. Wrapping with adhesive tape protects ferrous metals, particularly pipelines, joints, valves, and other fittings by excluding the environment from the substrate. For further protection against accidental damage and to promote adhesion of the wrapping tape it is good practice to clean thoroughly from the substrate any rust products and to prime with an inhibitive primer before taping.

Buried pipelines are often supplied wrapped at works with bitumen or coal tar reinforced by glass fibre and only the joints require wrapping at site.

When applying wrapping tape an overlap of at least half the width of the tape is recommended and for coating pipes of up to 300 mm diameter it is good practice to use a tape of width matching approximately the diameter of the pipe. Application by hand is satisfactory for small jobs but for large installations, such as long pipelines, fully automatic or semi-automatic methods are used. The skills lie in obtaining a consistent tension throughout the operation, uniform bonding and the avoidance of air pockets.

Three types of wrapping are commonly available.

13.3.1 *Petroleum-jelly tapes.* These consist of fabric of natural or synthetic fibre or glass cloth impregnated with a mixture of petroleum jelly and neutral mineral filler. They should be used in conjunction with a petroleum-jelly primer. The coating is permanently plastic; it is suitable for application to irregular profiles and should be smoothed by hand, taking care to avoid any air pockets. When used above ground, these tapes should be protected by a bituminous-tape overwrap in situations where they may be subject to damage by abrasion. They are also suitable as insulation to avoid bimetallic contacts.

13.3.2 *Synthetic resin or plastic tapes.* The most readily available synthetic tapes are polyvinyl chloride (PVC) and polyethylene tapes. These polymer strips, usually 125 µm to 250 µm thick with a fabric core, are coated on one side with a compact adhesive, normally of synthetic rubber base. They are usually available in a range of colours if pipe identification is required.

Synthetic resin or plastic tapes are suitable as insulation to avoid bimetallic contacts, particularly in damp or dirty conditions.

Best protection is obtained if the steel is first cleaned and coated with a conventional rust inhibitive primer. For exterior exposure black polyethylene tape is preferred to polyvinyl chloride because its surface degrades much less on exposure to sunlight and weather.

13.3.3 *Coal tar and bitumen tapes.* These tapes are used mainly for buried pipelines. They have a high resistance to moisture and good adhesion to steel. The fabric reinforcement is usually made from glass fibre. The steel should first be cleaned and given a coating of coal tar or bitumen primer. According to the temperature expected in service so can the low properties of the tape be varied. For some high temperatures and especially for high-duty requirements, the grade of coal tar or bitumen used is such that it is necessary to heat the tape to soften it sufficiently for good application and bonding, and to heat the overlap when applied, to obtain the best seal.

13.3.4 *Two-pack taping.* In this method of high-duty protection a woven tape is impregnated, after wrapping, with a two-pack solventless composition, normally a polyester or two-pack epoxy. The technique used is similar to that used in the preparation of glass fibre moulding, except that the resin-impregnated glass cloth is intended to adhere to the metal substrate. This method is used especially for shafting exposed to marine conditions and for surfaces which may be subject to cavitation corrosion.

The surface to be protected should first be thoroughly cleaned to bright metal, then primed with a two-pack epoxy (or similar). It should then be wrapped with glass cloth in sheet or tape form and the cloth impregnated with a two-pack polyester or two-pack epoxy composition. It is good practice to apply a thin coating of the impregnating resin before applying the reinforcing substrate; then several layers are built up and the final surface is trowelled smooth. The coating will then set to a hard glass-like tough protective coating which is impermeable to water.

13.3.5 *Plastic sleeves.* Polythene and similar plastics may be used as protective sleeves on pipes and are sometimes shrunk on to the metal. For spun iron pipes and castings the application of a non-adherent but snug-fitting polythene sleeve gives good protection. The sleeving is applied at the time of laying the pipe and joints are taped with adhesive strip.

13.4 Protection of steel by cement and allied products. Cement-mortar linings are widely used for the internal protection of water mains. Special formulations and coating procedures are used. They have limited impact resistance but may be repaired on site by fresh applications. Conversely, steel structures (and steel reinforcement) may be in contact with, or embedded in, concrete. All Parts of BS 8110 and BS 5950, relating to concrete and steel/concrete structures, contain relevant information.

Exposed steel may be covered with gypsum plaster and magnesium oxychloride cements, but it should first have been coated with a suitable bitumen coating that is resistant to water penetration while the plaster or cement is curing.

13.5 Cathodic protection. The degree of protection afforded by a cathodic system may be enhanced by paint coatings, but not all paint systems are compatible with cathodic protection systems and specialist advice should be sought.

14 Surface preparation

14.1 General. The surface preparation of the steelwork has a major influence in determining the protective value of the coating system.

For metallic coatings it is generally an integral part of the process and is included in the relevant British Standards. Paints may be applied to surfaces in a variety of ways and the type and standard of surface preparation should be specified as part of the protective coating treatment (see section 3).

The choice between blast-cleaning, acid-pickling, flame-cleaning, and manual cleaning[8] is partly determined by the nature of the coatings to be applied. It should be appreciated, however, that coatings applied to a properly prepared (e.g. blast-cleaned) surface will always last longer than similar coatings applied to flame-cleaned or manually cleaned surfaces. It should be borne in mind that some short-life coatings do not warrant the high cost of the standards of blast-cleaning which are required for long-life coatings.

14.2 Degreasing. Grease and dirt are best removed by emulsion cleaners followed by thorough rinsing with water, or by steam-cleaning, or by controlled high-pressure water jets.

Where it is necessary to use turpentine or similar solvents to remove oil or grease, the use of detergent or emulsion cleaner should follow and the operation should be completed by thorough rinsing with clean fresh water.

Degreasing by washing in solvent is not recommended (except in automatic degreasing plants) because this invariably leads to the spreading of a thin film of grease over the surface which can impair the coatings. It is equally important to avoid this spreading of grease when steam jets are used; the soil should be physically removed by scraping before cleaning.

CP 3012 covers the cleaning of metal surfaces.

14.3 Removal of scale and rust. The chemical structure of rust is described in **A.1.4**, and the important point to be noted is the presence of iron salts, such as sulphates and chlorides. These will cause early failure of paint coatings applied over them.

"Mill-scale" is the term used for the surface oxides produced during hot rolling of steel. It breaks and flakes when the steel is flexed and paint applied over it may fail prematurely. The extent of such failures is unpredictable but they frequently occur within a few weeks of painting, particularly in aggressive environments.

No protective coating can give long-life protection unless both the scale and rust are removed.

Information is given in **14.3.1** to **14.3.4** on the commonly used methods of preparing steel surfaces for the application of coatings.

14.3.1 *Blast-cleaning.* Abrasive particles are directed at high velocity against the metal surface. They may be carried by compressed air or high-pressure water, or thrown by centrifugal force from an impeller wheel. For some open blasting, high-pressure water without abrasives may be used. The various methods are listed in Table 5.

14.3.1.1 *Choice of method of blast-cleaning.* The choice will be determined mainly by the following factors.

a) *Shape and size of steelwork.* Centrifugal methods are economic for plates and simple sections; they can also be used for large prefabricated sections, e.g. bridge sections, but only in specially designed plants. "Misses" discovered by inspection can be cleaned with open-blast techniques. For large throughput of shaped items, e.g. pipes, both open and vacuum-blasting techniques can be used in continuous and automatic plants.

b) *Effect of the stage at which it is carried out.* For blast-cleaning on site, open or vacuum-blasting methods have to be used as on large fabricated sections, it may be impracticable to use centrifugal methods.

c) *Throughput.* Centrifugal plants are economic for a high throughput, but even with a low throughput the method may still be preferable to large-scale open cleaning.

d) *Environmental conditions.* Despite its relatively high costs, vacuum-blasting may be necessary to avoid contamination of the immediate area with abrasive. It should be ensured that the blast-cleaning process does not affect adjacent materials.

e) *Types of surface deposit to be removed.* Wet-blasting methods, with abrasives, are particularly suitable for removing entrapped salts in rust and for abrading hand-painted surfaces, e.g. two-pack epoxies, before recoating[9].

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[8] The term "manual cleaning", as used in the code, encompasses all methods of cleaning other than blast-cleaning, acid-pickling, and flame-cleaning.

[9] BSRA Report NS319. Removal of marine fouling and exhausted anti-fouling composition from ships' hulls by "soft-blasting" (1971).

14.3.1.2 *Stages for carrying out blast-cleaning.* Steel may be blast-cleaned either before or after fabrication. Sometimes it may be necessary both before and after.

Where steel is cleaned before fabrication it should be protected with a suitable blast-primer to avoid rusting before fabrication is completed. During fabrication, the blast-primer will inevitably be destroyed or damaged in places, e.g. by welding. Such areas should be cleaned and re-primed as soon as possible.

Where steel is cleaned after fabrication it may still be necessary to apply a blast-primer, but often the first coat of the full protective system can be applied.

14.3.1.3 *Abrasives.* Common abrasives for cleaning steel-work are classified in Table 6, with notes on their advantages and disadvantages. For size grades of shot and grit, reference should be made to BS 2451. It is essential to avoid the use of contaminated abrasives, as the following three types of contamination may occur.

a) Dry dust and detritus from the surface and the smaller fines from the breakdown of abrasives. They can be removed by automatic and recirculatory plants. Without such a cleaning process, abrasives should not be re-used.

b) Water, either on the surface, in the compressed air, or from conditions of very high humidity, forms agglomerates of dust and abrasive particles, inhibiting automatic cleaning processes.

c) Oil and grease on the surface or from the equipment preclude the re-use of abrasives. Such oil and grease should be removed before blast-cleaning.

The choice of abrasive will be determined mainly by economic considerations, but cast iron grit is recommended, particularly for surfaces to be metal-coated.

14.3.1.4 *Removal of surface dust after blast-cleaning.* All dust, residues and debris should be removed from the steel surface before the protective coating is applied. Dust reduces adhesion of paint coatings and encourages attack upon the steel by absorbing moisture.

Unless the dust can be automatically removed with vacuum hand-operated or centrifugal machines, separate vacuum cleaners should be used.

Table 5 — Methods of blast-cleaning

Methods	Advantages	Disadvantages
Dry methods using compressed air or centrifugal force		
Automatic plants based on centrifugal throwing of the abrasive	High production rates, lowest costs, no moisture problems, can be coupled to automatic application of primer, dust problems contained	High capital cost, high maintenance cost, lack of flexibility, i.e. not suitable for recessed areas etc.
Open blasting based on propelling the abrasive with compressed air	Simple to operate, very flexible and mobile in use in both indoor cabinets or special rooms or on site, low capital and maintenance costs	High cost of compressed air, low efficiency, liable to moisture entrainment from the compressed air, manually operated and a variable profile can result, operator requires protective clothing, serious dust problems
Vacuum-blasting based on propelling the abrasive with compressed air and immediately recycling by suction from the blast-cleaned surface	No dust problems, no special protective clothing for operators, fairly low capital costs	Can be very slow and therefore expensive on awkward profiles and girder sections. Where flat-plate or gun-head automation is possible it may be considered, but liable to moisture entrainment from the compressed air
Wet methods (hydroblasting)		
Open blasting based on projecting water at very high pressure	Simple to operate, very flexible and mobile in use, suitable for removing soluble contaminants, at very high pressure can remove mill-scale, no dry dust hazards	Slow if firmly held contaminants are to be removed, dangerous at very high pressure if proper precautions are not taken, limitation of drying surface before painting unless approved water-based or water miscible primers are used, requires availability of water and drainage, operators require protective clothing
Open blasting based on projecting water at high pressure and entraining abrasive into the water stream	Simple to operate, very flexible and mobile in use, suitable for removing all firmly held contaminants as well as soluble contaminants	Dangerous at very high pressure if proper precautions are not taken, limitation of drying surface before painting unless approved water-based or water-miscible primers are used, particulate dust hazard remains, requires availability of water and drainage, operators require protective clothing
Open blasting based on injecting low pressure water into a compressed air stream which is carrying an abrasive	As above	High cost of compressed air, low efficiency, limitation of drying surface before painting unless approved water-based or water-miscible primers are used, dust hazard reduced, operators require protective clothing
Open blasting using steam-cleaning		Similar to the above according to whether abrasive is or is not entrained

Table 6 — Classification of abrasives used for cleaning steel

Abrasive	Hardness	Normal usage	Advantages	Disadvantages
Chilled iron-grit	60 to 80 RC	Captive blasting and open blasting with recovery systems	Relatively cheap, cleans very quickly, will chip under repeated impact with work surface, presenting fresh cutting edges	Breaks down fairly quickly. In centrifugal wheel plants, special protection is required to reduce wear on moving parts
Chilled iron-shot	60 to 80 RC	Captive blasting only	Relatively cheap, very hard, should break down to grit in use	As chilled iron-grit. Because of ricochet effect is not suitable for open blasting or in open cabinets
High-duty chilled iron-grit or iron-shot	55 to 64 RC	Captive blasting and open blasting with recovery	Breaks down less quickly than chilled iron	More expensive than chilled iron, rendered spherical in use, poorer and slower rate of cleaning than chilled iron
Heat-treated chilled iron-grit or iron-shot	30 to 40 RC	As high-duty	As high-duty	As high-duty
Steel grit	60 to 67 RC 47 to 53 RC	Captive blasting mainly	Does not break down so quickly as chilled iron, causes less wear in centrifugal wheel plant	More expensive than chilled iron, rendered spherical in use and is less efficient, supplied in various hardnesses but at best is not so hard as chilled iron-grit and therefore cleans more slowly
Steel shot	41 to 49 RC	Captive blasting only	As for steel grit	As for steel grit, tends to hammer-in rather than loosen scale, ricochet effect makes it unsuitable for open blasting
Cut steel wire	41 to 52 RC	Captive blasting only	As for steel shot and grit, wears down as fairly even sizes	High cost, rendered spherical in use and slower cleaning than chilled iron
Aluminous oxide (corundum)		Not common in the United Kingdom	Extremely hard	Expensive, hardness of dust is a danger to machinery unless used in sealed captive blast plant
Copper slag		Open blasting only	Cheap, no silicosis hazards	Initial particles rather coarse, breaks down to dust very quickly, angular particles tend to embed in workpiece
Iron slag		Open blasting only	As for copper slag	As for copper slag
Sand		Open blasting	Cheap	In United Kingdom, Factory Inspector's approval is required, danger of silicosis

14.3.1.5 *Standards of blast-cleaning.* The four qualities of blast-cleaning given in BS 7079-A1 are listed as follows:

Sa1	Light blast-cleaning
Sa2	Thorough blast-cleaning
Sa2½	Very thorough blast-cleaning
Sa3	Blast-cleaning to visually clean steel

NOTE 1 The equivalent of the three qualities Sa2, Sa2½ and Sa3 in the Swedish Standard SIS 05 59 00 have similar designations.

BS 7079-A1 should be referred to for the complete requirements for the preparation of steel substrates.

NOTE 2 Until further Parts of BS 7079 are published the methods of measuring cleanliness given in appendices F and G may be used.

14.3.1.6 *Surface profile.* The method of assessment of the abrasively blast-cleaned profile is given in BS 7079-C1 and BS 7079-C2 for qualities Sa2½ and Sa3. Three qualities of profile grades are given: fine, medium and coarse but for most protective coatings it is generally advantageous to have as small an amplitude as can be economically achieved. This helps the avoidance of "rust spotting" which can occur with rough surfaces, where the coating does not completely cover the peaks.

The profile size is largely governed by the type and size of abrasives and by the method of blasting. Fine abrasives clean more quickly and more thoroughly than coarse abrasives, except where it is necessary to crack very heavy mill-scale. In modern automatic plants for plates and sections, the scale can be cracked by steam-cleaning and heating before blast-cleaning.

Profiles needed for sprayed-metal coatings are specified in BS 2569 and tend to be of greater amplitude than those specified for paint coatings.

Generally for paint the size of the abrasive particles should not exceed G 17 (see BS 2451).

Automatic plants give the most consistent profiles. For manual operation, angles near the vertical give lower profiles, particularly when large abrasives are used.

Instrumental methods of controlling preparation for painting are described in appendix F.

14.3.1.7 *Surface quality of steel.* Blast-cleaning is most effective on steel that has not been allowed to rust.

Where steel has been allowed to rust badly, longer times for blast-cleaning may be required. Sometimes 1st quality standards cannot be economically achieved. It is therefore advisable to blast-clean steel as soon as is practicable after rolling.

Steelwork should be sound and free from such segregation cracks, laminations or surface flaws as might preclude its satisfactory protection against corrosion, both initially and in service. Surface laminations, shelling, cracks, crevices, inclusions and surface flaws should be removed by chipping and/or grinding before painting or metal-coating. Burrs and sharp edges should be removed before painting. When excessive grinding has been necessary the dressed areas should be re-prepared to the necessary quality, including filling or welding as required.

14.3.2 *Acid-pickling.* Mill-scale and rust can be removed by acid-pickling. A particular type of pickling, known as the "Duplex" or "Footner" process has a final treatment in hot 2 % phosphoric acid solution. This leaves a thin phosphate coating on a warm steel surface, to which the paint should be applied immediately. This method is not generally used outside the pipe industry, but large plates for storage tanks have been pickled in this way.

Generally, pickling is done by specialist firms.

14.3.3 *Flame-cleaning.* In flame-cleaning a high temperature oxyacetylene flame is passed over the surface to be cleaned. The effect of the heat is to remove scale and rust, partly by differential expansion and partly by evolution of steam from moisture in the rust. After flame-cleaning the surface is wire brushed before painting.

The method may be useful for maintenance work, particularly in damp weather. The first coating should be applied while the surface is still warm and dry. The flame-cleaning of high-strength friction-grip-bolted joints and the adjoining areas should be totally prohibited.

The method does not remove all rust and scale and is in no way a substitute for blast-cleaning.

14.3.4 *Manual cleaning*

14.3.4.1 *General.* Tools such as wire brushes, hand-scrapers, vibratory-needle guns and chipping hammers are available. They may or may not be power operated and are often used for maintenance work or for the preparation of steelwork to be exposed in non-aggressive conditions, such as:

a) easily accessible steelwork in rural areas;

b) steelwork inside buildings where conditions are non-corrosive;

c) steelwork to be encased in brickwork, concrete, etc.;

d) internal surfaces of enclosed spaces that are to be painted.

They should not be used for the preparation of steel where high quality long-life systems are to be used.

Powered tools incorrectly handled may produce marked surface roughness which could make it difficult to protect adequately by paint.

It is difficult to achieve a satisfactory standard for any length of time by manual cleaning.

14.3.4.2 *Standards of manual cleaning.* Swedish Standard SIS 05 59 00:1967 lays down two standards of manual cleaning, St2 and St3, and these are correlated to four initial steel rust grades A, B, C and D.

In practice it is difficult to reproduce these standards because of the difficulty of sustaining good operator performance.

14.4 Attention to detail. Apart from surface preparation of the main bulk of the steelwork, attention should be paid to the details, particularly the following.

a) Sharp edges that may have a deleterious effect on coatings should be removed.

b) Burrs caused by removal of temporary lugs, etc. should be ground flat.

c) Welds should be dressed and weld spatter removed by grinding.

d) Nuts and bolts should be properly treated.

e) Fasteners, such as pipe-hangers, should be treated before being fixed to the main structure.

Section 3. Specifications and technical requirements

15 Introduction

15.1 The scope of this section. The term "specification" as used generally in this code connotes "the means of communicating requirements regarding the quality of materials and standards of workmanship necessary to provide good protection to ferrous construction materials and components against deterioration by corrosion". But when used with an initial capital, thus: "Specification", it refers to the physical document, so named, which is part of a set of Contract Documents.

A protective system is sometimes specified by defining the required performance of the coatings, but whatever the reason for preparing a Specification in that way, at some later stage a specification of materials and workmanship will have to be prepared to establish clearly what is required. This section of the code is therefore devoted largely to the preparation of clauses for the latter type of specification.

A statement of technical requirements and the writing of specification clauses on how to fulfil them may appear to warrant separate treatment but the statement has much in common with the specification clauses used to communicate such information, and in this section, therefore, considerations of specifications and technical requirements have been combined.

Model and typical clauses have not been provided since the main object has been to include technical information and advice on how to prepare clauses to cover a wide variety of materials and techniques.

15.2 The need for specifications. The potential life of a protective system is unlikely to be realized unless:

a) the correct choice of system is made (see section 2);

b) the materials used in the system can be supplied when required and with the properties attributed to them when making the choice;

c) the materials are applied in conditions and with standards of workmanship described elsewhere in this code as good practice;

d) the handling, transport and storage (over which the main contractor has minimal control) of all materials and coated components results in no damage to the integrity of the materials or coatings that cannot be completely restored;

e) the erection procedures cause no damage to the coatings that cannot be completely restored;

f) such restoration of damaged areas results in a protection at least as good as that of the undamaged areas.

There are many variable factors (both natural and otherwise) which can influence the fulfilment of all these conditions for success, and it follows that no two projects can be exactly similar. This is one reason why a "Specification" should always be included in a set of contract documents.

15.3 The prime functions of a Specification. Whether it concerns new structures or maintenance work, the prime functions of a Specification for protective treatment are as follows.

a) To state the means by which the required life of the protection system is to be achieved. ("Means" includes materials, surface preparation, application, storage, handling, erection, and inspection at all stages.)

b) To serve as a basis for accurate pricing and tendering.

c) To be a complete reference document for suppliers of materials, contractors, subcontractors and all other parties to a contract.

d) To provide a basis from which disputes, controversies, and arbitrations can be resolved.

15.4 Responsibilities in preparing a Specification. The Specification is usually prepared by the purchaser or by his representative (who is usually the Consulting Engineer or Architect). In certain circumstances, however, it may be prepared by others; e.g. a contractor or supplier who is submitting an offer for the supply of work, materials, or service, or a corrosion consultant employed by any party to the contract for the specific purpose of preparing the Specification.

Whoever does this work has several special responsibilities; they are to ensure that:

a) The materials specified will be available when wanted (see **21.1**).

b) The details of the requirements are given as completely as is dictated by the complexity of the work to be done, regardless of the amount of the work or the value of the contract.

c) The standards to be achieved at every stage are in fact achievable.

d) The methods of operation specified for every stage of the work from the purchase of the materials to the final acceptance of the completed structure, are in fact possible and practicable. (For example, a Specification that requires manual cleaning for surface preparation, in the belief that weathered steel will be provided, becomes impracticable if only steel with semi-adherent mill-scale is available. The Specification should allow for such possibilities.)

15.5 The communicative value of a Specification. The above-mentioned responsibilities in the preparation of a Specification are all of a technical nature and the details of how they should be fulfilled are given later in this section.

There are, however, other responsibilities which are of equal importance. It should be remembered that Specifications are the authoritative means of communication between engineers, designers and their representatives on the one hand and manufacturers and contractors on the other. This is true of all contract specifications. A protective coating specification, however, will have an unusually wide readership. In order that the supply and application of a protective coating system be successfully accomplished, all members of the team involved should have access to the same information. It follows that all, or at least the relevant parts, of the information contained in the Specification should be circulated to everyone concerned, including foremen, chargehands and operators of preparation and application equipment; possibly also to shippers, storemen and transport drivers.

Everyone of these is expected to understand what is required of him, so the wording of each part of the document should be clear, concise and absolutely proof against misinterpretation by the person(s) whose duties and responsibilities are defined in that part. The assumption should never be made that anyone expected to comply with an instruction in the Specification will correctly infer the intended meaning of that instruction if the wording of it can have any possible other meaning, however remote and unlikely. Nor should it ever be assumed (or intended) that an ambiguity is clarified by its context.

15.6 Schedules. A structural complex can rarely be protected against corrosion by a single protective system applicable to all parts of the structures. It is more likely that economies can be achieved by using different protective systems for various parts of the structure. The prime function of the Specification is then to state which system is required for each component or group of components in the structural complex. This is best done by the use of one or more "schedules", which should contain all the relevant items in the following list of basic information.

Basic items	Requirement
Component or part of project	Can be identified by reference to drawings
Sections of members	References in schedules
Special requirements	Areas such as connection surfaces requiring special treatment
Coating system	May be covered by a reference to a standard or to this code
Surface preparation	Reference to appropriate standard
Metal coating	Spray or galvanize to the appropriate British Standard
Coating thickness	Special requirements (if applicable)
Sealing for sprayed-metal coatings	Material and number of coats (if applicable)
Priming coat	Type or product name and number. Colour (if applicable)
Stripe coat	Type and product name and number. Colour (if applicable)
Undercoat	Type and product name and number (if applicable)
Finish	Any special finish requirements
Film thickness	Total or individual as required
Inspection	Levels to be observed

Such a schedule may be included as an integral part of the Specification, or as a separate document, according to whether it requires to be related to working drawings or fabrication drawings. If the schedule is a separate contract document, the Specification should be worded so that the schedule has the same mandatory authority as the Specification.

When preparing such schedules it should be remembered that fabrication works and coating shops are often geographically separated, so fabrication drawings may not be available to the coating operators. In such cases a comprehensive "coating schedule", with diagrams if necessary, should be supplied to the coating operator, preferably as an integral part of the Specification.

The schedule should, where necessary, define those areas that are not to be treated in a special manner.

The following features of a structural complex are those frequently requiring special treatment (especially where paint coatings are specified).

a) Meeting faces of connections.

b) Contact surfaces with concrete.

c) Machines or bearing surfaces.

d) Areas associated with plated and galvanized components.

e) Cover plates.

f) Welds and areas adjacent to welds.

It is essential that the identification marking of such areas be understood by all parties and the Specification should define how such identification marking is to be made.

15.7 Details. Following the schedule, the Specification should set out, in logical sequence, all the instructions deemed necessary to ensure that the potential lives of the various coating systems are realized. No detail should be omitted if such omission can adversely affect the achievement of that aim.

Clauses **16** to **33** of this section are intended as a guide from which the technical details required can be selected.

15.8 Definition and allocation of responsibilities. A protective coating scheme, perhaps more than any other single aspect of a major construction project, requires the cooperation of many officers and operators of different trades and professions and of many suppliers and subcontractors with independent managements. Such cooperation will be most effective if each responsible party knows, as early as possible, the exact limit of responsibility within the overall organization of the project. Thus any difference of opinion or controversy that may arise within a contract regarding materials and workmanship, or any departure from the Specification may be resolved without delaying the progress of the work and without resort to arbitration.

It may not be possible to write all such details into a Specification that is being prepared before all other technical details are finalized, but the desirability of such an inclusion should be borne in mind throughout all the stages of design, choice of coating system, choice of materials and planning of the methods of surface preparation and coating application. Methods of transport, handling, storage and erection are equally important phases of the total work which will affect the interrelation and hence the definition of responsibilities.

The following is an example of the sort of complexity that can make the division of responsibility both difficult and important.

A coating system may be such that all stages can be completed at the fabricator's works or by a specialist firm of coating contractors. On the other hand it may be convenient, or economic, or necessary that surface preparation and possibly part of the coating be done by the fabricator and part or all of the coating by the coating contractor. In such cases the division of responsibility is clear cut, but the issues are not always so simple.

For reasons dealt with in detail in other sections of this code, it may be convenient, desirable or necessary for one or more stages of the coating system to be applied on site before or after erection, and possibly by a different contractor. Decisions on the apportioning of work between works and site, and between contractor and contractor, should be made at some appropriate stage in the design. It may happen that circumstances arise after the award of the contract which require the arrangements to be changed.

The important fact is that divisions of responsibility for the performance required of the coating have been introduced. The Specification should allow for this, and after the initial definition of responsibilities should state how and/or by whom the responsibilities should be re-allocated in the event of changes in the planned procedures.

Clauses **16** to **33** give advice on how each phase of the protective treatment operations should be specified.

16 Surface preparation

16.1 Degreasing. Suitable degreasing procedures should be specified for all surface preparation (see **14.2**).

16.2 Removal of rust and scale. The detailed instructions will be determined by the choice of cleaning method (see **14.3**). Points to be considered for each method are given in **16.2.1** to **16.2.4**.

16.2.1 *Blast-cleaning.* Specification clauses for blast-cleaning may vary according to whether a paint or metal coating is to be applied.

16.2.1.1 *Salt contamination of blast-cleaned surfaces.* In addition to defining the surface cleanliness of blast-cleaned surfaces, it may also be necessary to specify the minimum permissible contamination of the surfaces by deposits of hygroscopic salts. These will be revealed by testing (see appendix G), and the inclusion of clauses in the Specification to cover washing with water or wet blast-cleaning may be necessary.

It should be ensured that any salt solutions resulting from the washing of surfaces can be drained or flushed away so that there can be no further precipitation of salts by the drying-out of the surfaces of the cleaned steel (or of any other surfaces nearby).

16.2.1.2 *Blast-cleaning for painting.* The required standard of cleaning can be defined by reference to the appropriate quality in BS 7079. The Specification may also include information on the following.

a) Method of blast-cleaning.

b) Abrasives and any restrictions on type and size.

c) Profile, e.g. the maximum amplitude of the surface roughness suitable for the protective system. It is also advantageous to specify the instrument to be used for measuring surface roughness.

d) Standard of cleanliness. Reference should be made to BS 7079 or Swedish Standard SIS 05 59 00. Where appropriate the method of measuring cleanliness (e.g. "Surclean") may be specified. In certain instances, it may be preferable to specify final cleaning using vacuum equipment to reduce dust nuisance in the coating area.

e) Reference plates prepared for inspection purposes should be of a similar grade of material to that of the general surfaces and they should be prepared in a similar manner. The surfaces of the reference plates can be preserved by using silica gel or by lacquering. Replica films, usually of a melamine or non-ferrous metal, can be obtained but they are usually treated as inspection aids rather than preserved samples prepared to an established standard.

f) The blast primer should be applied before the surface has deteriorated below an acceptable level. Maximum periods between surface preparation and application of blast primers should be specified.

16.2.1.3 *Blast-cleaning for metal-spraying.* BS 2569 specifies a performance requirement for metal-spraying and blast-cleaning, therefore blast-cleaning is not usually specified separately.

16.2.1.4 *Blast-cleaning for galvanizing.* Any special blast-cleaning requirements, including sample plates, should be specified if the blast-cleaning forms part of the preparation of surfaces for thicker zinc coatings.

16.2.2 *Acid-pickling*

16.2.2.1 *Standards of pickling.* Pickling for galvanizing and plating is part of each individual process and is not normally specified separately (but see CP 3012:1972, clauses **2.5** and **2.6**). There are no British or other Standards for acid-pickling and the method varies from works to works. The Footner process (see **14.3.2**) has been used for many years as a broad description of one satisfactory method of preparing steel for painting. Cold pickling processes are also now being used, but should not be specified without the relevant controls.

16.2.2.2 *Removal of rust and scale.* This may be simply specified as complete removal by pickling of mill-scale and rust.

16.2.2.3 *Cleanliness of the surface.* The Specification should call for washing to remove all excess acid and salts, leaving no foreign deposits on the steel.

16.2.2.4 *Overpickling.* This can result in the pitting of steel or in heavy deposits of phosphate, according to the process. The need to avoid overpickling should be covered by an appropriate clause in the Specification.

16.2.3 *Flame-cleaning.* Flame-cleaning is not usually specified for new work, but is commonly used to prepare surfaces for maintenance painting (see **14.3.4** and **50.2.2**).

The following precautionary actions should be specified.

a) Avoid overheating, because it causes distortion of members or modification of steel properties.

b) Ensure that rate of flame movement is sufficiently slow to avoid deposition of moisture.

c) Wire-brush the surfaces immediately after application of the flame, then use dry air-blow or vacuum equipment to remove detritus.

d) Select correct mixture ratio of gases to give best results.

e) Apply priming paint to surfaces that are still warm but not hot from the flame-cleaning process. This requirement may be considered to be of sufficient importance to require reheating and further cleaning of surfaces that have cooled. It may, however, be desirable to limit the surface temperature to a maximum of 40 °C before paint is applied.

16.2.4 *Manual cleaning.* (See **14.3.4**.) Descriptive specifications for cleaning with hand-held tools are difficult to prepare. Reference can be made to Swedish Standard SIS 05 59 00 for pictorial representation when appropriate. Other factors that should be considered during the preparation of specifications for manual cleaning are as follows.

a) Possible use, or limitations regarding the use, of various types of power tools.

b) Use of bronze tools to reduce risk of sparking in areas subject to risk of explosion.

c) Methods of removing dust and detritus.

d) Limitations on use of hand-held tools to prevent surface damage such as indentations, cuts, peaks or burrs.

17 Coating system

The coating system should be clearly specified. Where British Standards exist, as for metal coatings, the relevant standard should be quoted and so should system references in accordance with Table 2 where appropriate; alternatively the product references given in this code (see section 2) may be quoted, together with the proprietary name of the product where appropriate.

Where a system reference in accordance with Table 2 is not used, each part of the system should be specified separately as indicated in section 2, e.g. a paint system should be separated into blast primer, main primer, undercoat(s), and finishing coat.

To assist application and inspection, a difference in the shades of colour of successive coats may be specified. When choosing the shades, the need for obliteration by the finishing coat should be taken into account.

The Specification should include details of the remedial action to be taken when part of the coating system is damaged during transport, handling, storage, or erection (see clauses **24**, **25**). The details given should ensure that the remedial action specified is capable of restoring, to the damaged coating, the same potential life as that of the undamaged areas.

The use of alternative materials or systems may be permitted by clauses in the Specification (to assist the contractor in the preparation of a competitive tender or for any other reason). The need to substitute alternatives may also arise, for a variety of reasons, during the execution of the contract. Should the use of alternatives be permitted, either as a part of a tender submission or during the execution of the contract, it is important to ensure that all possible combinations of alternatives are compatible one with another and with all other aspects of the overall contract. The responsibility for the correct performance of alternative systems and systems employing alternative materials should be clearly established.

18 Stripe coats

Extra coats of paint may be specified for areas where the shape and/or plane of application result in thinly applied coatings, e.g. at the edges. Such areas are often also subject to severe abrasion. To compensate for these effects, stripe coats of paint can be applied; stripe coats of primer and/or undercoat can be used to give increased film thicknesses, and stripe coats of finishing paint can be used to improve abrasion resistance. Stripe coats are normally applied first in order that they will be covered by the full coat, thus ensuring that there will be a double film thickness on the most vulnerable areas.

19 Control of thickness of paint coating

The two methods of specifying the film thickness are based on:

a) control of wet-film thickness;

b) measurement of dry-film thickness.

Dry-film thickness is the final requirement but the measurement of wet-film thickness is often convenient as a quality control procedure. It is essential to obtain, at an early stage, a good relation between the wet- and dry-film thicknesses for the coating system to be used. Using wet-film-thickness measurement, it is possible to detect departures from specification requirements and to correct them during the application process. This reduces the necessity for dealing with substandard dried or cured coatings.

It is not usual to specify wet-film thicknesses and their relation with the thickness of dry film can be established when preparing test panels.

Dry-film-thickness gauges measure only the total film thickness present when the reading is made. Wet-film-thickness measurements indicate only the thickness of each individual coat.

The type of gauge that is to be used for the measurement of film thickness should be specified.

Variation of film thickness is inevitable and although a minimum thickness can be specified, it is often preferable to specify a nominal thickness. Where a relevant British Standard exists (e.g. BS 2569) it should be quoted. In other cases it should be specified that over any square metre of a scheduled area (see **15.6**) the average of the readings taken should equal or exceed the nominal thickness and in no case should any reading be less than 75 % of the nominal thickness. In the Specification for the particular project, a specifier may feel justified in using a different percentage but it is essential to use figures that are based on practical requirements for the systems being used and surfaces being coated. The use of unrealistic figures can result in extra costs and these will not be justified by the results obtained.

It is not usual to specify destructive testing to measure film thickness. It can, however, be used in cases of dispute and most Conditions of Contract make provision for this.

Specifications can place more emphasis on wet-film thickness for quality control when solventless coatings, especially those with high-build properties, are used.

Having defined the quality control method by use of the film thickness, it is not usual also to define the rate of paint application in l/m^2 (litres per square metre). It may be, however, that when the coating of test areas is specified, manufacturers' figures for coverage can be checked during the tests and the records will provide useful data for inspection purposes.

It is important to consider roughness, profile and cleanliness of the proposed steel surfaces when preparing specifications for liquid-applied anticorrosion coatings on steelwork. Changes in profile can result in variations in the readings of a magnetic film-thickness gauge at different points of the same coating.

20 Control of thickness of metal coating

20.1 Galvanizing. Where necessary, information on coating thickness to supplement the information given in BS 729 or other appropriate British Standards, should be included in the Specification.

20.2 Sprayed metal. The thickness requirements and also the permissible tolerances, where applicable, should be included in the Specification.

21 Materials

21.1 Availability. It is advisable to check with the manufacturers and/or suppliers, to ensure that sufficient supplies of the specified materials are or will be available to meet the programme. If alternative materials are subsequently permitted, owing to a change of programme or other requirements, they should be as suitable as those previously chosen and compatible with one another, whatever combination is eventually used.

21.2 Control of materials

21.2.1 *Storage.* The Specification should define storage conditions for materials. When geographical locations and meteorological conditions of storage are likely to be in any way abnormal, the manufacturer of the materials specified should be informed so that any special recommendations for storage can be made. These and any other recommendations made by the manufacturer, should be included in the Specification, together with details of maximum and minimum temperatures, suitable buildings, shelf life, etc. Instructions should be given regarding batch numbering and its relation to date of receipt so that a sequence of storage can be organized to ensure that materials are issued from the store in the same order as that in which they were received.

21.2.2 *Testing.* It is not usual to test materials in the condition in which they are delivered to the applicator (i.e. to take samples from freshly opened containers). The Specification may however require samples to be provided and retained in original unopened containers for subsequent testing should the coatings fail to perform in a satisfactory manner.

Adulteration of paint can occur between the opening of a new can and the application to the surfaces. Detection of excess thinners in paint usually requires samples to be taken from spray-equipment containers, kettles or other receptacles. The Specification should state what are the contractor's responsibilities for providing samples and also what tests are necessary should he be required to arrange for them with an approved testing establishment.

21.3 Preparation for use. The Specification should stipulate that the following precautions be taken when preparing materials for use.

a) Correct materials, including batch numbers, colour, etc., should be supplied.

b) All the paint components of a coating system should preferably be obtained from the same manufacturer. However, if this is not possible, it is essential to ensure compatibility between products (see **12.1.4**).

c) Proper mixing should be carried out in accordance with specified instructions, e.g. the manufacturer's data sheets.

d) No thinners or other additions should be allowed, except as recommended by the manufacturer in agreement with the Engineer. Any relaxation that will be permitted, e.g. the thinning of a brushing grade to give it a consistency suitable for spraying, should be clearly indicated in the Specification.

e) Arrangements should be made for keeping paint (other than thixotropic materials) stirred to maintain the correct consistency during application.

f) Problems arising from either very hot or very cold conditions at time of application, should be referred to the paint manufacturer.

g) Materials taken from store should attain the temperature recommended for use before being applied.

22 Application of protective coatings

22.1 General. There are two basic methods of specifying how protective coatings should be applied:

a) to use a performance-type specification, i.e. to stipulate the coating material and thickness required, leaving the applicator to use the most suitable and economic method; or

b) to use a complete method specification, i.e. to specify in full detail the type of equipment and method of application.

Some specifications can be very concise where references can be made to a British Standard that fully defines the process and quality required. It is important however, when detailing work to be done on site to consider any possible limitations imposed on the process by adjacent operations.

22.2 Painting. The type of paint chosen frequently decides the method of application.

Brush, spray and roller are the methods commonly used to apply paints to structural steelwork, although other methods (e.g. dipping) may be used.

22.2.1 *Brush-painting.* The advantage of brushing is that it can apply shear forces within the paint where they are most required and so affect the consistency of the paint that it will spread into crevices and other irregularities. It has a disadvantage that it is labour intensive and slow for large areas.

Brush application has also the following advantages.

a) It is useful for small areas where a high proportion of masking would be required if spray application were used for general surfaces.

b) It is an alternative to spraying where toxic or other health hazards preclude that method.

c) It is less likely than spraying to result in contamination of surrounding areas by paint.

The best results are obtained when specifications require the first coat of inhibitive primers to be brush-applied and this will apply to stripe coats where they are used. It is also often found to be convenient to brush-apply stripe coats of intermediate and finishing coats, even where other methods are used for applying full coats. (It is essential to ensure that the grade(s) of paint supplied suit both methods of application if there is any possibility that they might both be used.)

An extra brush-applied undercoat and/or finishing coat can be specified to ensure a good coating thickness at the edges of members. This technique provides extra benefit when undercoats and finishing coats are spray-applied.

Good quality animal bristle or nylon bristle should be used for brush-painting. (See BS 6150 and BS 3900-A5 respectively for notes for guidance on paint application and large-scale brushing tests.)

22.2.2 *Spray-painting.* In spray-painting, the liquid paint is atomized and projected on to the surface. One of the two following methods may be used.

a) Conventional air spraying, in which atomization is induced with compressed air and a low-pressure stream of paint droplets is issued from the nozzle.

b) Airless spraying, in which a stream of paint is projected at very high pressure through a small nozzle and the sudden release of pressure, as the jet issues, atomizes the paint.

Paint may also be applied by electrostatic spray but this method is not generally used for structural steelwork.

Conventional air spray enables paint to be applied rapidly but waste is high compared with brush-application. Airless spray has an even higher speed of application and wastes less paint than air spray; it is generally the most economical method of application for structural steelwork.

To achieve good results spray equipment should be properly handled by trained operators. The higher rates of paint deposition obtained when using airless-spray equipment means that more skill is required by the operator to obtain uniform coatings.

The application of paint by spray equipment may be restricted by factors which include the following.

a) Overspray may not be tolerated.

b) Some types of paint create a toxic hazard when sprayed.

c) Some areas of structures may not be suitable for spray-painting.

d) Specified paints may not be available in a quality suitable for spraying.

e) High winds can make spraying difficult.

22.2.3 *Other methods.* Roller application is useful for large flat areas.

For dip-painting, surface preparation is followed by complete immersion in paint. This is the favoured method of coating surfaces when access to internal surfaces is difficult for normal application equipment. It is used largely for applying protective coatings to pipes.

Some materials used for the provision of very thick coatings have a very high viscosity and can be applied only by daubing or trowelling. It is useful to consult the manufacturers' literature when preparing specification clauses for the application of these materials.

22.2.4 *Surface finish.* Where the main requirement is the maximum uniformity of paint coatings, the normal criteria of a specification are cleanliness and the amplitude of profile variations. Where aesthetic or other considerations demand a smooth finish it may be necessary to include in the Specification further clauses regarding the smoothing of surfaces and/or filling between coats. Where such a finish is required there is usually a limit to the choice of application method and the Specification should define that limit.

22.2.5 *Paint-application-procedure trials.* On large projects paint-application-procedure trials are recommended. The same labour and equipment proposed for the main work should be used and details should be included in the Specification.

22.2.6 *Other general requirements of a painting Specification.* In addition to the foregoing specific instructions, the Specification should include the following requirements.

a) Each painter employed should be skilled and experienced in the method he is using and the supervisor should be skilled in each method under his control.

b) No paint should be applied to any surface until that surface has been prepared and cleaned to receive the paint in accordance with the Specification.

c) No further paint coat should be applied until the previous paint coat has dried or cured sufficiently to receive it. With some coating materials, it is advisable also to place a limit on the maximum period between coats to avoid intercoat contamination and to eliminate any other possible cause of intercoat adhesion failure.

d) Where, for any reason, the Specification has omitted relevant details, and where such details are given in manufacturers' data sheets, the relevant manufacturers' instructions should be observed as if they had been included in the Specification.

22.3 *Galvanizing and metal-spraying.* The application of zinc and aluminium by these methods is covered by various British Standards (see clause **11**) which safeguard the quality of the finished product.

The Specification should indicate areas not to be coated with metal. For example, the interior of a box girder may be left untreated when the outside is metal-sprayed. In addition the fabricator may decide to leave some weld fusion faces uncoated. Such faces can be masked with tape and the permanent protection can then be subsequently applied.

The shape of a steel fabrication may prevent access to some surfaces for metal-spraying, or it may be too large for galvanizing. Large flat units such as joist sections are well suited to metal-spraying but for small sections, as in lattice construction, galvanizing would be more economical.

22.4 Wrapping. The following important aspects of wrapping processes should be covered by the Specification.

a) The percentage side lap of parallel wrapping strips.

b) The overlap at end joints and at other joints in the wrapping.

c) The method of application of the wrapping or tape so that it adheres closely to the surface without sagging or air pockets.

d) Smoothing of the contour of any protuberances by the application of a suitable mastic before wrapping.

e) Avoidance of folds. The material should be slit along the line of a fold and pressed flat with any necessary additional applications to complete the sealing of the surface.

f) Smoothing of petrolatum-impregnated[10)] materials to a satisfactory finish on completion of the wrapping.

[10)] Petrolatum is petroleum jelly used for impregnation.

22.5 Mastics and sealants. The terms "mastics" and "sealants", as used in this code, cover a wide range of materials normally used for various methods of waterproofing joints and surfaces. They usually have a viscosity that makes them unsuitable for the normal brush, spray or other types of application used with liquid coatings.

The more common types of mastics and sealants, together with some of their more important properties, are listed in Table 7.

It is not practicable to list all the possible applications for each type of mastic or sealant and it normally follows that the material with the properties most suited to the performance requirement of the particular application is used. Some of the more important factors to be considered are listed below.

Durability, which depends on environment.
Permeability.
Elasticity or plasticity.
Creep.
Application method: pour, trowel or gun.
Cost.

Most of these materials are obtained as proprietary articles and the Specification requirements to obtain successful applications will therefore be based largely on manufacturers' information. However, the Specification may include clauses to cover the following more important aspects of good application.

Surface preparation.
Priming of surfaces if necessary before application of mastic sealant.
Correct method of application to proper thickness.
Precautions to be adopted during application.
Special drying or curing requirements.

23 Working conditions

23.1 General. The conditions under which protective coatings are applied have an important influence on the quality and life of the complete system. It is easier to control conditions in an enclosed shop than on an exposed site, and for some coating systems application in a shop is essential and should be specified.

When a specification defines the limits of environmental conditions in which coating work can proceed, it should take into account the application properties of the materials being used and should suggest practical methods for improving the immediate environment of the application and drying and curing processes. Generally wide controls (such as specifying that no operation may be undertaken when the temperature is below 4 °C or the relative humidity higher than 80 %) may lead to unneccessary interruptions of work.

Some materials and application processes are not so sensitive to inclement conditions and some relaxation may be permitted in the Specification. These requirements may affect system selection where work is carried out in difficult environments.

23.2 Temperature. The temperatures of the environment and of the surface to be coated can affect the following characteristics of paint before, during and after application.

a) Solvent retention.

b) Viscosity of liquid coatings and consequently the brushing and spraying properties.

c) Thickness and appearance of dry films.

d) Drying time.

e) Pot-life, curing time and overcoating periods of two-pack materials.

The Specification should insist on compliance with the manufacturers' recommendations regarding temperature limitations.

Where it is necessary to raise ambient temperature within an enclosure or to heat a surface, only indirect heating or electrically heated blowers should be specified. For most coating processes, the Specification should prohibit the use of heaters that exhaust combustion products into the working environment. (Exception may be made where flame-cleaning is specified for surface preparation.) A temperature change within the normal range has little effect on metal-coating application unless it affects the dew-point of the environment; the Specification requirements can therefore be less stringent.

23.3 Humidity. The Specification should stipulate that coatings are not applied to surfaces where the relative humidity of the atmosphere is such that:

a) condensation is present on the surface; or

b) it will affect the application and/or drying of the coating.

The Specification should further stipulate that:

c) when a rising relative humidity reaches a value such that it produces either of the conditions given in a) and b) above, the application of coatings may not be started, or, if already started, shall be suspended; and

d) during the time that the relative humidity remains at or exceeds that value the work may not be started or resumed.

When selecting limiting values of relative humidity, the thermal inertia of large sections should be considered relative to condensation. A contact thermometer should be used to determine if the surface temperatures are above or below the dew-point. It is advisable to ensure that the steel temperature is maintained at not less than 3 °C above the dew-point.

When heating is being used to control the relative humidity of the environment in enclosed working spaces, it is usual to specify that heaters which exhaust combustion gases into the working environment should not be used (see **23.2**).

23.4 External conditions. In order that the Specification is not unduly restrictive, clauses may be included that will permit preliminary preparation to be done in the open under conditions that would not be suitable for final preparation. Preliminary surface preparation may include removal of oil and grease, initial blasting, chipping, wire-brushing, etc.

Table 7 — Common types of mastics and sealants

(Reproduced from the Engineering Equipment Users Association Handbook No. 31 (1973), by permission of the Association.)

Sealant or mastic	Type of change	Pot-life	Cure time (drying time)	Application methods	Primers	Operating temperature, °C	Elongation (maximum)	Tensile strength, MN m^2	Hardness (Shore Scale A)	Shrinkage (typical	Approximate relative cost (with bitumen as unity)
Polysulphide (two-part)	Cure	Hours	Days	Pour Gun	Yes	– 50 to 110	150 to 500	0.35 to 0.88	15 to 50	0.3	7 to 8
Polysulphide (one-part)	Cure	Not relevant	2 to 3 weeks	Gun	Yes	– 50 to 110	100 to 250	0.35 to 0.88	15 to 60	< 1	8 to 12
Epoxy (two-part)	Cure	Hours	Days	Pour Gun	No	– 20 to 100	5 to 15	14 to 70	90 to 100	0	4 to 6
Epoxy polysulphide	Cure	Hours	Days	Pour Gun	No	– 20 to 110	10 to 20	7 to 21	40 to 80	0.3	8 to 10
Polyurethane (two-part)	Cure	Hours	Days	Pour Gun	Yes	– 55 to 90	250 to 450	0.35 to 1.4	10 to 40	0	4 to 5
Polyurethane (one-part)	Cure	Not relevant	2 to 3 weeks	Gun	Yes	– 55 to 90	250 to 450	0.35 to 1.4	10 to 40	0	4 to 5
Silicone (two-part)	Cure	Hours	Days	Pour Gun	Yes	– 60 to 120	50 to 250	2.8 to 4.2	20 to 50	0.1	12 to 14
Silicone (one-part)	Cure	Not relevant	Days	Gun	Yes	– 60 to 120	50 to 250	2.8 to 4.2	20 to 50	0.1	12 to 14
Acrylic (one-part)	Thermoplastic	Not relevant		Hot Gun	Yes	– 20 to 75	100 to 270	0.35 to 2.8	5 to 20	0	5 to 6
Butyl (one-part)	Solvent release	Not relevant	Days	Gun	No	– 20 to 75	5 to 10	0.17 to 0.7	5 to 15	< 5	2 to 3
Oil-based	Solvent release skinning	Not relevant	Weeks	Gun	No	– 10 to 70	5 to 50	0.35 to 0.14	5 to 10	< 3	1 to 2
Bituminous	Thermoplastic	Not relevant		Pour Gun	No	– 10 to 70	5 to 20	0.7 to 1.7	10 to 30	< 1	1.0

Surface preparation immediately prior to application of protective coatings, however, should not be carried out under conditions of rain, fog, mist, sleet or snow, nor where temperature and relative humidity are such as to cause dew to form on surfaces to be treated. These restrictions also apply to most priming and coating operations. It is also necessary to protect the coatings where the drying or curing process is not sufficiently advanced to withstand any imminent deposition of moisture or wind-borne dirt and dust.

The Specification should usually include clauses that require work to be suspended when sea spray, dust, or other pollutants are contaminating the surface. It should also require such surfaces to be further cleaned and prepared before additional coatings are applied.

23.5 Contamination of prepared surfaces and wet film. Where surface preparation, coating work, or other processes likely to cause contamination are proceeding simultaneously, the Specification should require precautions to be taken to ensure that prepared surfaces or surfaces with a wet coating are not contaminated.

23.6 Shop conditions. When the Specification stipulates that all coatings are to be applied in an enclosed shop, the entire programme of fabrication surface preparation and coating application should be planned in detail at an early stage in the design procedure.

Cleaning operations that produce, dust and detritus, particularly nozzle blasting, should be geographically separated from coating operations. It has been found in some large fabrication works that the necessary conditions for protective coating operations cannot be maintained without the erection of special structures inside the factory to separate the two processes.

Where separate accommodation is provided for different parts of the preparation and coating processes, it is essential to arrange that prepared or partially coated surfaces are not allowed to deteriorate or to become contaminated in any manner, especially as a result of being taken outdoors and/or moved through contaminated environments.

It may be advisable to check that the contractor can fulfil the specified requirements of cleanliness, temperature and humidity before starting the work.

23.7 Lighting. Adequate lighting of surfaces is essential. This may be provided as a general service for all trades and contractors, or it may be the responsibility of the coating contractor, in which case some reference should be made in the Specification to illumination for work and inspection. One method of ensuring adequate illumination is to define the number of lumens falling on the surface; 500 lumens has been found to be a satisfactory figure for most operations. However, this may not be high enough for dark colours or for applications where insufficient colour contrast between successive coats is available, e.g. grey metallic zinc priming of blast-cleaned surfaces.

It is difficult to provide adequate lighting for blast-cleaning operations. However, this is not so critical if adequate lighting is provided for inspecting the quality of the cleaning on completion. Badly cleaned areas resulting from inadequate lighting can be given further cleaning.

23.8 Hot conditions. The Specification should state the conditions that will prevail when coating hot surfaces or applying coatings in hot environments where such conditions are not within the control of the contractor. The system included in the coating schedules should be suitable for application to these surfaces and/or in these conditions.

23.9 Health and safety. Contractors carrying out coating work are required to comply with all relevant regulations (see section 6).

Clauses should be included to require precautions to be taken to avoid risk to health and safety where there are hazards additional to those covered by the statutory regulations and others. There may be special requirements relative to the owner's premises or other areas where the work is carried out.

24 Handling, transport, storage and erection

24.1 Selection of coating systems. One of the factors taken into account when selecting a coating system for a particular item is its resistance to mechanical damage during service. When works-coated steelwork is involved, the risk of damage to coatings during handling, transport, storage and erection is greatly increased and the coating's resistance to mechanical damage assumes prime importance.

In addition to the risks of mechanical damage, coatings applied at works may also be subjected to many different adverse environments during transport and storage of steelwork before erection. Marine and other contaminating environments of various types, high humidity, and prolonged exposure for a variety of reasons may have to be allowed for. In some cases covers and other forms of protection may be provided prior to erection but in most cases, the coating system shall take these requirements into account in addition to fulfilling its role when in normal service.

Mechanical damage to coatings is of less consequence when only part of the system has been applied, because the making-good of damage to a full coating system is more difficult and costly, and may even be impossible where patch-painting of a final coat is not permitted. However, the adoption of a policy of partial coating at works and completion of the system at a later stage may lead to problems of intercoat contamination, and the resistance of the coating to the effects of adverse environments during transport and storage is reduced.

24.2 Methods of preventing damage. Care in the selection of coating systems will help to minimize damage to coatings before erection. Features which can be incorporated in the design of the fabrication and other measures which can be adopted to reduce further the effects of mechanical damage are as follows.

a) The design should include lifting lugs or brackets where practicable.

b) The provision of a special lifting harness, nylon slings, rubber protected chains and chocks, etc.

c) An adequate drying/curing period for each coat and for the complete system before handling.

d) Methods of loading that will reduce site handling to the minimum.

e) Order and timing of loading to reduce site storage to the minimum.

f) Special supports, packings and lashings on the vehicles and trucks, and stacking in holds and on decks, to avoid chafing.

g) Special wrapping of coated pipes and packaging of smaller items.

24.3 Storage of coated steelwork. The degradation of coatings on stored steelwork can be minimized (especially in poor environments) by the adoption of the following precautions.

a) *Separators.* Coated surfaces should preferably not be in contact. Wrapping, packaging or crates used to reduce damage whilst items are in transit may perform this function. For large items, timber packings should be specified.

b) *Stacking.* Components should be stacked in such a manner that there can be no ponding where cover is not provided. It may be necessary to limit the number of layers in a stack. The bottom layer should be laid on packings raised above the ground and the rain splash zone. Timber, usually of a softwood variety, provides a good surface on which coated steelwork may be stored with minimum damage to the coatings. Timber packing may be set on top of concrete or other more rigid supports. The area of the timber in contact with the members should be sufficiently large to avoid damage to the coatings, taking into account the dead weight of the steelwork stacked on the packing. The number of positions of the packing should ensure that steelwork is not distorted. Packings should be reasonably clean and free from any contaminating agents which may adversely affect coatings.

24.4 Responsibilities for preventing damage. The responsibilities for care of the coatings should be given careful consideration, since the benefits of careful coating work and handling whilst the items are at the works can be lost by rough treatment during transport to, or storage on, the site. The possible variations in the methods of transport and handling whilst steelwork is being moved and erected and also in storage environments, and other considerations are limitless. It is not possible to give firm recommendations and the requirements for each project should be considered individually. It is essential, however, that the responsibilities at the design and erection stage are clearly defined and that decisions on coating systems, design requirements, methods of transport and handling, equipment used and other special measures, are taken with a clear understanding of all requirements.

25 Treatments for connections and other special areas

25.1 General requirements. The treatment specified for the surfaces of bolts, nuts and other parts of connections should ensure that such surfaces have a standard of protection against corrosion at least equal to that provided for the general surfaces.

The coatings on some surfaces of connections and connectors are more liable to mechanical damage during erection and assembly than those on general surfaces. Specification of different coating systems may help to reduce the greater risk or the effects of such damage.

Alternatively the coating of connection surfaces may be delayed until after erection.

Other surfaces of connections that may require special treatment are the meeting faces of structural connections made with high-strength friction-grip bolts.

25.2 Bolts. Some of the treatments that may be specified are as follows.

a) Black bolts in steelwork that has been manually cleaned after weathering may be prepared and coated in the same manner as the general surfaces.

b) Where black bolts are to be used for connections and all surfaces are to be prepared by blast-cleaning after bolting-up is completed, the exposed surfaces of the bolts, nuts and washers should be cleaned at the same time as the general surfaces. This also applies if high-strength friction-grip bolts are used in similar circumstances.

c) Where general surfaces of steelwork are prepared by blast-cleaning before bolting-up and it is not practicable subsequently to utilize the same preparation method for the connector surfaces, then pickling of the bolts may be specified to remove scale and to assist in manual preparation of the exposed surfaces for coating.

BS 4604 states that high-strength friction-grip bolts are normally supplied with a light coating of oil. This coating will be removed by weathering and/or swabbing with solvents. Pickling of these bolts for plating or other coating process should not be specified without full consultation with the manufacturer and the Engineer (see also **8.2**).

d) Electroplating with zinc or cadmium should be specified in accordance with the requirements of BS 3382-1 and BS 3382-2. The thickness of the coating should ensure that the protection offered is similar to that provided for the general surfaces. It is usual to specify additional paint coatings where plated bolts, with protective coating equivalent to that used on the general surfaces, are not available.

Where the components are subsequently to be protected with a full paint system, then the plating should be specified "without passivation" and any corrosion products visible after assembly should be removed before priming with one of the special types suitable (see section 2).

Where the components are not to be painted, then the plating thickness should be 25 µm min. and passivation should be specified, the colour to be agreed by the Engineer.

Cadmium-plated connections should be identified; on no account should they be flame-cut or welded, because of toxic fumes, which can be lethal.

Where zinc plating is specified for high-strength friction-grip bolts, etc., see h) below.

e) Sherardizing should be specified in accordance with the requirements of BS 4921:1973, class I (30 µm min.) Primers of suitable types should be applied as soon as possible after assembly. Phosphate passivation may be specified for improved performance and satisfactory adhesion of paint coats.

f) Mechanical plating, when available, may be specified for the higher-strength steel bolts to give the minimum thickness for galvanizing followed by centrifuging (see g) below). The process does not require pickling of the steel and this should be stated.

Corrosion products should be removed before painting and the primers should be of a suitable type.

g) Bolts may be specified as being galvanized according to the requirements of BS 729. It is normally further specified that they are centrifuged to ensure free running threads. The minimum coating thickness specified is 43 µm, but thicker coatings can be obtained where required. Where general-grade high-strength friction-grip bolts are required, a galvanized finish may be specified subject to the recommendations of c) above.

Passivation of coating should be omitted from the specification requirements where the surfaces of galvanized connectors are to be painted.

h) Where zinc coating is preferred for high-strength friction-grip bolts, screwed rods, etc., then one of the following should be specified for the associated nuts, to prevent galling.

1) Allowance should be made in the manufacture of these items to ensure sufficient clearance on screw threads to maintain a minimum coating thickness.

2) Tapping to remove zinc, and threading the nuts on to the bolts at works to reduce corrosion in storage.

3) Electroplating the nuts with cadmium instead of zinc to a thickness equivalent to that on the bolts.

i) Spraying of bolt heads and shanks may be justified in some circumstances.

j) All fixings should be stored in such a manner as to ensure that they do not become corroded or contaminated. Exposed parts of fixings should, after assembly, be degreased before surfaces are prepared or coatings applied. Access to coat the surfaces of connections can be difficult and it is often necessary to specify that paint shall be applied by brush.

25.3 Surfaces of connections joined by bolts

25.3.1 *Non-friction-grip bolted connections.* Where the surfaces of fabricated components are prepared and coated before erection, the surfaces of the joints are usually coated at the same time. The joint surfaces of steelwork erected with a mill finish are usually specified to be coated with priming paint, especially where the joints are subsequently exposed to external conditions. As a further protection against the ingress of water into the joint, a further coat may be specified with joint surfaces being brought together while the paint is wet. This requirement may also be specified for steelwork prepared and treated with a blast primer where the remainder of the system is applied after erection.

Brackets, clips, cable-hangers and similar items to be bolted to blast-cleaned steel with a blast primer should (if they are not factory-finished) be cleaned and primed in a similar manner before being fixed.

25.3.2 *Faying surfaces of structural connections joined by high-strength friction-grip bolts.* It is important that the friction characteristics of such faying surfaces be preserved. Paint coatings may affect them adversely. Therefore, where general surfaces are protected by paint coatings it is usual to specify that the faying surfaces are masked, or in some other way shielded from the painting process.

If the faying surfaces are blast-cleaned at the same time as the general surfaces of the steelwork, it may be advantageous to specify masking and that it should be retained as a temporary protection, being removed only immediately before assembly. In such cases the type of masking should be specified to ensure minimum contamination by adhesives. The method of preparing surfaces after stripping the masking should also be specified.

Where paint over sprayed metal or galvanizing is the specified protective system, masking may be used to prevent paint being applied to the faying surfaces of connections. Roughening of galvanized surfaces to improve the slip coefficient should be carried out before masking is applied.

Edge sealing of the faying surfaces can be specified to prevent corrosion where steelwork is located in poor environments. The specification clauses should ensure that the edges on both faying surfaces are painted for a distance of 15 mm inside the perimeter of the connection.

In similar environments, where load-indicating washers or bolts with load-indicating heads requiring feeler gauges for measuring shank tension are used, it is advantageous to specify that crevices should be sealed by applying high-build paint or mastic compatible with the coating system. This sealing should be carried out after the final tightening of all bolts.

25.4 Welded work. Where steelwork is prepared and primed before fabrication, the following procedures should be specified.

a) The whole surface should be coated where weld-through primers are used.

b) Where primers are not to be applied in the weld area, masking or removal of the coating by grinding should be specified. A strip approximately 50 mm wide is normally sufficient but this may vary according to the depth of weld and/or for other reasons.

c) Where welding is required subsequent to the application of a multiple-coat system, the Specification should require each coat to be stepped back about 30 mm to allow for preparation of the weld surfaces and for making-good after completion of the weld.

Where subsequent welding of metal-sprayed steelwork is required, it is preferable for the weld area to be masked with a strip about 25 mm wide before metal-spraying. Sprayed metal is not easily removed by grinding.

Weld surfaces on mill-finished steelwork should be specified to be prepared in a similar manner to that for the general surfaces, with special attention to the removal of scale and weld spatter by grinding or chipping. This also applies to weld areas on steel surfaces treated with prefabrication primers.

Alkaline deposits left on the surface by some welding processes are removed when the surfaces are prepared by blast-cleaning, wet-blasting, pickling and/or galvanizing. Other methods of surface preparation do not remove these deposits and the Specification should provide for washing the weld areas with clean water to ensure that deposits are removed before proceeding with the preparation of general surfaces for coatings.

25.5 Clearance for coatings. Most of the British Standards relating to metal coatings make some provisions regarding clearances for coatings on the threads of screwed connectors. Specifications for coatings and design of fabrications should take such allowances into account. Similar provisions for coatings other than metal should be made as necessary.

26 Manhole and joint cover plates, pipe couplings and other small items

In addition to the precautions for packaging and storage, there are other special measures that should be specified for items such as manhole and joint cover plates, pipe couplings and other small items. Where possible, galvanized or sprayed-metal coatings should be applied. Since cover plates for high-strength friction-grip bolted joints are often reversible, the treatment should not only be the same as for the main faying surfaces, but should also be specified for both sides of the plates, including edge treatment and sealing.

27 Machined and bearing surfaces

Machined and bearing surfaces should be protected with suitable adhesive tape or other temporary protection. Satisfactory storage should also be arranged until erection or assembly.

28 Steel in contact with other materials

28.1 Coating system. The system selected for coating steel surfaces in contact with other materials should not be adversely affected by these materials.

28.2 Steel embedded in concrete. Concrete cover of adequate thickness offers sufficient protection in most environments. Coatings can affect the bond between steel and concrete, so masking of the contact surfaces whilst coating the exposed areas of partially embedded steel may be specified.

It is usual, especially in adverse environments, to specify that coatings to such items shall extend to a minimum distance of 75 mm into the concrete (or to the full depth where this is less than 75 mm). If corrosion occurs at the interface of the steel and concrete it will form corrosion products which will, in time, cause spalling of the concrete. Good detailing is essential and may entail the use of brackets with non-ferrous bolts and isolating layers or other similar measures. The use of galvanizing or other suitable coatings with additional protection to the built-in parts is usually warranted for components that are located in a poor environment and/or are required to have a long service life.

28.3 Steel in contact with timber. Measures that may be specified include the following.

a) Damp-proof layer between surfaces (e.g. bituminous paint, membrane or other compound with low permeability and sufficient durability). This is important with timber impregnated by the use of water-borne salts.

b) The galvanizing of steel surfaces gives a suitable protection to steel in contact with timber, except where the timber has been impregnated by the use of a water-borne salt preservative process. In the latter case corrosion of the zinc will occur.

c) Use of plastics washers and gaskets.

28.4 Steel in contact with other metals. Some of the more common measures specified to minimize the effects of electrolytic action, by introducing a layer of material at the interface, are as follows.

a) Coating both surfaces; a corrosion-inhibiting primer may be used on the steel surface with a barrier coating on the surface of the other metal.

b) Layer of material of low permeability between surfaces (e.g. adhesive PVC tapes).

c) Use of mastics and sealants.

d) Coating both surfaces on both sides of joint, especially where corrosion cells can form in crevices.

e) Use of plastics washers and sleeves for bolts.

28.5 Steel in contact with or near rain-washed concrete. Aluminium coating on steel in contact with wet concrete is subject to alkali attack and should be sealed or painted or both.

28.6 Steel near to surfaces subject to treatment with road (de-icing) salts. Zinc and aluminium coatings should be sealed or painted or both, as appropriate, where they may be subjected to concentration of chlorides such as may arise when rain (or thaw) follows the application of road de-icing salt.

29 Surfaces inaccessible on completion

The use of the term "inaccessible surfaces" usually means that the maintenance of coatings on such surfaces is not possible. It usually follows that they are not visible and appearance is therefore not important. However, excessive corrosion of steel in such locations can result in extensive replacement and although the use of good coatings can delay the onset of corrosion, a better solution is often obtained by eliminating such features in the design stage. This applies especially where fabricated steelwork is located in poor environments and/or is required to have a long service life.

Inaccessible surfaces may be acceptable for fabrications with short lives and/or those located in good environments. The parts of structures where such conditions exist can usually be classified as surfaces that are inaccessible after fabrication is completed, and in these cases it follows that the types of coatings used on plates or sections before they are assembled may dictate the fabrication process. For example, welding may not be practicable without damaging coatings to which there is no access after completion of fabrication. In a different classification are surfaces that are accessible after fabrication but become inaccessible after erection because of cladding or other similar reasons. These surfaces are usually more easily dealt with, in that transport or erection damage can be made good and additional protection in the form of tape or further coatings can be applied where necessary before the surfaces are concealed.

30 Ancillary equipment

It may be that ancillary equipment to be installed in the structure is not included in the general structure specification or contract. It is essential to consider the specifications for the coatings of all such components in relation to the main coating Specification, to ensure that all coatings in the completed structure or fabrication are compatible.

31 Use of desiccants

Electric dehumidifiers and suitable quantities of silica gel may be specified as a means of preventing corrosion. For such treatments to be successful:

a) all components should be effectively sealed; and

b) regular inspection and servicing should be instituted.

32 Remedial work

32.1 General. Remedial work is usually required for one or more of the following reasons.

a) Inadequate preparation.

b) Unsatisfactory application of the coating, e.g. low film thickness.

c) Degradation of the coating at a greater rate than expected.

d) Physical damage.

32.2 Defects resulting from unsatisfactory application. Where protective coatings are found to be defective on completion owing to surface defects resulting from inclement weather during the drying or curing period, it may be sufficient to specify rubbing down, followed by the application of further coating materials. With some of the materials used for coating work, a similar remedy may be specified to correct low film thickness. This can apply only where there are no problems resulting from bad preparation, surface contamination or intercoat adhesion failure.

32.3 Defects resulting from inferior preparation, materials, or workmanship. The Specification should allow for complete removal of coating systems which, on completion, are found to be defective as a result of inferior preparation or quality of materials and/or standard of workmanship in the priming or undercoating. Recoating may be permitted on a patch basis, or complete retreatment of all member surfaces may be required. Irrespective of the areas involved the Specification should require complete removal and preparation, followed by the full coating system.

32.4 Early degradation of coatings. Where there is early degradation of coatings by blistering, peeling, flaking, cracking or lack of adhesion, the Specification should require the same remedial measures as detailed in **32.3**.

32.5 Other remedial measures. In all other cases, such as change of colour, remedial measures in accordance with **32.2** may be specified.

33 Specifications for maintenance coatings

33.1 Factors for consideration. Maintenance procedures are considered in section 5. The specifications will be similar to those prepared for new work, but the following additional factors should be considered when preparing specifications for maintenance coatings.

a) The method of surface preparation may be limited to flame-cleaning or manual cleaning.

b) The specification for maintenance painting may be very similar (apart from preparation and priming) to the original painting specification where the initial coatings were mainly applied after erection.

c) When the execution of maintenance work is delayed it frequently happens that rust develops on some areas, and clauses are required in the Specification to cover the preparation and priming of such areas in addition to those for preparing surfaces of the existing intact films.

d) Accessibility for maintenance operations may be a problem.

e) Changes in the environment may have occurred since the initial coating system was selected.

f) There may be restrictions on operations because of fire risks, possible contamination, etc.

g) The weather may have an unduly disruptive effect on the application of the selected maintenance system, in which case alternatives may have to be considered.

33.2 Compatibility of maintenance with original system. Where the Engineer considers that the original treatment was successful, the first contract documents may be helpful in the writing of a maintenance specification. If these are available, the original Specification can be used again with, where necessary, modifications for surface preparation.

33.3 Location of different treatments. When different treatments are to be applied to different areas the operations to be carried out on each surface should be clearly specified. This may be done by means of drawings or schedules. If the work is marked-up on site, the materials used for marking should not interfere with the efficacy of the treatments.

Where extra or stripe coats are to be applied, a contrasting colour should be provided and the areas concerned should be specially indicated.

33.4 Coating schedule. A Schedule of Systems, as for new work, should be prepared, taking into account any special programme requirements.

34 Final check

The Specification, when complete, may be a very complex document. Before it is issued or included in a set of contract documents, the final draft should be subjected to a detailed examination to ensure that all instructions are clear and unambiguous, and especially that no mutually conflicting, contradictory or impossible requirements are included.

Section 4. Inspection

35 Introduction

The potential durability of a coating system can be realized only if it is applied to a suitably prepared surface, in the correct manner and under correct conditions. These three requirements are discussed in detail in section 3. However, painting and metal coating differ from many other industrial processes in that they are susceptible to operator abuse or adverse environmental influences throughout all stages of the work. Furthermore, it is generally difficult to deduce from examination of the completed work what has occurred. Consequently, the coating may fail prematurely, but more often the effect is a reduction in long-term durability.

Painting work should be inspected at every stage and it is important to include any surface preparation, priming or painting before delivery to site. It is preferable to use an inspection team independent of those engaged on the application work.

Inspection is not a substitute for adequate supervision and proper specification. Its primary purpose is to check that the coating specification is being properly followed, and where, for any reason, this is not so, the inspection should lead to the instigation of immediate remedial action. The Specification should state the type and degree of inspection that is to be carried out so that the contractor is fully aware of its implications before the tendering stage.

Some specialist inspection organizations provide a wider service than inspection as used in the strict sense here. For example, they provide consultancy services which could be involved in pre-site meetings, drawing-up of the Specifications, etc.; this is discussed in clause **40**.

36 Duties of the Inspector

The Inspector's duties will be determined by the nature of the inspection, e.g. the type and level required and whether it is to be carried out by the contractor or the Engineer. Some or all of the following instructions will be included.

a) Ensure that all appropriate clauses of the Specification and manufacturers' recommendations are complied with and that any deficiencies are immediately brought to the notice of the Client paying for the inspection. The Inspector has no power to suspend work (or to take any comparable action) unless that power has been delegated.

b) Maintain records of work done and supply progress reports.

c) Check that all the areas in the coating schedule have been completed.

d) Provide records of the work for maintenance purposes.

37 Levels of inspection

The level of inspection, which should be adequate for the particular job, will be determined by a number of factors, including the following.

a) Type of protection treatment, i.e. the tolerance of the material to be used. (For example, galvanizing requires a level of inspection lower than that for sprayed metal, which in turn is less than that normally required for painting.)

b) The requirements of the coating, i.e. its end use.

c) The cost of inspection relative to the value of the contract, particularly if several work locations are involved.

d) Quality of supervision to be expected of the coating applicator.

Three levels of inspection are recognized. They are defined as follows.

1) *Full.* All operations observed by an Inspector and passed as complying with the Specification before the next stage is started. (For larger projects, this may require a team of inspectors.)

2) *Intermittent.* Part of all operations observed by an Inspector and passed as complying with the Specification before the next stage is started.

3) *Occasional.* All operations observed initially by an Inspector for setting standards of workmanship. *Ad hoc* visits by an inspector thereafter.

The levels of inspection required should be specified in the inspection schedule.

38 Inspection schedule

The inspection schedule is a document that specifies the type and scope of inspection required. It serves to promote smooth running of the work by informing all concerned of the stages at which inspection will be carried out. Furthermore where the Engineer is commissioning a specialist organization it provides him with detailed information on the service offered.

The schedule is a specification for inspection and should include at least the following information.

a) Part of the project to be inspected.

b) Stage at which inspection will be made, with reference to the work stages in Table 8, where appropriate.

c) Standards (from coating specification).

d) Instruments or methods to be used.

e) Method of reporting.

39 Inspection record and reports

The compilation of clear and adequate records of inspection work is an important part of the Inspector's duties. Apart from providing the necessary information on progress, etc., they should subsequently prove to be a valuable guide to the reasons for failure or success of a particular coating system. It is important that the Inspector should keep a daily log book and that its information should be transferred to a more permanent record for circulation to all interested parties and for eventual retention by the Client.

Reporting of inspection work may be on the basis of a single structural item, e.g. bridge beams, tanks, etc., or on a time basis, e.g. weekly. The latter method is commonly used for complex structures and reduces paperwork but can lead to difficulties in the subsequent identification of the history of particular areas.

Typical report forms have not been included in this code because of the variety of requirements and methods of presentation, but in most cases at least the following information is required.

a) Appropriate information regarding the contractor and the works inspection organization.

b) Identification of areas coded.

c) Relative dates when work was carried out.

d) Condition of surfaces before preparation.

e) Condition after preparation.

f) Information on systems being applied.

g) Equipment and techniques used.

h) Working conditions.

i) Weather or ambient conditions.

j) Type of quality control checks carried out, and results.

k) Type of instruments used.

l) Handling or stacking procedures after painting.

m) Compliance or otherwise with specification.

40 Inspection organization

Inspection may be carried out by firms specializing in this field. Where required to do so they may offer additional services, including the following.

a) Pre-contract site meetings with all interested parties.

b) Advice on design difficulties that may affect a proper implementation of the Specification.

c) Pre-contract inspection, i.e., an inspection of the applicator's works to ensure that the premises and equipment are adequate.

d) Where necessary, advice on improvements in equipment, handling, etc.

e) Preparation of the Specification.

f) Liaison with coating manufacturers.

g) Advice on health and safety hazards.

The Engineer will decide where he requires these additional services, which on major projects may be essential if he has no suitably experienced staff of his own.

Specialist organizations should employ fully trained, full time inspection staff. Trust has to be placed in the inspection team carrying out the work and this entitles the Engineer to expect the team to be composed of personnel of suitable experience. At present there is no easy way of determining this other than by reputation.

41 Measurement of film thickness

41.1 Methods available. Measurement of the thickness of paint or metal coating is an essential part of the inspector's duties.

BS 3900-C5 describes the determination of paint film thickness by a number of methods. Some are destructive and are used mainly in cases of investigation or dispute. For field determination, one or more of the following methods is usually adopted.

a) Dry-film-thickness gauges using the magnetic flux or eddy current principle.

b) Wet-film-thickness gauges of the wheel or comb type.

c) Calculation from the quantities of paint used.

The first of these can also be used for metal coatings.

All the gauges and procedures for their use are described fully and detailed in BS 3900-C5, but the following additional points should be noted.

41.2 Procedures. When using wet-film gauges the following procedure should be included.

a) Several measurements should be made before the paint has set or has lost an appreciable proportion of the solvent.

b) Information on the wet-film thickness necessary to give a specified dry-film thickness should be obtained from the paint manufacturer but can be checked using a dry-film-thickness gauge.

c) The painted surface should be reasonably smooth. The readings may be disturbed by surface roughness but close-pitched irregularities, such as result from blast-cleaning, do not invalidate the use of the wet-film gauge, if the object is to measure the thickness of coating above the peaks.

When using dry-film gauges the following procedure should be included.

a) Check that the instrument correctly records the thickness of a standard shim placed on a bare steel surface of the same quality (so far as practicable) in the same surface condition as the steelwork on which the measurements are to be made. The thickness of the shim selected should be approximately equal to the expected thickness of the protective coating. If the type of instrument does not permit the adjustment of the zero reading, the reading obtained with the standard shim should be recorded; if there is a discrepancy, the actual measurements should be adjusted accordingly.

b) Repeat the calibration at least once an hour if working on the same surface, and before measuring film thicknesses on the insides of angles, however formed, and at points nearer than 15 mm from an edge.

c) Take care that the magnet or instrument case is normal to the test surface.

d) Watch carefully for evidence of indentation of the paint film during measurement; pull-off magnetic gauges show some advantage in this respect. If indentation occurs, it is often sufficient to interpose a thin standard shim, making the necessary correction to the observations.

e) Note that thick paint coatings may contract after initial measurement owing to loss of remaining solvent.

41.3 Calculations. Mean applied wet- and dry-film thicknesses can be calculated from the paint consumption on a test area and a knowledge of paint properties, from the following formulae, using available data.

a) $$t\,(\text{wet}) = \frac{1\,000\,B}{A}$$

b) $$t\,(\text{dry}) = \frac{10\,B \times C}{A}$$

c) $$t\,(\text{dry}) = \frac{10\,B \times D \times E}{A \times F}$$

d) $$t\,(\text{dry}) = \frac{1\,000\,B}{A}\left(1 - \frac{D \times G}{100\,H}\right)$$

where

t (wet) is the wet-film thickness (in µm)

t (dry) is the dry-film thickness (in µm)

A is the surface area coated (in m^2)

B is the volume of paint consumed (in litres)

C is the solids content of paint (% by volume)

D is the density of wet paint (in kg/l)[a]

E is the solids content of paint (% by weight)

F is the density of dry paint (in kg/l)[a]

G is the volatile content of paint, i.e. $100 - E$ (% by weight)

H is the density of volatiles (in kg/l, as liquid)[a]

[a] This is not an SI unit, but it is more convenient, (1 kg/l = 1 000 kg/m^3).

If paint consumption is measured by weight, B in the above formulae should be replaced by W (= weight in kg of paint consumed).

Alternatively the paint manufacturer's conversion factor from coverage (m^2/l) to average dry-film thickness (µm) can be employed when available.

Measured film thicknesses will tend, on average, to be lower than calculated values because of paint losses in application. The loss factor depends on the method of application (see appendix E, note 4).

In the absence of data specific to a given paint, approximate dry-film thicknesses can be obtained by the use of formula b) and the nominal volume solids values given in the product sections of Table 4.

42 Sampling of materials

It may be advisable to take and keep representative samples of materials such as abrasives, paints (see appendix D), etc., for use in case of dispute, and where appropriate, the samples may be sent to a specialist laboratory for examination and evaluation.

43 Inspection guide

The inspection guide (see Table 8) shows many of the types of defect that may be found during or after the various protective coating operations.

It is not intended to be a comprehensive list but is a guide to the more common defects. It should be borne in mind that new techniques, processes and materials may produce new potential defects as well as advantages.

The suggested action in the guide may be only one of a number of ways of dealing with a problem. The aim should be not only to remedy defects already evident but to prevent their recurrence.

It is emphasized that the inspection guide should be used in conjunction with the Specification and the inspection schedule. Where defects arise from processes not covered in these documents, agreement between the parties concerned is necessary before remedial action is taken.

Under the various "work stages" in Table 8 are listed suggestions for inspection instruments and equipment. In addition the Inspector should have available for general inspection work items such as liquid-sample containers, specimen bags, torch, mirror, magnifying glass, sharp knife, marking chalks and all the appropriate standards, material data sheets, specifications, etc. which are appropriate to the work in hand.

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
A. Raw steel					
1	Inaccessibility for treatment of surfaces	Visual	Design precludes access for specified treatment	Inform Engineer that the work cannot be performed as specified. Provide him with a record of work actually done	See clause **7**
2	Oil or grease	Visual	Cranes, jigs, machinery, trucks etc.	Scrub with emulsion cleaner. Rinse with fresh water	CP 3012, 1972 Not applicable for galvanizing
3	Excessive corrosion with pitting	Visual	Old stock or severe storage conditions	Allow for longer or improved surface preparation; then check for removal of soluble corrosion products (see appendix G)	Where appropriate, refer to Steel Inspector
4	Welding discontinuities, residues, spatter,	Visual	Poor welding practice	Refer to Engineer for re-welding as necessary. remove residues and spatter,	Refer to Engineer to prevent repetition
5	Sharp edges, rough welds, burrs, laminations, shelling, undercut welds	Visual	Poor fabrication	Radius edges; fettle welds and burrs as necessary. Grind out laminations and shelling. Undercut welds (extent of treatment dependent on type of coating and severity of exposure)	
6	Distortion, dishing, buckling, undercut welds	Visual	Poor fabrication	Refer to Steel Inspector	
B. Blast-cleaned steel					
1	Oil or grease, dirt, dust, detritus, water	Visual or adhesive tape or filter paper or reflectometer	a) Poor working conditions	Treat oil or grease as for **A.2** Shield working area from contamination. Improve vacuum cleaning	See clause **23**
			b) Contaminated grit	Discard grit and re-blast with fresh supply. If greasy, treat as for **A.2**	See clause **16**
			c) Contaminated compressed air	Improve oil and water traps on air supply. If greasy treat as for **A.2**	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
2	Surface too rough relative to coating thickness	Visual	a) Excessively corroded raw steel	Longer blasting time and extra coats, refer to Steel Inspector	For sprayed-metal coating a much rougher surface is acceptable than for paint coatings
		By instrumental comparison of blast profile with standard	b) Incorrect grit size and/or angle of blast	Extra costs to be agreed. Change grit for subsequent work and/or improved angle of blast	
3	Residual mill-scale	Visual and/or "Surclean" comparison with standard	Inadequate blasting	Re-blast to the required standard. Heavy mill-scale may require initial treatment with larger size abrasive or a switch to a mixture of grit and shot	"Surclean" may have limitations in the determination of percentage of mill-scale
4	Residual rust	Visual	Inadequate blasting	Re-blast to the required standard (heavily corroded steel may require smaller size abrasive); then check for removal of soluble corrosion products (see appendix G)	
5	General darkening or rusting	Visual and/or "Surclean" comparison with standard	Too long delay between cleaning and coating or conditions too humid or metal too cold	Re-blast to the required standard and coat quickly. Improve conditions	
6	Lamination/shelling	Visual	Poor rolling of steel at mill	Refer to Steel Inspector/Engineer for possible quality regrading of steel. Grind out	
C. Pickled steel					
1	Rough and/or pitted surface	Visual	a) Incorrect concentration of acid and/or inhibitor	Correct acid and inhibitor concentrations and temperatures of the pickling bath	
			b) Too long in pickling tank		
			c) Corroded surfaces before pickling	Refer to Engineer	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
2	Dark patches	Visual	Residual mill-scale or rust	Re-pickle	
3	Dark patches with sticky surface	a) Test with pH-paper	Residual acid		
		b) Test with chloride paper	Residual chlorides	Re-rinse or scrub small areas with clean water	
4	Powdery or crystalline deposits	Visual or pH-paper test	Poor rinsing	Re-rinse	
5	Carbon deposits or smut	Visual or with white cloth	Contamination of pickling baths	Brush off and re-treat if severe. Filter reagents and replace rinse	
6	Acid surface	pH-paper	Poor rinsing, or over-acidity of final process	Re-rinse or re-treat after pH adjustments of tanks concerned	
7	Too heavy phosphate deposits	Laboratory check	Too long or too strong a process	Special re-treatment necessary	
8	Cold surface	Contact thermometer	Too long delay before priming	Adjust programme to ensure that advantage of coating on warm surface is maintained	
D. Flame-cleaned steel					
1	Moisture deposits	Visual or filter paper	Rate of travel of flame too high	Reduce rate of travel until no moisture is deposited	
2	Detritus residues	Visual or adhesive tape	Poor wire-brushing and cleaning	Improve removal of dust and detritus after flame-cleaning by air blow or vacuum	
3	Cold surface	Touch or contact thermometer	Too long delay before priming	Adjust programme so that coating is applied to warm surface	
4	Distortion	Visual	Too much heat on too low a gauge material	Refer to the Engineers concerned	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
E. Manually cleaned steel (includes use of hand-held power tools)	See **A.2** and **A.4** of this table	—	—	—	Prior removal of the following is essential: a) Loose mill-scale and other debris by most suitable means b) Flux residues by scrubbing with fresh water c) Oil and grease by emulsion cleaning
1	Rust, slag and loose scale	Visual comparison with standard and/or written instructions	Inadequate work and/or tools	Further work with less worn or more suitable tools, if necessary	
2	Burns, sharp cuts, peaks of steel	Visual and touch	Improper use of power tools	Remove defects by most appropriate means and control methods of working with power tools	When chipping, avoid gouging and production of sharp edges
3	Burnished surfaces	Visual	Too vigorous brushing (manual or power)	Mark area for emulsion cleansing before painting and control more closely the wire brushing operations. Use of a pretreatment primer would also help subsequent adhesion	
F. Environment during application					
1	Too cold	Air and contact thermometers	Poor air conditioning in works or externally inclement weather	Improve temperature to acceptable level, but little or no licence should be allowed with limit specified. Open-flame heaters should not be used	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
2	Too hot	Contact thermometer	Heated surfaces	Reduce temperature below 35 °C or to whatever higher temperature is allowed with special paints	If necessary, rearrange programme to avoid over-hot conditions
3	Too damp	Hygrometer of visual	Poor air conditioning in works or externally inclement weather	Improve air conditioning to acceptable level	Try to avoid depositions of dew before paint is “set”
4	Too wet	Visual and/or moisture	a) Rain, sleet or snow	Protect operations with suitable sheeting, but avoid causing condensation	Where cleaning and painting in adjacent areas additional covers are required to prevent contamination of the paint
			b) Condensation	Provide suitable ventilation	
5	Too dark	Visual	Insufficient lighting and/or dirt on glass cladding	Improve lighting; clean glass	Where appropriate confirm with luxmeter
6	Too dusty	Visual	a) Too much wind	Shield work or delay it till wind abates	
			b) Poor dust extraction	Protect work from blasting dust, improve extraction	
7	Air too foul	Smell and/or instruments	Poor ventilation	Improve ventilation to point where TLVs of solvents, etc. are not exceeded and/or provide fresh air supply to operators	
G. Paint mixing and storage[a]					
1	Wrong weight of container of paint	Spring balance	Poor filling of containers or wrong paint	Reject all full under weight containers. A check on other containers with the same batch numbers will probably indicate if material is at fault	
2	Wrong specific gravity	SG cup and balance	a) Poor mixing of paint	Reconstitute if possible	

[a] Whenever there is anything unusual about the paint other than the potential defects listed in G1 to 8 refer to the paint manufacturer.

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
			b) Thinning or over-thinning	Reject all paintwork where such paint has been used and either remove by stripping or, if agreed by the Engineer, apply an extra coat of the correct paint	
3	Thin consistency	Visual and/or flow cup	a) Defective or wrong paint	As for G, 1 and 2 above, as applicable	
			b) Poor mixing		
			c) Thinning or over-thinning		
4	Thick consistency	Visual and/or flow cup	a) Defective or wrong paint	As for G, 1 and 2 above, as applicable	
			b) Poor mixing		
			c) Thinning not as specified	Control the correct use of thinners. Adjust viscosity	
			d) Outside the pot life	Discard all paints affected	
5	Wrong colour in container	Visual comparison with wet standard	a) Wrong paint supplied	Obtain supplies of correct paint	
			b) Poor colour matching or variation in raw materials	Set aside until manufacturer certifies supply as satisfactory	
			c) Not thoroughly mixed	Re-mix and check as for G, 2 or 3 above	
6	Wrong colour and other characteristics when thoroughly mixed	Visual, instrumental	Wrong proportions of multi-pack materials	Discard unless proportions used are known and can be corrected	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
7	Paint contaminated with moisture	Visual	Dirty paint store, in adequately heated and/or ventilated	Clean up paint store, provide adequate heating and ventilation	
8	Deterioration of paint in tins, setting, separation, gelling, etc.	Visual	a) Old stocks outside the stipulated storage period b) Use of stocks out of delivery order, leading to cause a) above c) Storage conditions too hot or too cold	Refer stocks to manufacturers for clearance before permitting further use	
H. Metal coatings (sprayed, galvanized, plated, sherardized)[a]					
1	Thin coating	Instrumental	Incorrect processing	Reject, reprocess where possible or agree additional coats, provided that surface has not become contaminated.	
2	Random bare spots	Visual	Incorrect processing	Reject if areas are large or are the result of unsatisfactory preparation, but by agreement small areas can be made good by adequate surface preparation and suitable zinc-rich paint, low-melting-point alloy sticks or metal spray	Small items, such as fasteners should be returned to the processor

[a] Full inspection techniques for metal coatings are given in:
"Inspection of sprayed aluminium coatings", Association of Metal Sprayers;
"Inspection of sprayed zinc coatings", Zinc Development Association;
"Galvanizing Guide", Zinc Development Association.

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
3	Corrosion products	Visual	Poor storage conditions or over-long period before further treatment	Reject all rusted material and any from which a substantial part of the coating has been lost. Obtain fresh supplies or completely re-treat as specified	
4	Unsatisfactory adhesion	Instruments	Incorrect processing	Reject	
J. Priming					
1	Over-thick areas, sagging, curtaining	Visual and/or instrumental comparison	Failure to brush out properly or too heavy spray application	Scrape off excess, wipe off while still wet, or otherwise remove. Re-prime to give the correct thickness	Particular attention is required to ensure that each primer is not applied too thickly. Loss of adhesion to subsequent coats may occur
2	Thin areas, grinning through	Visual and/or instrumental	Not enough paint applied	Further application	
3	"Dry spray"	Visual or touch	Incorrect spraying technique or high winds, especially with zinc epoxide and zinc silicate paints	If noticed at time of application, brush surface with hard bristle brush and re-apply. If noticed at a later stage, re-blast and re-prime.	
4	Corrosion products	Visual	Too long storage in primed state	a) If rusting or rust spotting, re-blast and re-prime b) If zinc corrosion products show on a metallic zinc primer, especially in a sheltered situation, scrub with fresh water and dry	
5	Colour change or soft paint near welds	Visual or touch	Non-removal of welding flux, residues have saponified the paint	Remove all the affected paint, by most appropriate method, to bare metal. Scrub affected areas with water and mild detergent, rinse thoroughly and allow to dry. Re-prepare surfaces as specified and prime immediately	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
K. Painting					
1	Sagging, curtaining	Visual	Over-application of paint	If this is forbidden in the Specification remove paint by scraping or other effective method and re-paint	
2	Areas of low thickness, grinning through	Visual, instrumental	Under-application of paint, poor spray pattern	Apply extra coat or coats, as appropriate, within the recommended limits of the recoating period	
3	"Orange-peel" effect	Visual	Poor spraying techniques	Correct all adjustments to spraying equipment and operator technique	May be difficult to avoid with heavy compositions
4	Lifting, wrinkling, etc.	Visual	a) Incompatibility of solvents with the state of the previous coat b) Wrong interval between coats c) Drying conditions too fast	Reduce all affected paint by most suitable means to a firm sound substrate and replace all coats as necessary	
			d) Surface contaminated e) Over-thick coats	Reduce all affected paint by most suitable means to a firm sound substrate and replace all coats as necessary	

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
5	Poor intercoat adhesion	Visual	a) Surface contaminated, see “notes” column	Remove and abrade surface, recoat	There are several other causes but these are the commonest in practice, e.g. with oil, grease, water, powdery deposits
			b) For epoxy or urethane types, too long interval between coats		
			c) Incompatibility of the components of the painting system, see “notes” column		E.g. previous coating insufficiently cured to withstand solvents
6	Loss of gloss, rough surface	Visual or touch	a) Airborne dust and dirt, and overspray	Rub down surface with suitable abrasive paper before further coating. If the affected coat was the final coat it should be repeated	
			b) Condensation during drying	Refer to paint manufacturer before proceeding with further coats. If the affected coat was the final coat, re-apply	
7	Slow drying	Touch	a) Unsuitable ambient conditions, or too heavy coating	Defer further coats until paint is completely dry	There are several other causes, but these are the commonest in practice
			b) Mixing error for two-pack materials	Remove the coating and re-apply using correct two-pack mix	
8	Pinholing	Visual	a) Contamination of paint or spray airlines, see “notes” column	Remove and repaint affected area	Particularly with silicones, oils or water
			b) Air entrainment in paint, see “notes” column		Particularly with airless spray

Table 8 — Inspection guide

Work stage and code	Potential defects	How determined	Likely cause	Suggestions for action	Notes
9	Cissing	Visual	Contamination of surfaces, mainly with oils and greases	Remove and re-paint affected area	
10	No colour difference between paints for successive coats	Visual	Wrong paint or poor specification	Supply in stock may be tinted to give intercoat colour contrast but consult paint manufacturer	
L. Handling and transport					
1	Contamination of cleaned surface by dirt or sweat	Visual	Bare hands or dirty lifting tackle on cleaned surface	Re-cleanse area with clean water	
2	Easily damaged coating	Visual or touch	Insufficient drying period before handling	Repair damage to coating, allow longer drying and hardening times	
3	Damage by lifting tackle and other handling gear	Visual	Lifting points not included in design, no purpose-made gear provided	Repair damage. Agree improved methods of handling	
4	Chafing in transit	Visual	No special support packings or lashings provided on wagons. Poor stowage	Repair damage, no further loading without adequate measures to prevent damage	
5	Components adhering together	Visual	a) No special packaging provided	Repair damage or return for recoating. Agree packaging methods	
			b) Stacked before paint is thoroughly dry		This happens especially with chlorinated rubber coatings

Section 5. Maintenance

44 The need for maintenance

All structures, no matter how good the protective system, eventually need maintenance treatment. The effect of deterioration, however, is variable, for it depends upon both the degree of deterioration (which is rarely uniform) and its position on the structure.

The need for maintenance of a protective system can become apparent in one of three ways, arranged below in descending order of the cost of rectification of the observed deteriorations.

a) Mechanical failure of the structure.

b) Visible failure of the coatings, as noticed "in passing" or during a casual (i.e. non-scheduled) inspection.

c) Discovery of incipient or advanced failure of the coatings by properly planned inspections at regular intervals and comparison of observations with reliable records of previous inspections.

There is therefore an obvious advantage in conducting properly planned inspections and keeping reliable records, both of which should form important parts of a comprehensive Maintenance Schedule for any structural complex, however small.

Corrosion-induced failure of a structure is nearly always caused by severe corrosion at a few especially vulnerable points. Maintenance procedures should therefore be directed primarily at these points, see appendix A.

If deterioration is neglected for so long that it results in mechanical failure, the remedial measures necessary are beyond the scope of this code.

Secondary aims of maintenance are as follows.

a) Preservation of the whole structure from deterioration and the need for repair, so that it performs its required function safely, efficiently, and economically throughout its designed life.

b) Preservation of its appearance as specified by legislation or by the user's requirements.

45 Basic considerations of maintenance procedure

If recommendations for maintenance painting are to be comprehensive they will also, necessarily, be complex for the following reasons.

a) Structures of all ages and types must be catered for.

b) There is a wide range of environmental conditions.

c) The functions of existing structures may change and existing maintenance procedures, formerly successful, may need to be changed.

d) The required functional life of the structure and the required life of its aesthetic appearance may be different, and the methods and materials for preserving them may not be compatible.

e) Accessibility may limit the frequency with which inspections of the structure's integrity can be made.

f) Rehabilitation of a deteriorated (or damaged) surface coating may be insufficient by itself to restore the integrity of a protective system. Other work may be necessary if the full designed life of a renewal coating is to be achieved.

g) Site conditions may render it difficult or impossible to make a simple repair which would otherwise be sufficient.

Any or all of these aspects may have to be taken into account when compiling a maintenance schedule.

46 Factors affecting decisions on maintenance

46.1 Condition of coatings (see Table 10.) On blast-cleaned surfaces, initial breakdown may take the form of pinpoint rusting at peaks in the steel surface that have not been adequately covered with paint. The presence of mill-scale on the surface will cause lifting of the paint.

Repainting should always be carried out before the finishing coats have ceased to protect the priming coat properly, or before they have deteriorated to such an extent that they no longer provide a suitable base for the new paint. It is unnecessary to remove the bulk of the old paint and this procedure, in time, leads to the build-up of a thick paint film all over the structure. Provided that breakdown is not permitted to proceed beyond the chalking stage, only minimal surface preparation is necessary.

Galvanized coatings may be maintained at any time, depending on protective, decorative and economic requirements, but maintenance is more effective if it is done while a substantial part of the coating is still serviceable. Galvanized-plus-paint coatings may be maintained while the paint layer is still basically sound, or at a later stage [see Table 3, note i)] provided that the zinc coating is still sound and will accept a new paint system.

Sprayed-metal coatings should always be resealed or repainted as soon as any appreciable attack on the metal coating itself is manifested by the presence of white corrosion product in patches and nodules. At this stage, surface preparation is minimal. A check should be made to see that the paint itself was not the cause of the white product.

46.2 Variability of deterioration according to location.

Ideally, recoating should become necessary at exactly the same time over all parts of the structure, but in practice the coatings on some parts of a structure deteriorate more rapidly than those elsewhere. Whether or not this is important depends upon the positions of the defects. There will usually be a choice between repainting of the entire structure and patch painting.

46.3 Factors affecting deterioration

46.3.1 *General.* It is important, when considering the advisability of renewing coatings, to evaluate the consequences of not doing the work. It is not sufficient to consider only the extent of the deterioration. The rate of deterioration may have changed since the structure was originally designed and erected. It is important to know how it has changed or how it may further change. This involves a study of records of previous maintenance coatings, (if any) and those of inspections between previous coatings (if any) and since the last coating.

It is also important to know the causes of the deterioration, and this involves a study of the design of the structure and the changes in the environment.

46.3.2 *Effects of design on rates of deterioration.* In the erected structure there may be locations (unforeseen in the original design) where the relative orientation of surfaces is conducive to corrosion. Modifications should be made so as to eliminate such conditions, especially those described in 1), 2) and 3) below. For example:

a) intermittent welds may need to be sealed;

b) drainage may need to be introduced, or improved, where water can otherwise lie on horizontal surfaces or flow over steelwork;

c) accessibility for painting may need improvement.

Badly corroded stress-carrying members need the attention of a structural engineer.

Although a smooth surface is advantageous for protection, the use of fillers may disguise a loss of section and thus lead to a false sense of security.

In the particular case of bare steel it should be noted that plain steel surfaces exposed to freely circulating air, even when devoid of paint, corrode at a slow rate of 25 µm to 125 µm per year in all but the most aggressive environments. Metal deteriorates at a much faster rate when:

1) it is badly ventilated so that condensation remains for long periods;

2) it traps water; or

3) it is subject to constant seepage of water, generally where corrosion sores have already developed in old structures.

46.3.3 *Effects of environment on rates of deterioration.* The general environment may vary from year to year, but departures from the well known average are rarely of long duration.

The local environment, however, may be continually changing. The general improvement in recent years, resulting from anti-pollution legislation, may be more than offset by the existence of, or future construction of, sources of local pollution. For example, a heavily used motorway may blanket some area with combustion products or unburnt diesel oil, or a factory using processes which produce exceptional contaminants could create bad local conditions, even in rural areas.

46.4 Type and use of structure. The type of structure and the use made of it both have a bearing on the performance of the protective coatings and should be taken into account. For example, some parts of a structure may be affected by spillage and others by abrasion.

47 Factors affecting choice of procedure

47.1 Environment. Steam, exhaust gases, fumes and grit may all be present in industrial environments, and all are prejudicial to good painting. Moreover, access may be difficult, or possible for only a limited time (as in the case of marine structures).

The seasons have little effect on the timing of indoor paintings of existing structures, but when the structure is exposed, inclement weather seriously interferes with protective coating operations. For outdoor structures the work should be programmed, so far as possible, for periods when favourable weather can be expected.

Generally it is undesirable to paint when the steel temperature is less than 3 °C above the dew-point but judgement may be exercised to raise or lower this figure according to whether the temperature difference is increasing or decreasing. It is not always practicable to calculate dew-points, especially on the smaller jobs. In such cases it is common practice to specify a temperature below which paint should not be applied; this is generally 3 °C, 4 °C, or 5 °C, chosen so as to ensure that there is no moisture or ice on the surface.

On sites overseas the local meteorological data, especially for rainfall and humidity, will provide guidance as to the best times for painting.

If painting has to be done when the general atmospheric conditions are unsuitable, these conditions should be improved locally by providing shelters or screens and if necessary, artificial heat, with good ventilation. (Portable dehumidification equipment is also available.)

It should always be borne in mind that work done in unsatisfactory conditions will not produce such a satisfactory result as that done under correct conditions and is likely to lead to early and sometimes costly failure.

47.2 Constraints on site. Activities (other than painting) on or near the site may place severe restrictions on the times at which painting can proceed. In some cases conflicting activities can be temporarily suspended by advance arrangement, as in the case of many rail and road structures, but in other cases it may not be possible to carry out surface coating work except during periods when other activities are normally stopped, for example, during close-down periods or annual holidays.

There may also be the problem of physical access to the structure concerned. Limitations of both the approach to, and the space around, the structure will affect decisions on the equipment and methods used.

48 Organization

48.1 Labour. The surface preparation for, and the application of, modern protective coatings are highly skilled jobs and the operatives must be properly trained; the use of unskilled labour can cost more than it saves. For large concerns owning extensive steel structures, there are two ways of maintaining their protective coatings. They can train their own permanent staff, or let the work out to contract. The choice between these policies is influenced by the nature and volume of the work.

48.2 Inspection. Whether work is carried out by direct labour or by contract, there should be adequate inspection, to ensure that critical parts of the work have been prepared to the necessary standard before being overcoated.

A structural engineer should decide what is critical for the work concerned. See section 4 for guidance.

48.3 Conduct of work on site. Sites should be kept tidy and care should be taken to avoid contamination of any other activity taking place on or near the site. Control should be exercised over dust and fumes or other emissions which may affect the environment, and appropriate disposal of waste products arising from the painting work should be properly organized.

49 Choice of maintenance method

The decision whether to patch-paint or re-coat completely is largely an economic one. It will be influenced by the accessibility of the structure. If much scaffolding is needed, so that the cost of access is a high proportion of the total cost, it may be economical to re-coat the whole structure while on site. This is certainly so when an excessive amount of patch-painting of small areas, say upwards of 10 %, would be involved.

If maintenance is undertaken at the right time, it should not be necessary to strip all the old coating before repainting the structure. The ideal condition, in which none of the old paint needs more than thorough washing down, is rare. Some parts of the structure will need repainting before the main body of the paint has neared the end of its life. Where the majority is in good condition and only a small proportion is poor to very poor, it may be better to repair the defective areas by patch-painting and to leave the rest alone until later.

50 Choice of procedures

For the work to be effective, surface preparation should be carried out to a satisfactory standard for the material to be applied. Whilst some methods achieve this easily, it is more difficult with others and there are site limitations. The methods available are not equal in effectiveness or cost. The advantages and disadvantages are described in **51.2**. This is true also of application, the different methods available have advantages and disadvantages in different conditions, as described in clause **53**.

Some general notes for guidance are given as follows.

a) All removable parts impeding access to the work should be removed before work commences.

b) Manual methods may be the only suitable ones in certain circumstances, but will result in an inferior surface as compared with other methods, such as blast-cleaning.

c) Washing down before repainting is always desirable, especially in marine environments, because it may remove chlorides from the surface, but it is unlikely to remove sulphates. Consideration should be given to problems of drying after washing.

d) Some modern paints become very hard when fully cured and special preparation, such as light blasting or the use of emery, may be required to obtain good undercoat adhesion.

e) Thick films such as those obtained with pitches or bitumens often develop deep cracks. These materials can be overpainted but the cracking cannot be eliminated without complete removal of the film.

f) The maintenance system chosen depends to some extent on the original process and the standard of surface preparation which can be achieved. Some two-pack materials are not always suitable for maintenance and trials and compatibility tests should be carried out before using them.

g) The standard of protection required varies with atmospheric pollution and for different parts of the structure, i.e. areas subject to condensation and restricted air movement require better protection than fully exposed steelwork.

h) Sometimes the film becomes embrittled and loses its adhesion. In these cases complete stripping is essential.

51 Surface preparation

51.1 General. Particular attention should be paid to the cleaning out of crevices and other places where dust and dirt have collected. Debris tends to build up at ground level. Crevices frequently occur that are so positioned or dimensioned that standard scrapers, brushes, and other tools will be ineffective. In such cases it is essential that special tools should be devised to ensure adequate cleaning and painting. If the work is to be carried out by contractors, a clause in the Specification should demand the design of such tools and require their approval by the Engineer.

Coatings on old structures frequently have numerous lengthy cracks and fissures. When recoating it will save time and produce a better result to caulk them after applying the primary coat.

It is recommended that for structures with large areas requiring treatment a reference area of structure is prepared. The area chosen should be as typical as possible of the structure and will generally include areas of sound paint as well as corrosion sores, so as to permit demonstration of the treatment of the boundaries of corroded areas, as well as the complete removal of rust and loose scale. The area should not be less than 1 m^2 and should be cleaned to the correct standard. When the work is to be carried out by contract, agreement should be reached that the standard is a practicable one for the structure in question. Immediately the cleaning has been completed, two coats of clear varnish should be applied over one-third of the area. The remaining area should then be repainted with the priming paint to be used on the structure. The additional coatings specified for the structure should then be applied as painting proceeds, all coats being at the specified film thickness. Each successive coat should leave a width of 100 mm of the preceding coat exposed, then the appearance of each successive coat will provide a visual guide to the standard of painting to be provided. On completion, and after obtaining the approval of the Engineer, the different parts of the reference panel should be overcoated with appropriate coats to complete the system.

51.2 Factors appropriate to use of different methods on site

51.2.1 *Blast-cleaning with or without the addition of water.* Several methods are available.

a) Open blast. There may be problems with abrasives and debris on some sites. Before using this method the effect of such debris on persons, property, water courses, electric cables, etc. should be determined. The size of equipment may also be a problem.

b) Recirculating blast overcomes most of the objections to open-ended blasting but is much slower and there may be difficulties with some irregular shapes. Size of equipment may be a problem on some sites.

c) Hydroblasting with or without the addition of grit overcomes some of the objections to dry blasting but has an additional problem of drainage. It is not acceptable near electrical equipment. Size of equipment and the need for a suitable water supply may be a problem and care is necessary to protect the operator and those nearby, particularly when using a high-pressure jet.

No one method may be sufficient by itself and all methods may need to be supplemented by the use of hand-held tools, such as lump and chipping hammers, wire and dusting brushes.

51.2.2 *Flame cleaning.* Reasonably portable equipment can be used in some locations where blast-cleaning is not practicable. Care is needed to ensure that surface temperatures are not allowed to become excessive. In the case of structural steelwork of substantial sections an upper limit of 200 °C surface temperature is considered advisable by some authorities. Thinner sections may have to be cleaned at a lower temperature. Steps should be taken to ascertain what temperature is suitable in particular cases. As a general guide, sections thinner than 0.5 mm should not be flame-cleaned. Care should be taken to consider the effect of heat transference to other parts of the structure, and particularly to any materials in contact with the other side of the steel. The existence of pipes and cables should be noted.

Flame-cleaning should not be used near high-strength friction-grip bolts or cold-worked high-tensile steels. It should also not be used to remove thick coatings of tar or bitumen; and it is not an economical procedure for stripping old intact paint. As a rough guide, its use should be considered only when the breakdown on the old paint has reached grade Re 6 (roughly 20 % of rust by area) of the European scale[11] or beyond. It is important to take into account that flame-cleaning will destroy the protective coating on both sides of the plate. It should be noted that flame-cleaning does not provide a suitable surface for many sophisticated coatings such as zinc silicate, epoxide and polyurethane two-pack coatings, etc.

51.2.3 *Powered tools.* There are very few site limitations other than those of space and access for compressors at some sites.

51.2.4 *Hand-operated tools.* There are no site limitations, but it is difficult to ensure an adequate standard of cleaning for more than very limited areas.

52 Application

See clause **22**.

53 Standards of preparation

The surfaces requiring preparation can range from severely corroded steel to firmly adherent paintwork.

The different methods available for removing corrosion do not produce the same standard of finish. The commonly specified, and desirable, requirement to remove all rust and corrosion cannot be achieved except by blast-cleaning. But while some materials require a blast-cleaned surface for adequate adhesion, others can be applied satisfactorily to surfaces prepared by other methods provided that they result in an adequate standard. The cost and practicability of achieving such a standard varies, and if it can be obtained with difficulty over a small area it cannot generally be realized at all over large areas.

Where blast-cleaning is adopted, the aim should be to clean the surface to a standard equal to SA2½ of Swedish Standard SIS 05 59 00 or BS 7079-A1, Sa2½, or a higher standard called for by the paint manufacturer. Where other methods are used it will not be possible to clean the surface properly, but the aim should be to remove as much rust as possible. The difficulty of providing an adequate written description of an acceptable surface applicable to the varying conditions found in practice has led some authorities to try the use of visual aids. For large or important work the standard should be agreed on site and recorded, preferably by the use of a reference area. In the case of special materials the standard should be that called for by the manufacturer.

In the case of paintwork, all dust and loose and poorly adherent material should be removed by brushing and scraping, all grease, oil or other stains should be removed by a suitable solvent or emulsion cleaner which will not attack the paintwork. This should be applied by swabbing to avoid spreading the oil or grease to adjacent surfaces.

54 Standards of application

54.1 General. In all methods the aim is to produce a uniform coating of the film thickness specified, free from pinholes, missed areas, runs, sags or curtains, and wrinkling or other blemishes which may impair durability.

54.2 Brushing. The film produced by brushing should be free from brush marks, consistent with good practice for the type of paint used.

54.3 Roller-coating. Roller-coating should be conducted so as to give a uniform full wet coating, the inaccessible areas being coated by brush to the specified film thickness.

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[11] See footnote "†" below Table 9.

54.4 Spray application. Spray application should give a full wet coating with a minimum of spray pattern (orange-peel effect). Each successive pass should overlap the previous pass to give a uniformly even film. This applies equally to air spray and airless spray.

55 Recommendations for coatings

55.1 General. A variety of systems may have been applied to old steelwork and it is impracticable to set out detailed guidance for each case. The following notes, however, provide a step-by-step approach.

a) If the existing material and the system are known, obtainable, and have proved satisfactory, it is advisable to use that part of the system which is applicable.

b) The initial film thickness (at least) of the original system should be restored. An additional stripe coat may be desirable at places that have proved particularly vulnerable, such as expansion-joint edges, bolts, rivets and welds.

c) If for any reason, the existing material cannot be used, specialist advice should be obtained. If this is not available then consideration may be given to the materials listed in 1) and 2) below, provided that they satisfy a test of compatibility with existing materials and that there are no special requirements such as particular resistance to abrasion or chemicals.

1) Surfaces not subject to condensation.

External: conventional micaceous iron oxide or chlorinated rubber paint.

Internal: conventional micaceous iron oxide or alkyd paint.

2) Surfaces subject to condensation.

External: gelled bitumen or chlorinated rubber paint.

Internal: chlorinated rubber paint

d) Primers that can be overcoated the same day should be used, so that minimum protection can be built up as quickly as possible.

e) The thickness of existing paintwork should be checked with an inspection gauge. Exposure of the previous coat is no guide to thickness.

55.2 Previously painted steelwork. For previously painted steelwork, the preparations and treatments listed in Table 9 are recommended.

55.3 Previously metal-coated steelwork with or without additional coating. Where previous coatings were galvanizing, sprayed zinc or sprayed aluminium, the preparations and treatments listed in Table 10 are recommended.

Table 9 — Treatment of previously painted surfaces

Surface conditions	Surface preparation	**Treatment** (see note 7) [see also **55.1** notes a) to e)]
1. Paint film intact, slight chalking or checking of top coat only, no significant colour change	Leave alone or wash down only if a)	a) No coating required
	Bristle brush and dust down if b) (see note 5)	b) Recoating required by legislation or by appearance requirements. Apply one or two finishing coats as required
2. Paint film firmly adherent, considerable chalking, cracking down to primer or undercoat only, no rusting	Wire brush (see note 5) to remove all loose material and dust down	Intermediate and finishing coats as necessary
3. Erosion or blistering or loss of adhesion at or above substrate and/or light rusting (not worse than Re 3 (see note 4) for thin films) Thin film (see note 1) Thick film (see note 2)	Scrape and wire brush (see note 5) to remove rust and loose material	a) Prime any derusted patches. Build up film thickness with appropriate intermediate and finishing coats overall b) Patch prime and undercoat derusted patches. Build up film thickness with intermediate coat(s) as necessary. Apply finishing coat overall
4. Thick film with rusted area less than one quarter (see notes 3 and 8)	a) Rusted patches; remove rust by best means available. See clause **53**	Patch prime bare metal
	b) Paint conditions 1,2 and 3 as described above	Apply intermediate coat (see note 5) and finishing coat(s) (see note 6) to required thickness
	c) Sound paint: nil if patching is adequate	
	d) Sound paint: wire brush if finish coat is required (see note 5)	
5. Thick film with rusted patches greater than one quarter of area (see note 3) Thin film rusting worse than Re 7 (see note 4)	Remove all coating and rust by best means available. See clause **53**	Build up new system of primer, intermediate coat(s) and finishing coat(s)

NOTE 1 A thin film is defined as one less than 150 µm thick.

NOTE 2 A thick film is defined as one greater than 150 µm thick.

NOTE 3 Area is defined as any surface of the structure which is reasonably identifiable for treatment purposes. The condition of all parts of a structure will not necessarily be the same. In deciding the required treatment it is necessary to consider the condition of areas as large as practicable for treatment purposes and deal with each on its merits.

NOTE 4 Re 3 is taken from "Echelle Européenne de degrés d'enrouillement pour peinture antirouille" obtainable from the Paintmakers Association, Alembic House, 93 Albert Embankment, London, SE1 7TY.

NOTE 5 For certain hard finishes special treatment may be necessary to abrade the surface.

NOTE 6 It is a matter of judgement whether to patch paint isolated patches of rust only or to patch paint rusted areas and overcoat the whole. In the latter case it is sometimes desirable, if time permits, to apply additional intermediate coats to bring the patches to a similar thickness to the surrounding areas, before overcoating the whole surface.

NOTE 7 When selecting a material for use in overcoating it is necessary, unless there is definite knowledge of the materials being overcoated, to test the compatibility of the proposed material with existing materials.

NOTE 8 See also BS 6150 and BS 3900.

Table 10 — Site treatment of previously metal-coated steelwork

Initial condition	Present condition	Surface preparation	Replacement of metal where required	Paint treatment over	
				Sprayed metal	Galvanizing
Bare metal coating	Areas of corrosion and/or some rusting of substrate[a]	If metal is to be replaced, blast-clean	Spray metal to appropriate specification, see Table 3	Not normally necessary. If overcoating is required, see Table 3 and **11.3**	
		If metal not to be replaced, clean corroded areas by best means available	Not applicable	Build-up cleaned areas with suitable paint system and, preferably, apply chemical-resistant finish overall	Build-up cleaned areas with suitable paint system and, preferably, apply chemical-resistant finish overall
	Areas with some white corrosion products	If decoration required wash to remove salts, using stiff brush if necessary. Remove loose material with non-metallic brush	Not applicable	Apply sealing coat and chemical-resistant finish for maximum life	Apply suitable surface pretreatment followed by, preferably, chemical-resistant finish
		If decoration not required, no action is necessary	Not applicable		
	Areas in sound condition	If decoration is required, wash to remove salts, using a non-metallic brush	Not applicable	Apply suitable paint which should be chemical-resistant for maximum life	Apply suitable surface pretreatment; follow by suitable paint which should be chemical-resistant
		If decoration not required, no action is necessary	Not applicable		
Sealed or painted metal coating	Areas of corrosion or some rusting of substrate	If metal is to be replaced, blast-clean	Spray metal to appropriate specification, see Table 3	See Table 3 and **11.3**, consider one or two coats overall, preferably chemical-resistant	See Table 3 and **11.3**, consider one or two coats overall, preferably chemical-resistant
		If metal not to be replaced, remove corrosion product by best method available	Not applicable	Build-up cleaned areas with suitable paint. Apply one or two coats overall, preferably chemical-resistant	Build-up cleaned areas with suitable paint. Apply one or two coats overall, preferably chemical-resistant
	Areas with some degradation of paint, dissipation of sealer, or loss of adhesion of either	Remove loose material with non-metallic brush	Not applicable	Apply further coats of paint or sealer, preferably chemical-resistant	Apply further coats of paint or sealer, preferably chemical-resistant
	Areas in sound condition	If decoration is required, dust-down	Not applicable	As above	As above
		If decoration is not required, no action is necessary	Not applicable		

[a] It should be confirmed that the apparent rusting emanates from the substrate.

Section 6. Safety and health

NOTE 1 This section of the code gives recommendations for dealing with typical aspects of safety and health which arise in the work of coating iron and steel structures. It does not give complete coverage of all such aspects, because that is beyond the scope of this code. It is the duty of users of the code, in so far as they are responsible for safety and health, to ensure that all statutory requirements are met.

NOTE 2 The legislative references in clauses **56** and **57** provide a holding position in view of the impending changes in legislation resulting from European Directives. The Framework Directive which will be implemented by the Proposals for Health and Safety (General Provisions) Regulations and Approved Code of Practice and other directives stemming from this means that some of the legislative references (in clauses **56** and **57**) may become obsolete.

56 Legislation

56.1 General. A number of Acts of Parliament contain provisions relevant to surface coating work and these should be taken into account when planning such work. The Acts should be studied directly for detail and coverage, together with any other legislation relevant to particular situations.

The Health and Safety at Work etc. Act 1974 imposes a general duty on employers to protect persons at work against risks to health or safety.

Note should be taken of The Control of Lead at Work Regulations 1980, The Control of Substances Hazardous to Health Regulations 1988 and the Approved Code of Practice 1988, and Carcinogenic Substances Approved Code of Practice 1988.

The Noise at Work Regulations 1989 deal with the legal obligations of employers to prevent damage to hearing.

56.2 Factories Act 1961. The provisions of the Factories Act 1961 and the Regulations and Orders made under the Factories Act remain in force but are now subject to the enforcement procedures of the Health and Safety at Work etc. Act 1974. The relevant provisions within the Factories Act itself include the following.

> Section 131 “Prohibition of employment of women and young persons in painting buildings with lead paint”.
>
> Section 132 “Prohibitions supplementary to sections 129 to 131”.

Relevant Orders and Regulations under the Factories Act include the following.

> The Factories (Cleanliness of Walls and Ceilings) Order 1960 (S.I. 1974 as amended by S.I. 1974 No 427) which states the time limits for, and the methods of, cleaning and painting factory interiors.
>
> The Construction (General Provisions) Regulations 1961 (S.I. 1580), which deal with the appointment of safety supervisors, ventilation, work adjacent to water, and the safe transport of materials.
>
> The Construction (Working Places) Regulations 1966 (S.I. 94), which deal with scaffolding, slung scaffolding, bosun’s chairs, etc.
>
> The Construction (Health and Welfare) Regulations 1966 (S.I. 95), which deal with first aid, washing, toilet and messing facilities.
>
> The Construction (Lifting Operations) Regulations 1961 (S.I. 1581).
>
> The Protection of the Eyes Regulations 1974 (S.I. 1681 as amended by S.I. 1875 No. 303) which apply to all surface preparation (except sand papering) and spray painting.
>
> Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 (S.I. 917).

56.3 The Control of Pollution Act 1974. This Act covers environmental pollution such as noise and the disposal of toxic wastes.

57 Operational hazards

57.1 General. Some of the operations involved in the surface protection of a structure give rise to conditions that are potentially hazardous to the structure itself and/or surrounding property, whilst others pose hazards to the health and safety of the operatives.

Especially prevalent among these hazardous conditions are the furne and vapours which rise naturally by evaporation of solvents in some paints and strippers; and the pollutants which are induced by operations, such as:

a) fumes from lead-based paints when flame-cutting or flame-cleaning;

b) dust from lead-based paints when rubbed-down dry;

c) dust or fumes from some modern hard-setting paint;

d) fumes from heating cadmium-coated components.

Caution should always be exercised in any operation which generates dust or fumes.

The potential hazards of fumes are greatly increased in confined spaces where dust and fumes can accumulate and where there is little or no ventilation, for example, inside a tank or small room or between girders under a bridge deck. It should be remembered that similar conditions can also occur in the open air if the air is still and/or there is a ventilation trap. Such conditions usually necessitate the use of respirators supplying clean air and/or forced ventilation. Persons working in such conditions should be within sight of others outside the danger area. In these cases the advice of the Health and Safety Executive should be sought.

57.2 Hazards to structure and surroundings. Any operation is hazardous if it involves naked flame or the production of sparks in a restricted area. In such a case, flammable vapours (arising naturally by evaporation of solvents or induced artificially by operations) can accumulate and create a risk of fire, which becomes a risk of explosion if the working space is confined or poorly ventilated. The risk of damage to the structure and surroundings in these conditions; is apparent and paralleled by the risk of injury to people nearby. Therefore such hazards should be identified and suitable precautions taken.

57.3 Risk of injury

57.3.1 *Eyesight.* Many of the operations involved in surface preparation produce particles which can damage the eyes directly, and dust and some types of fumes, which can also cause eye afflictions. Eye protection is essential for operatives doing such work and for those nearby.

57.3.2 *Hearing.* Many of the operations involved in surface preparation give rise to a high level of noise. Further information is contained in the Health and Safety Executive leaflet, IND(G)75(L), Introducing the Noise at Work Regulations, a brief guide to the new requirements for controlling noise at workplaces, and in HSE Noise Guides 1 – 8.

See also BS 5228.

57.3.3 *Respiratory system.* Some of the operations of surface preparation and paint application give rise to dust or fumes which necessitate the provision of good ventilation and respiratory protection for operatives and those nearby. If other methods of controlling exposure are not possible, suitable respiratory protective equipment which is either type approved or conforms to a standard approved by HSE, should be worn. See also BS 2091, BS 4275 and HSE Guidance Notes EH 40, Occupational Exposure Limits, and EH 16, isocyanates, toxic hazards and precautions.

Some fumes, notably from cellulosic materials, not only affect the respiratory system directly but can have further unpleasant effects on the gastric system.

Further advice can be obtained from the Health and Safety Executive.

58 General hygiene

The various materials encountered in dealing with old paint and applying the new paint include some that are potentially harmful, and it is therefore necessary to maintain a high level of personal hygiene. In particular, hands should be protected with silicone free barrier cream before work starts and impervious industrial gloves may be needed if heavy contamination of skin is likely. Afterwards hands and exposed areas of skin should be cleaned with an approved hand cleaner. Hands should not be cleaned with paint solvent or thinners.

Overalls worn for work should be removed before eating or going home and should be laundered at frequent intervals, and all possible steps should be taken to avoid paint getting on to the skin.

Some materials will require additional precautions and advice and these should be sought from the manufacturer.

When operatives are working in such conditions (for example, inside a box girder) that access to toilet facilities is not quick and easy, consideration should be given to the provision of toilet facilities nearer to the work site.

Appendix A
General principles of corrosion and its control

A.1 Corrosion

A.1.1 *Corrosion is a natural phenomenon.* Like most metals, iron has a natural tendency to revert to its oxides by combining gradually with oxygen and moisture, forming rust.

The high economic cost of corrosion is accounted for mainly by the outlay on preventive measures rather than by the destruction of metal.

A.1.2 *Mechanism.* Most corrosion processes are electrochemical. Corrosion cells are set up on the metal surface through heterogeneities in the metal itself or in its environment. Common causes are, according to location, as follows.

a) *In or on the metal.* Residual mill-scale or foreign matter, e.g. dust.

b) *In the corrosive medium.* Differences in the concentration of saline matter and oxygen as well as variations in physical properties such as flow velocity and temperature.

c) *Contact between dissimilar metals,* e.g. steel and copper alloys.

A.1.3 *Microbiological corrosion.* Corrosion can also occur in soils and waters as a result of microbiological activity. Micro-organisms such as sulphate-reducing bacteria utilize hydrogen, which would otherwise accumulate and eventually stifle attack; other organisms promote the supply of oxygen needed for corrosion cells; yet others can destroy protective coatings or consume corrosion inhibitors, such as nitrites added to cooling waters.

A.1.4 *Rust.* The initial corrosion product of iron is ferrous hydroxide, $Fe(OH)_2$. This reacts with water and oxygen to form higher oxides and hydroxides, notably hydrated ferric oxide $Fe_2O_3 \cdot H_2O$ and magnetite Fe_3O_4. Most rusts have stratified structures and, moreover, they are generally impure. Most rusts are contaminated with solid particles and/or water-soluble salts.

Sometimes rust stimulates the corrosion of steel by retaining moisture on the surface, but more often it tends to retard the attack. The composition of the metal affects both the composition and properties of the rust layer and, consequently, affects the extent of corrosion over a long period.

Rust formed in a sulphur-polluted or chloride atmosphere is especially dangerous because it contains corrosion-promoting salts. These are concentrated in pits on the steel surface and are very difficult to remove. The usual manual methods of cleaning are ineffective in this case, because they leave salt traces in the pits which promote further corrosion, leading to blistering and often to rapid failure of paint over corroded steel.

A.1.5 *Corrosion in air*

A.1.5.1 *Controlling factors.* Serious corrosion will occur only if the air is polluted and sufficiently humid.

a) *Pollution.* Inland, the severity of corrosion is roughly proportional to the sulphur pollution of the air and, in marine atmospheres, to the quantity of chlorides (sea salts) present (see Table 11).

b) *Humidity.* In pure air, the critical level of relative humidity is about 70 % but, in fact, corrosion occurs at much lower humidities when deliquescent particles settle on the steel. For example, the relative humidity should be reduced to 30 % to prevent corrosion in ships' holds.

Table 11 — The effect of atmospheric pollution on corrosion (1)[a]

Three sites in Great Britain mild steel (Cu 0.3 %)		**Three sites in Nigeria[b] ingot iron (Cu 0.03 %)**	
Relative sulphur pollution (SO_3), mg/dm^2/day	Rate of corrosion, µm/year	Relative chloride pollution (NaCl), mg/dm^2/day	Rate of corrosion, µm/year
0.5	57	0.8	56
1.9	82	3.1	380
3.6	110	11.1	950

[a] Numbers in parentheses in this appendix refer to the bibliography in appendix J.

[b] The most corrosive of these three sites was at the high water mark on a surf beach; the least corrosive only 370 m inshore. At 60 km inland the rate of corrosion had fallen to 5 µm/year.

A.1.5.2 *Effect of environment.* General classification, such as "rural", "industrial" and "marine", can be useful guides to the probable conditions at a site, especially if records are available from a nearby meteorological observatory. But for practical purposes, it is the "microclimate" immediately surrounding the structure concerned that matters. The general effects of rainfall, sunshine and atmospheric humidity are locally modified by the orientation of the steel surface, by its degree of exposure, and by the circulation of air over it. The diurnal variation in the difference between steel and air temperatures is also important, because this determines whether or not condensation occurs. The thickness of section can significantly affect the difference between steel and air temperatures.

The classification of environments in respect of aggressiveness may differ according to whether it is based on the corrosion of bare steel or on the breakdown of a given protective coating. For example, although the corrosion rate in tests carried out at Sheffield was about four times that at Calshot, the durability of a paint scheme was virtually the same (see Table 12). This was because the heavy atmospheric pollution at Sheffield (largely due to smoke when the tests were made some years ago) caused rapid corrosion but also retarded actinic breakdown of paint.

Table 12 — Comparison of paint performance with the corrosion rate of bare steel (2)

Test site	Sheffield	Calshot
Type of environment	**Industrial**	**Marine**
Rate of corrosion of mild steel over 5 years, μm/year	109	28
Life to failure of a 4-coat painting scheme, years	6.1	6.0

A.1.5.3 *Rate of corrosion in air.* Under normal conditions, the rate of corrosion of an unprotected mild steel surface which is freely exposed outside in the United Kingdom is between about 25 μm per year in rural districts and about 125 μm per year in industrial districts. Overseas, the rate varies from nil to about 1 000 μm per year, the highest rates occurring in certain marine environments (see Table 11).

A.1.6 *Corrosion in soil*

A.1.6.1 *Controlling factors.* Soil characteristics are the main criteria controlling the corrosion of buried iron and steel. Serious attack is more probable in disturbed soil, as when a pipe is laid in a trench, than in undisturbed soil as when a pile is driven into solid ground. Troubles can occur when steel piling with mill-scale is driven into the ground since part of the scale may be removed giving rise to a corrosion cell.

The oxygen content of the soil and the drainage are most important. There is a distinction between aerobic soils, which are well aerated, and anaerobic soils, which contain no free oxygen, but some soils alternate between these conditions because of seasonal fluctuations in the water table.

In aerobic soils, such as sand or chalk, air has reasonably free access to the buried metal and water can drain away readily so a layer of rust can form on the bare metal and this may retard or stifle further attack.

Despite the absence of atmospheric oxygen, heavy corrosion can occur in anaerobic soils through micro-biological processes. The most important of these is the metabolism of "sulphate-reducing" bacteria which utilize hydrogen which would otherwise accumulate on the metal surface and prevent further attack (3). The necessary conditions occur in heavy clay, some waterlogged soils, harbour mud and other media such as sludge in oil tanks.

The pH-value of the soil is a significant factor and, in general, acid soils are aggressive and highly alkaline ones are inert. The electrical resistance of the soil is similarly significant with the likelihood of severe corrosion decreasing as the resistance rises.

A.1.6.2 *Stray-current corrosion.* Potential differences, such as may occur along a pipeline, can cause electric currents to enter the structure, travel along it and leave it. The (positive) current reduces or represses corrosion where it enters but aggravates corrosion where it leaves.

Such conditions can occur when a pipeline or armoured cable runs through dissimilar soils, under varying soil cover, near to streams and ditches, or under a road. Corrosive currents can also originate from nearby d.c. traction systems or cathodically protected structures.

A.1.6.3 *Rate of corrosion in soil.* It is not possible to generalize on corrosion in soils. Rates of 8 µm to 35 µm per year were observed in tests over 15 years in Great Britain (4). Moreover, tests carried out in America showed that corrosion generally slows down with time (5). For many structures, however, such as pipelines, the rate of pitting is the important factor, and it can be very rapid. In the most aggressive British soils, pits up to 4 mm deep have been found in pipe specimens after 15 years and an even higher rate of pitting (2.6 mm in 5 years) occurred in an embankment made up from ashes.

A.1.7 *Corrosion in water*

A.1.7.1 *Controlling factors.* The corrosion rate is governed primarily by the oxygen content, the chemical composition and the temperature of the water (6).

a) *Oxygen content.* Most natural waters are sufficiently well aerated to ensure continuing corrosion. Rusting in many industrial waters, e.g. cooling waters, is often associated with their high oxygen content.

b) *Chemical composition.* Natural waters vary greatly in composition. They range from certain lakes, which are almost pure water, to the concentrated brine of the Dead Sea. Estuarine waters are less saline than sea water but are often polluted.

Statements in the literature on the effect of chloride concentration on the rate of corrosion are often erroneous since oxygen concentration is the main factor. In salt-spray tests there is little change in the corrosion rate over the range 0.05 % to 10 % of sodium chloride (7).

The nature of dissolved solids and the amount of free and combined carbon dioxide in solution are important. Some waters deposit calcium carbonate on corroding steel at ordinary temperatures or when they are heated; others can be made to do so by chemical treatment. If, as usually happens, the calcium carbonate film has a favourable crystal structure, it will stifle further attack. Calcareous deposits of some protective value can also form on iron and steel immersed in sea water, especially when cathodic protection is applied.

c) *Temperature.* The effect of temperature on the corrosiveness of water varies with the operating conditions but in general, rusting proceeds more rapidly as the temperature rises. In quiescent solutions the corrosion rate of iron increases by a factor of 3 to 4 on raising the temperature from ambient to about 75 °C, and thereafter the rate decreases.

A.1.7.2 *Effect of flow.* Water movement often accelerates corrosion by promoting the supply of oxygen to the metal surface; high water speeds may also prevent adhesion of protective corrosion products. Under adverse conditions increase of flow rates can increase corrosion rates by a factor of 100 (8).

In turbulent water, damage due to corrosion is often aggravated by erosion and by cavitation. The latter can lead to the rapid destruction of dynamic components such as ships' propellers.

A.1.7.3 *Other factors.* The internal corrosion of steel water pipes may produce tubercles of rust, which restrict oxygen supply locally and cause corrosion by differential aeration [see **A.1.2** b)]. Anaerobic conditions favourable to the growth of sulphate-reducing bacteria are established beneath these incrustations, steel then becomes severely pitted, and cast iron suffers graphitic corrosion (see **A.2.2.2**). Sulphate-reducing bacteria can also cause corrosion in polluted rivers and harbours and in storage tanks containing, e.g. crude oil.

A.1.7.4 *Rate of corrosion in water.* The range of 75 µm to 125 µm per year is representative of the general wastage of mild steel in still sea water. Corrosion rates are greater in splash zones or under high flow rates, e.g. 500 µm per year. Fresh water is rather less corrosive.

The rate of pitting is often much greater than general corrosion and it can be severe, especially if mill-scale is left on the steel.

A.1.8 *Corrosion rates of zinc and aluminium.* In view of their use as protective coatings for steel, the corrosion rates of zinc and aluminium are also of interest.

a) In the open air in Great Britain, zinc corrodes at a rate which ranges from about 1 µm to 15 µm per year according to the environment (3). The same rates generally apply to zinc coatings (see Figure 1), but they do not show to advantage in sheltered, humid and sulphur-polluted conditions. The "white rusting" of galvanized steel that occurs during shipment or storage is caused by sulphur or chloride pollution in a closed and humid environment.

b) Sprayed-aluminium coatings give excellent protection to steel in air: coatings 80 µm thick have been found to have lives of 20 years or more in industrial and marine environments (3). Their performance on a surf beach was outstanding (9). They are not widely used in soil although they have long life totally immersed in sea water (10).

A.2 Control of corrosion

A.2.1 *Basic methods.* There are four main methods for preventing or controlling corrosion.

a) Treating the environment.

b) Insulating the steel from the environment by means of a protective coating.

c) Cathodic protection.

d) Attention to design (see **A.3**).

A.2.2 *Relative corrosion resistance of different types of iron and steel.* In some cases, the danger or severity of corrosion can be reduced by the choice of a more resistant metal. The characteristics of the main types of ferrous metals in this respect are summarized below.

A.2.2.1 *Structural steel.* Structural steels manufactured by different processes corrode at substantially the same rate. The minor variations in their carbon content, analysis and microstructure have little effect.

The mill-scale on hot rolled steel is a potential source of corrosion and is injurious to the performance of protective coatings; it should be removed.

A.2.2.2 *Cast iron.* The casting skin formed on cast iron in the mould is more adherent than mill-scale and has some protective properties. If it is removed, unalloyed cast irons corrode at substantially the same rate as descaled mild steels but there is an important difference in the effects of corrosion on the two materials.

Ordinary grey cast irons corrode in a peculiar way. They contain about 8 % of elements other than iron, mainly carbon in the form of graphite, phosphorus as iron phosphide, and silicon. The graphite and iron phosphide are inert and remain in situ after the iron has corroded away. The silicon becomes oxidized to silica or silicates, which help to bind the other constituents. Thus, the corrosion process leaves behind a non-metallic "graphitic corrosion residue", which largely retains the appearance and shape of the original iron, although its mechanical strength is negligible.

A.2.2.3 *Low-alloy steel*[12]. Low-alloy steels corrode more slowly than mild steel when freely exposed outdoors (11). In time their corrosion rate falls to a low value and they are designed to be used unprotected. These steels have been widely used in the bare condition in both rural and industrial environments in North America and on a small scale in the United Kingdom.

A.2.2.4 *Stainless steel.* The resistance of stainless steels to atmospheric corrosion far surpasses that of ordinary or low-alloy steels. The best of them, e.g. the 18/10/3 Cr-Ni-Mo type, are virtually incorrodible in dust-free air. They owe their immunity from corrosion to a thin protective oxide film, which reforms spontaneously if it is damaged but anything that interferes with this film jeopardizes the corrosion resistance. Since chlorides tend to break it down, even Cr-Ni-Mo stainless steels may become slightly rust-spotted in marine environments. The passivity of the film is also impaired if supply of oxygen to it is cut off by dust settling on the surface. Consequently, the performance of stainless steels in all types of atmosphere is greatly improved by regular cleaning, say at monthly intervals.

For the same reason, stainless steels are liable to pit severely in soil, in wet timbers or in water. For example, a sheet 2 mm thick became holed within 6 months when immersed in the sea, where barnacles had settled and cut off the oxygen supply.

Some stainless steels become vulnerable to stress corrosion cracking in sea water after certain methods of heat treatment. Where such a set of conditions can be foreseen the advice of a metallurgist should be sought during design.

A.2.3 *Protection against atmospheric corrosion.* Rusting in atmospheric environments is best prevented by means of protective coatings, as has been fully discussed in the code.

Dehumidification of the air (12) is an alternative or a useful adjunct in some cases (see **A.3.2.2**).

Cathodic protection is impracticable, because of the absence of an electrolyte.

A.2.4 *Protection against soil corrosion.* The degree of protection should match the corrosiveness of the soil.

The most effective system is cathodic protection BS 7361-1 plus a protective coating. Bitumen sheathing, about 6 mm thick, or a thick coal tar pitch/epoxide coating should prove adequate in moderately corrosive soils. So should hot-dip galvanized coatings.

It may sometimes be useful to replace an aggressive soil by a non-corrosive backfill, e.g. limestone or clean washed sand.

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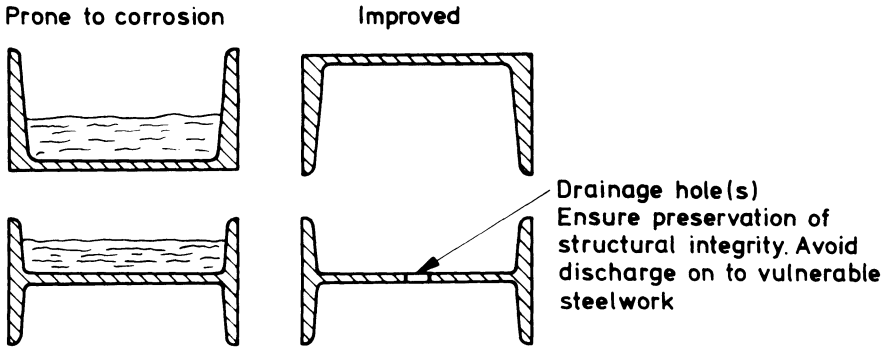
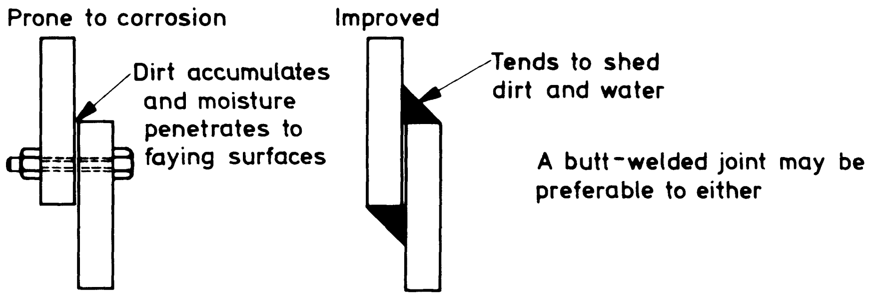
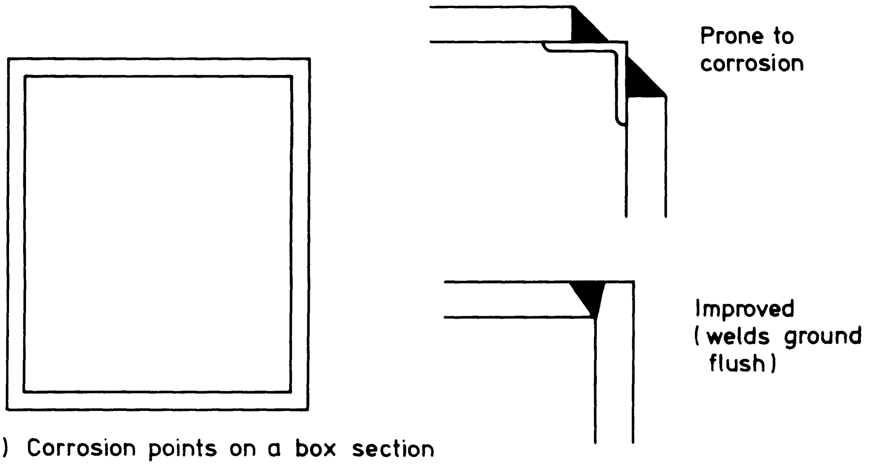
[12] Those intending to use low-alloy steel should consult the British Steel Corporation.



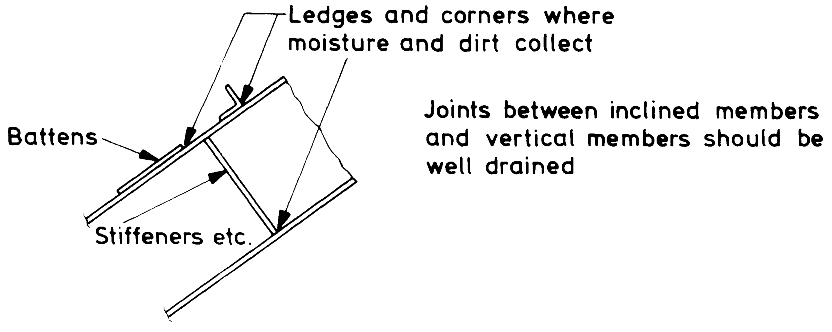
(a) Retention of dirt and water



(b) Comparison of bolted and welded lap joints



(c) Corrosion points on a box section



(d) Corrosion points on inclined members

Figure 2 — Corrosion points

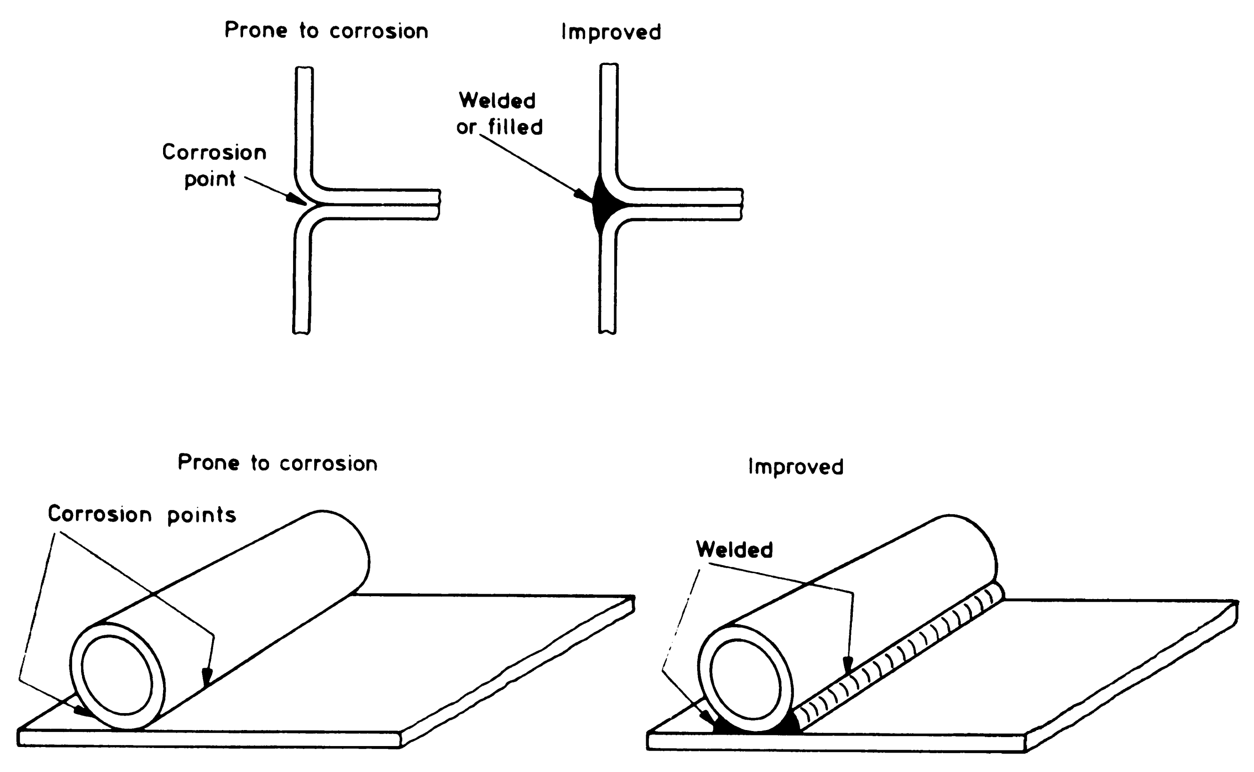


Figure 3 — Crevices

A.2.5 *Cathodic protection.* Cathodic protection is a system in which an electric potential is applied from an external source to oppose the natural flow of electric current that gives rise to electrochemical corrosion. This can be done by either the sacrificial anode method or the impressed-current method. In the first case the steel is connected to a metal of lower potential, e.g. zinc, so that the zinc becomes the anode and corrodes, leaving the steel as the uncorroded cathode. In the second system the current is applied from an external d.c. source. Again the steel becomes the cathode and usually graphite is used as a permanent anode.

Cathodic protection operates only in the presence of an electrolyte, and is often used to protect steel immersed in sea water and in corrosive soils. To reduce current requirements this method is generally used in conjunction with protective coatings on the steel. Only a small current is then required to protect breaks in the coating.

Detailed recommendations on cathodic protection are given in BS 7361-1, but further advice should always be obtained from a specialist.

A.3 Designing for the prevention of corrosion

A.3.1 *Introduction.* The danger of corrosion can be reduced and the efficiency of protection greatly increased by careful attention to design. Experienced designers acquire a "corrosion awareness" which enables them to eliminate potential corrosion hazards. The main points that arise are considered below under the following headings.

a) Entrapment of moisture and dirt.

b) Contact with other materials.

c) Coating application.

d) General factors.

The choice of suitable materials of construction and of adequate protective measures is an important function of design. It has already been dealt with in the code.

A.3.2 *Entrapment of moisture and dirt*

A.3.2.1 *Corrosion points.* Corrosion is most likely at points where rain, condensed moisture and dust collect. To avoid such corrosion points (see Figure 2) the whole surface should be as smooth as possible, without sharp edges, sharp corners, cavities or unnecessary protuberances. Welded tubular construction has an advantage in this respect (13).

A.3.2.2 *Joints.* Joints should be arranged to give clean uninterrupted lines. Generally, welds are preferable to bolts or rivets, butt welds to lap joints, and continuous welds to intermittent welds. If lap joints have to be used, appropriate welding or filling may be needed.

A.3.2.3 *Fasteners.* Care should be taken in the design of fasteners and the choice of material for them (14).

A.3.2.4 *Friction-grip bolts.* The faying surfaces of friction-grip-bolted connections need special treatment as discussed in **8.2** and **25.3.2**.

A.3.3 *Cavities and crevices*

A.3.3.1 *Filling.* Cavities and crevices should be avoided or, if unavoidable, filled with weld metal or mastic (see Figure 3).

Any large cavities that will become inaccessible when the structure has been completed should be sealed with weld metal; where required, the seal should be tested by internal air pressure. Another method is to fill the cavities with concrete which is vibrated into position. Small spaces may be filled with mastic or rust-inhibitive paste or steel packings coated with an inhibitive paint.

A.3.3.2 *Box sections.* If box sections can be properly sealed and tested without structural damage their internal surfaces should not need protection.

If hermetic sealing is impracticable, these surfaces will be subjected to alternating condensation and evaporation of moisture. This arises from the fluctuating difference between the internal and external temperatures which causes the enclosed space to breathe. In these circumstances provision of drainage holes and painting of internal surfaces may be necessary. Non-toxic primers and light-coloured finishing coats should be used as corrosion can remain undetected beneath a dark coating such as red iron oxide paint.

Protection can be prolonged by using desiccants to reduce the internal humidity. Silica-gel, used at the rate of 250 g/m^3 of void, is effective for 2 to 3 years inside a reasonably well sealed structure, if the manholes are kept closed. The desiccant should be renewed at intervals and it should not be relied upon if its presence is likely to be forgotten.

A.3.3.3 *Tubes.* In general, the remarks made in **A.3.3.2** apply to tubes and hollow sections. Internal protection is seldom necessary but in doubtful cases a coating can be applied inside at the time of manufacture.

A.3.3.4 *Enclosed steelwork.* When steelwork is enclosed in brickwork, boarding, plaster, and other materials, it is of prime importance that the surrounding space be kept dry, i.e. below the critical humidity for corrosion [see **A.1.5.1** b)]. If this cannot be done, an effective protective coating should be provided, particularly for steel surfaces in outer walls and behind dry casings for false ceilings. In some buildings, these may be exposed to process fumes.

The design should carefully avoid corrosion of steel panelling on the cold side of air spaces, whether filled with insulation or not. An air space should be left between the steel and the insulation and arrangements made for warm inside air to flow up through this.

A.3.4 *Circulation of air, drainage, and waterproofing*

A.3.4.1 *Circulation of air.* Free circulation of air around and through the structure should be arranged (see Figure 4); this hastens the drying of surfaces after rain or dew.

Protective coatings break down exceptionally quickly on sheltered surfaces, such as the eaves of buildings, where moisture lingers and such areas would benefit from the protection of special coatings.

A.3.4.2 *Drainage.* Arrangements should be made for shedding dripping water and condensation. Where necessary, lengths of pipe should be attached to the drain holes to carry the water clear so that it cannot be blown back on to the structure [see Figure 5(a)].

The design of storage tanks should permit complete drainage [see Figure 5(b)] or a sump should be provided from which condensed water can be pumped. To avoid water traps, the floor should be as smooth as possible, welded joints should be ground flush and any stiffeners should be fitted outside the plates.

Extra protection should be given to the most vulnerable areas by coating the bottom and about 300 mm to 400 mm up the sides.

Water traps should be avoided where steel stanchions enter the ground or are embedded in a concrete base (see Figure 6).

A.3.4.3 *Waterproofing.* (15). Many structures, especially bridges, are made of steel and reinforced concrete. The prevention of corrosion and deterioration depends on careful waterproofing and correct design of the concrete details to keep water away from the steel.

A.3.5 *Contact with other materials*

A.3.5.1 *Other metals.* Electrochemical corrosion can appear at contact surfaces between different metals.[13)]

Some metals, e.g. nickel and copper, aggravate the corrosion of steel while others, e.g. zinc, reduce it. The danger of bimetallic corrosion is most serious for immersed structures but should also be considered when designing atmospheric or buried structures. The latent corrosion cell can be made inert by one or more of the following methods.

a) Insulating the contact surfaces.

b) Making the joints watertight and using an impermeable coating to keep out the electrolyte, e.g. rain water.

c) Applying a metallic coating to the steel, so as to reduce the potential difference between it and the non-ferrous metal.

d) Imposing overall cathodic protection.

A.3.5.2 *Different types of steel.* Contacts between mild steels and/or low-alloy steels will not affect corrosion appreciably, if they are free from mill-scale. Trouble might arise, however, at contacts between these steels and stainless steels.

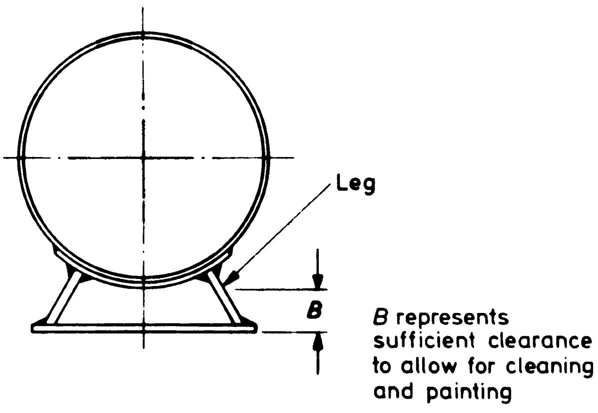
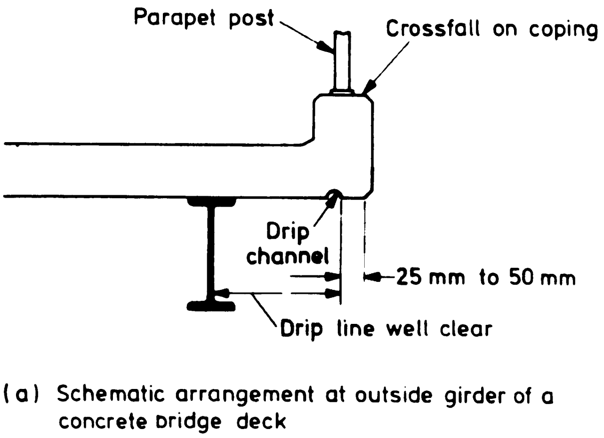
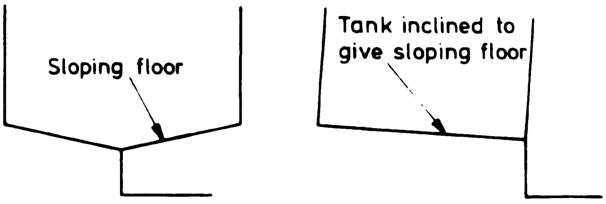


Figure 4 — Air circulation e.g. pipeline support



(a) Schematic arrangement at outside girder of a concrete bridge deck



(b) Schematic arrangement for tanks

Figure 5 — Drainage

A.3.5.3 *Concrete.* Portland cement concrete tends to inhibit the corrosion of embedded steel but it will not protect steel which is near the surface against corrosive attack. This subject is too complex to discuss in detail and is outside the scope of this code. In general, steel that is embedded in Portland cement concrete needs no additional protection if the provisions of all the parts of BS 8110 are followed. These include the following:

a) Correct composition and compaction of the mix.

b) Adequate depth of cover of the reinforcement at all points. From 50 mm to 60 mm is recommended for the most severe conditions, e.g. exposure to sea water, but 20 mm may be sufficient for indoor work. There is evidence that these figures can be reduced by 25 % if the steel is given a zinc coating of 500 g/m^2. The depth of cover should also be related to the maximum size of concrete aggregate.

The concrete cover should be continuous. If gaps are left in it, a corrosion cell may be set up (see Figure 7).

[13)] See PD 6484.

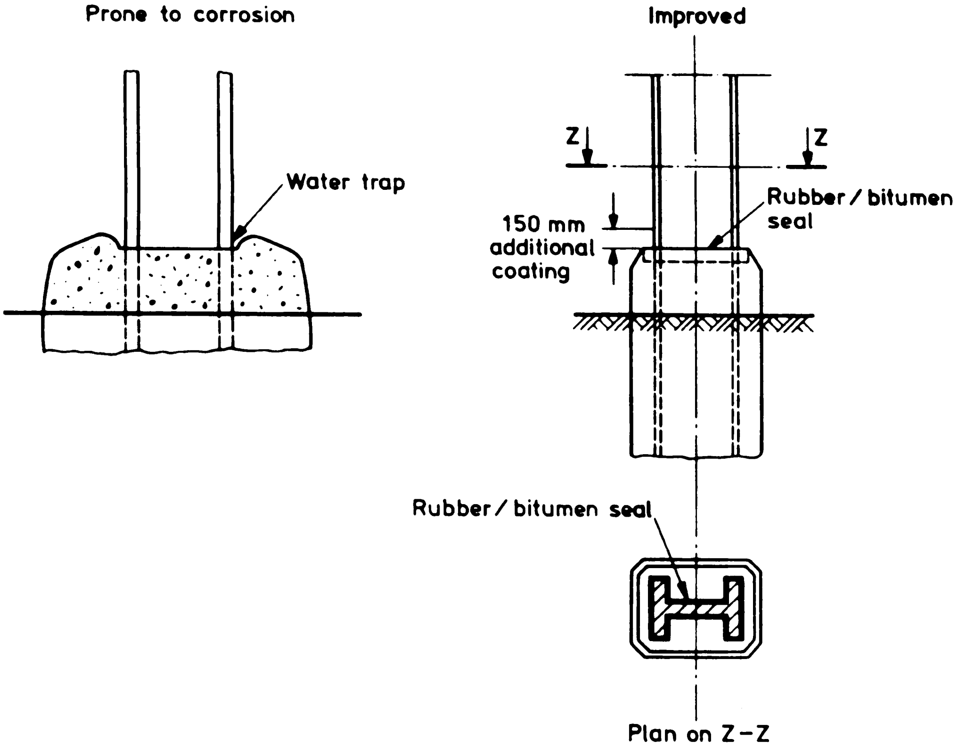


Figure 6 — Protection of a stanchion at ground level

A.3.5.4 *Timber.* Where steel is in contact with timber under corrosive conditions, the faces of both materials should be coated with hot tar or with a bitumen bedding compound containing fillers, immediately before they are brought together. An insulating sheet of plastic, e.g. polyethylene, may be used, especially if the timber has been treated with preservative.

Large washers of neoprene or similar material should be fitted under nuts and bolt-heads to prevent water entering the wood. The nuts and bolt-heads should be coated in the same way as the bolts.

Contact surfaces between zinc-coated or aluminium-sprayed steel and wood need similar treatment.

A.3.5.5 *Other materials.* Some other building materials, e.g. gypsum plaster, are corrosive. Suitable insulation, such as a waterproof membrane, should be provided where steel touches them and the penetration of water to the interface should be prevented.

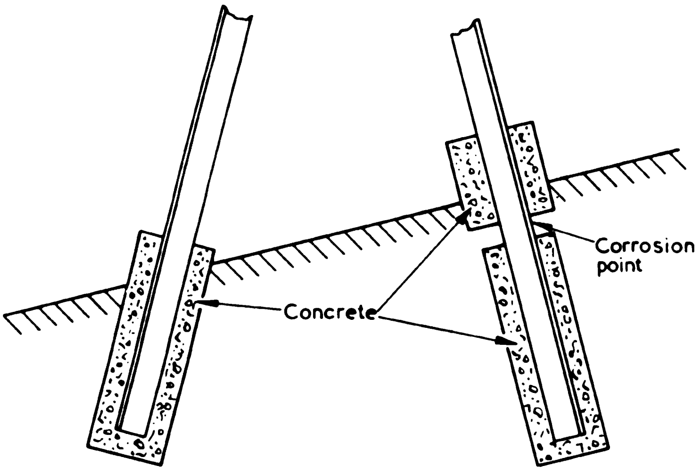
Problems can also arise through the evolution of corrosive vapours from plastics and other organic materials.

A.3.6 *Coating application*

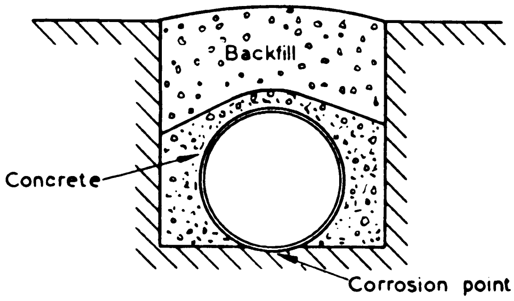
A.3.6.1 *General.* The designer should strive to ensure that the protective coatings can be applied with ease and efficiency, so as to achieve a continuous, uniform coating everywhere. Consequently, details such as back-to-back angles, recesses, deep corners and blind holes should be avoided (see Figure 8).

Sharp edges and corners cannot be coated evenly and coatings there are particularly vulnerable to damage; all edges and corners should therefore be radiused. Tubular sections are better than I or H sections in this respect.

A.3.6.2 *Galvanizing.* Vent holes and drain holes should be provided in assemblies that are to be hot-dip galvanized (see BS 4479). They serve to avoid internal pressures and airlocks during immersion, which may cause explosions. They also ensure that molten zinc is not retained in pockets on withdrawal.



A steel tower with precast concrete feet had to be erected on sloping ground. A concrete collar was cast in situ' to protect the upper leg at ground level. Severe corrosion occured at the gap that was left between the new and the old concrete



A pipeline was allowed to rest on the trench bottom (instead of on a concrete bed) when the steel was encased in concrete. Corrosion occurred along the unprotected part of the pipe (at the bottom)

Figure 7 — Corrosion at gap in surrounding concrete

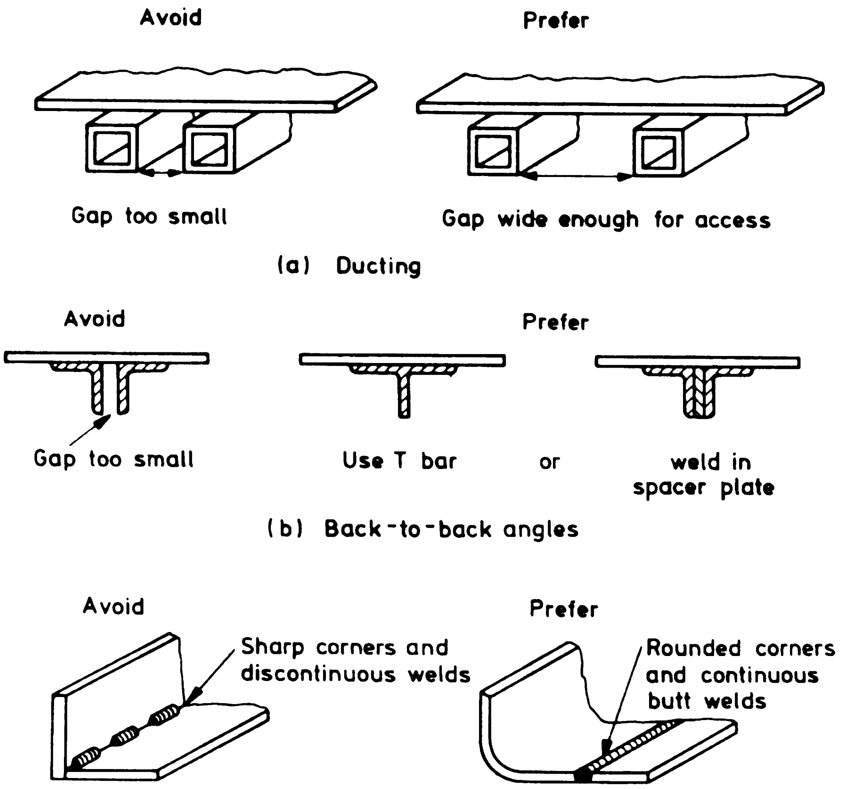


Figure 8 — Design for coating

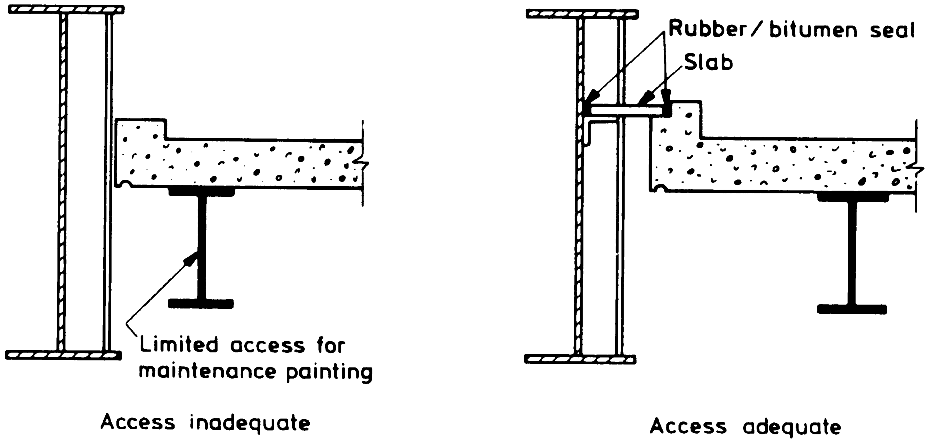


Figure 9 — Access for maintenance

A.3.6.3 *Dip-painting.* The details of steelwork that is to be dip-painted should resemble those for hot-dip galvanized steel (see **A.3.6.2**).

A.3.6.4 *Metal-spraying.* Sufficient access should be provided to all surfaces that are to be metal-sprayed (see BS 4479).

A.3.6.5 *Spray-painting.* The paint-spraying gun is more flexible and wieldy than the metal-spraying pistol, so the details recommended for metal-spraying (see BS 4479) should be adequate for spray-painting.

A.3.6.6 *Access.* The design should ensure easy access to all parts of the structure and thereby make it possible to inspect and renew the protective scheme without difficulty. Thus, any falsework, screens or hoardings that would impair access to the corrected structure should be easily removable.

Lack of forethought, may result in areas that can be painted in the shop becoming inaccessible later (see Figure 9).

Where the expense is justified, the design might include special fittings for the attachment of painting gantries or powered platforms and of awnings to shield maintenance work from bad weather. These should be robust and placed where they can be maintained without risk of accident.

A.3.7 *General factors*

A.3.7.1 *General design of the structure.* The general design of the structure can affect the performance of a protective scheme.

a) It is much easier to protect large flat areas than more complicated shapes. For example, truss types of bridge are more susceptible to painting difficulties than beam and girder types and it is easier to protect tubular construction than lattice work. Tubes may be better than wires for guys and similar supports.

b) Sometimes, part or the whole of a structure can be made detachable. It may then be economic to have them hot-dip galvanized and returned for re-galvanizing when necessary.

A.3.7.2 *Load-bearing members.* If the design permits, the load-bearing members should be located where the corrosive conditions are least intense. For example, the members supporting the roof of a tank for corrosive chemicals should be external to the tank.

A.3.7.3 *Services.* The locations of service pipes, cables and ducts attached to the structure, or passing through box girders, should be agreed with all interested parties before detail drawings are prepared.

Lack of attention to such matters can lead to the creation of corrosion points, which arise, for example, where pockets are formed by not keeping conduits clear of the steelwork or where steam and other exhausts from pipes are allowed to impinge on it. The time needed for maintenance is uneconomically prolonged if service equipment has to be moved before the work can begin.

A.3.7.4 *Faying surfaces.* Coatings on faying or flexing surfaces are particularly vulnerable to damage. For example, the failure of outdoor pipelines is most frequently due to the abrasion of the coating through the expansion and contraction of bearing surfaces. One possible remedy is to provide graphite pipe slides.

A.3.7.5 *Cathodic protection.* Where cathodic protection (see BS 7361-1) is to be applied, the design should ensure good electrical continuity throughout and, if necessary, insulation from neighbouring structures. Permanent and readily accessible insulated test leads should be fitted at representative points for checking the efficiency of the insulation.

Appendix B
Characteristics of paint binders

B.1 Binders for drying-oil-type protective systems

Description	Characteristics
Blend of raw and processed drying oils	Very slow drying; good surface wetting where steel cannot be well cleaned
Drying oil modified with phenolic or phenolic-modified resin	Good water resistance; suitable for primers and undercoats but yellows in light-coloured finishes
Alkyd or modified alkyd	Good all-round properties; 4 h to 8 h overcoating in good conditions depending on oil content (oil length). Prone to blistering in damp conditions
The modification may be:	
a) blending with raw or processed drying oil	Dries faster than blended oils alone, but slightly less tolerant of poor surface cleaning
b) copolymerizing with styrene or vinyl toluene	Faster-drying alkyd but less tolerant of poor surface cleaning. Vinyl copolymers are sensitive to solvents and recoating times are critical
c) combining with an isocyanate to form a urethane alkyd	Basis of one-pack polyurethanes. Components are usually selected to provide additional hardness to the finish
Alkyd modified with chlorinated rubber	Faster-drying alkyd with improved water resistance. Fair chemical resistance when ratio of chlorinated rubber to alkyd is 2 : 1 or more
Solution blends in suitable solvents. Chosen alkyd should be fully compatible with the chlorinated rubber.	Full chemical resistance and suitability for use with cathodic protection is doubtful while saponifiable component is present
Drying-oil epoxy ester (one-pack epoxy)	Faster drying than modified drying oil, with good water resistance, but yellows in light-coloured finishes
Urethane oil	Drying-oil film is hardened and toughened. Used for primers required to withstand rough handling
drying oils suitably modified with isocyanates	
Silicone alkyds	When silicone resin content exceeds 30 %, alkyd is durable and retains gloss. Especially recommended for finishing coats exposed to intense sunlight

B.2 Binders for one-pack chemical-resistant protective systems

Description	Characteristics
Blend of chlorinated rubbers and non-saponifiable plasticizers. NOTE For blends with alkyds see **B.1** “alkyd modified with chlorinated rubber”.	Very low water permeability. Quick drying. Can be overpainted with no adhesion problems, even after prolonged aging
Blend of vinyl chloride/acetate copolymers with or without non-saponifiable plasticizers NOTE Primers with copolymer should be maleic modified to assist adhesion.	Similar to preceding binder but much less tolerant of poor surface cleaning and has a higher water-vapour permeability. More durable in finishing coats exposed to intense sunlight. Low-build at normal viscosity

B.3 Binders for two-pack chemical-resistant protective systems

(For correct use of the terms "binder", "vehicle", "medium", see BS 2015.)

Description	Characteristics
Two-pack epoxy mixture of an epoxy resin and suitable curing agent	The epoxy resin is available at different viscosities (low viscosity for high build). The curing agent is either an amine or an amide. The reaction on mixing is temperature dependent and results in a highly chemically resistant binder. Amines, especially aliphatic amines, can be toxic until reacted and should be used with great care. The choice of curing agent also depends on required performance. Paint manufacturer's advice should be sought in every case
Curing agents	
aromatic amines	Good water resistance and low-temperature cure
aliphatic amine adducts	Good speed of cure and solvent resistance, but tend to give poor intercoat adhesion
aromatic amine adducts	Good intercoat adhesion and resistance to aqueous chemicals
polyamides	Slower curing rate and good pot life, best when blended with coal tar
Coal tar epoxy mixture of an epoxy resin with a suitable coal tar fraction	Coal tar is a diluent and cheapening additive which detracts little from general properties and gives slightly better water resistance. It is not satisfactory for solvent resistance and gives poor low-temperature flexibility. Recoating periods are critical and this leads to intercoat adhesion problems and a tendency to bleed into subsequent coats
Two-pack polyurethane	The polyester can vary from brittle to flexible; blends are made to suit finish requirements
mixture of suitable polyester resins with polyisocyanate curing agent,	
aliphatic polyisocyanate	Superior colour retention and UV-resistance; recommended for finishing coat
aromatic polyisocyanate	Suitable for primers, undercoats and finishes. Not used where it is important to avoid yellowing NOTE Two-pack polyurethanes have better weathering resistance and low-temperature cure than two-pack epoxies but are more difficult to formulate for high-build products and, during curing, are more sensitive to moisture.

B.4 Binders for specific uses in protective systems

Description	Characteristics
Polyvinyl butyral resins	
a) For two-pack pretreatment primer (see product sections of Table 4)	When mixed, the phosphoric acid reacts with resin and the metal surface to give a chemical bond. May be modified with phenolic resin for improved water resistance
b) For single-pack "blast primer" (see product sections of Table 4)	Modified with phenolic resin
Silicone resin	In the skeleton of the binder, silicon replaces the more usual carbon. This adds heat resistance to its value as a binder (e.g. aluminium silicones for steel chimney stacks)
Alkali silicates, (see product sections of Table 4)	Aqueous binder reacting with zinc-dust pigment; dries to a hard adherent cement-like structure with good abrasion resistance
Organic silicates, (see product sections of Table 4)	Alkyl ester hydrolyzing and reacting with zinc-dust pigment; dries to a hard adherent cement-like structure with good abrasion resistance. More tolerant than alkali silicates to variations in atmospheric moisture

Appendix C
Characteristics of paint pigments

C.1 Pigments used mainly for primers

Description	Characteristics
Red lead (also red/lead white/lead)	Suitable where oil content of binder is high (i.e. slow drying)
Zinc chromate	Available with different degrees of solubility. Solubility can inhibit corrosion but may also cause blistering. Paint manufacturer should be consulted before use
Zinc tetroxychromate	Used in pretreatment primer with polyvinyl butyral resin binder (see table A)
Zinc phosphate	Good general-purpose pigment for primers. Its light colour is an advantage if producing light tints; early rusting caused by thin films or overexposure can be seen
Metallic lead	Satisfactory performance for bridge protection and in paints for direct application to galvanized steel. Reactive in certain environments More suitable than red lead for oil-free binders
Iron oxide	Inert pigment of high staining power; yellow, red and black forms are suitable as a cheap additive. Use of red form in primers may mask initial breakdown by rusting
Zinc dust	Gives some cathodic protection to steel when used as a sufficiently high percentage of the total film to ensure electrical conductivity through the dry paint film to the steel. See BS 4652
Calcium plumbate	Used in paints for direct application to galvanized steel. See BS 3698

C.2 Laminar pigments used mainly for undercoats and finishes

Description	Characteristics
Micaceous iron oxide (MIO)	All these are used in protective coatings because the flakes lie parallel to the surface and overlap, forming a moisture barrier and improving tensile strength. MIO and aluminium protect the binder from UV-degradation. Leafing aluminium has high lustre. Aluminium and graphite are used for high temperature paints. Aluminium is not recommended for chemical resistance
Mica	
Aluminium a) leafing, coated with stearic acid b) non-leafing	
Graphite	
Stainless steel	
Glass flake	

C.3 White pigments for undercoats and finishes

Description	Characteristics
Titanium dioxide (rutile)	The principal white colouring pigment is rutile titanium dioxide. The anatase grade chalks on exposure to UV-light but is suitable for undercoats. A proportion of zinc oxide may be used for its antifungal and biocidal properties. A proportion of antimony oxide is used where special fire-retardant properties are required
Titanium dioxide (anatase)	
Zinc oxide	
Antimony oxide	

C.4 Coloured pigments for undercoats and finishes

Description	Characteristics
Iron oxides	Light-resistant cheap pigments available in shades of red, yellow and black
Carbon blacks	Very high staining power and, as relatively small additions, give high-opacity black finishes. As tinters they are the basis of grey finishes
Light-resistant organic or inorganic pigments	Pigments should be selected which are known to be adequately resistant to light when used with the binder specified
Light-resistant organic or inorganic pigments with good chemical resistance	The pigment as well as the binder should have the specified chemical resistance

C.5 Extender pigments for undercoats and finishes

Extenders, as used in anticorrosive protective compositions are inorganic compounds of limited opacity and low refractive index, they may occur in nature or can be made synthetically. The choice of extender depends on the property required of the protective coating.

Description	Characteristics
Oxides, mainly silicas	Naturally occurring as quartz (sand) and diatomaceous silicas such as kieselguhr. Synthetic silicas usually have a very fine particle size and are very transparent in binders. Sand is useful for abrasion resistance (deck and floor paints). Kieselguhr and synthetic silicas are useful in reducing gloss of finishes (e.g. to achieve matt finishes)
Carbonates	
calcium carbonate (chalks, limestone whiting)	Calcium and barium carbonates are also available in synthetic form. The carbonates are cheap extenders with good all-round properties but are not suitable for acid-resistant finishes and should be avoided where the environment is considered severe
calcium magnesium carbonate, (dolomite)	
barium carbonate (witherite)	
Silicates	
aluminium silicates (china clay, mica, bentonite)	Cheap extender, useful for anti-settling properties Good for producing a gel structure in formulations
calcium silicates (wollastonite, synthetic)	Alkaline in nature and stabilizes emulsion or water-based paints
magnesium silicates (talc, asbestine)	Assists suspension and controls settlement in primers and undercoats
calcium-magnesium-iron silicates (asbestos)	The fibrous nature prevents cracking of bituminous and like products
Sulphates	
barium sulphate (barytes (synthetic form), blanc fixe)	Insolubility makes it an outstanding extender in high-performance formulations
calcium sulphate (gypsum (synthetic form), precipitated calcium sulphate)	Because of its water sensitivity, should be used with considerable caution

Appendix D
Sampling of paint

Paint is more difficult to test than most materials used by the engineer, because the performance of a paint film depends on where and how it is applied. Chemical analysis is no guarantee of quality but gives circumstantial evidence of conformity with a specification, of probability of contamination of material used or of incorrect mixing. Physical tests of properties such as viscosity, density or non-volatile content are often easier to make and may be equally informative.

For these purposes comparison of a sample taken at the point of use with an agreed sample, either supplied with the manufacturer's tender or taken from the delivered material, is required. Where a dispute is likely to arise, three identical samples should be taken, one for the inspector, one for the painting contractor (or main contractor) and one for the manufacturer. It is best to take reference samples from all batches of material delivered even if no immediate tests are to be made. Whilst the agreed sample should be taken after carefully mixing the material under examination and using established sampling methods, point-of-use samples should be taken straight from the painter's kettle or spray pot.

Process samples of the "as applied" system, when properly identified, can be invaluable if a dispute over performance ensues.

Appendix E
Choosing the most economical defence against corrosion

The choice of the most economical defence against corrosion cannot be precise, because neither the timing nor the cost of future maintenance can be predicted accurately and rates of taxation change from time to time. Nevertheless, an overall economic appraisal should be made, for it may help to influence a decision when there is uncertainty regarding the choice of protective system or products that require a protective system.

Each product or protective system has its own pattern of capital and running costs. Choosing the optimum alternative requires care because some of the factors involved can be measured precisely whilst others can not, and the costs arise at different times.

A quick comparison of systems can be made by comparing present first costs plus maintenance costs at present values in each case. (Access and disruption costs should be taken into account at this stage.) The comparison can then be elaborated by the following procedure.

Step 1. Set out the alternatives, ensuring that they have the same basis of comparison. Write down the extra capital cost (if any) arising from the need to make the product from more expensive materials, to protect the product or structure, or to increase the thickness of steel to allow for wastage by corrosion. This capital cost may be a direct quotation or may be calculated (see note (c) below) but make sure that quotations or calculations are on the same basis.

Step 2. Add extra transport costs (e.g. when work goes to specialist processing plant instead of direct to customer or to site), extra mark-up (the main contractor may add a percentage on sub-contracted work) and extra administrative costs where appropriate and where not included in step 1.

Step 3. (Not relevant to private individuals.) Deduct tax allowances. Typically, for limited liability companies in the United Kingdom these comprise initial grants for certain projects in development areas plus first-year allowances, adjusted for corporation tax.

Step 4. Estimate the time that will elapse before the product or structure is available for use. Write down the cost in interest of any such delay assuming the capital sums involved could have been otherwise employed during the extra time required (compared with the product or system most speedily available).

Step 5. Estimate maintenance costs (after making an appropriate allowance for tax relief) during the life of the structure, including access costs such as scaffolding. In general, the future maintenance costs have to be estimated, making allowance for inflation and then discounted to present values (see maintenance terms in the equation below).

Step 6. Estimate cost of disruption during maintenance (or initially). As with maintenance costs, these have to be estimated, making allowance for inflation, and then discounted to present values.

The maintenance costs plus the initial cost are frequently assessed as the Net Present Value (*N*), which represents the sum of money that has to be set aside now to cover both initial and maintenance costs over the total life required.

$$N = F + \frac{M_1}{(1 + r)^{P_1}} + \frac{M_2}{(1 + r)^{P_2}} + \text{etc.}$$

where

F is first cost of the protective system;

M_1 is the cost of maintenance in the year P_1;

M_2 is the cost of maintenance in the year P_2;

r is the interest (or "discount") rate;

NOTE 12 % rate is written 0.12, etc. r can also be the expected rate of return on capital employed in the business.

P_1 denotes the number of years to first maintenance;

P_2 denotes the number of years to second maintenance, etc.

Maintenance costs are steadily rising and so have to be adjusted at present-day values (M) to allow for inflation at an annual rate r_1: (r_1 is expressed like r).

$M_1 = M(1 + r_1)^{P_1}$ etc.

Therefore:

$$N = F + \frac{M(1 + r_1)^{P_1}}{(1 + r)^{P_1}} + \frac{M(1 + r_1)^{P_2}}{(1 + r)^{P_2}} + \text{etc.}$$

In the simplest case, where the rate of inflation of maintenance costs is the same as the interest (or "discount") rate available on money (i.e. where there is no time-value of money), then $r_1 = r$ and the formula is simplified to:

N = F + the sum of all maintenance costs at present-day rates

= the aggregate of all initial and maintenance costs at present-day rates

Other costs can be treated as for the maintenance costs or for the first cost as appropriate. Table 13 illustrates a model cost-calculation table.

The following points should be borne in mind when making the necessary calculations.

a) For many protective schemes the initial cost in the factory is roughly proportional to total thickness, but life to first maintenance is not necessarily proportional to thickness;
e.g. relatively thin metal coatings in certain environments often have the longest lives to first maintenance.

b) Calculation of protection costs from fundamentals has been dealt with in industry-oriented handbooks, e.g. "Galvanizing for profit", Galvanizers Association, London, UK. In principle, first costs include:

materials

labour

overheads (including inspection, access equipment and tools for painting).

These are usually of the same order of magnitude, with materials being most costly for metal coatings and labour most costly for paint coatings.

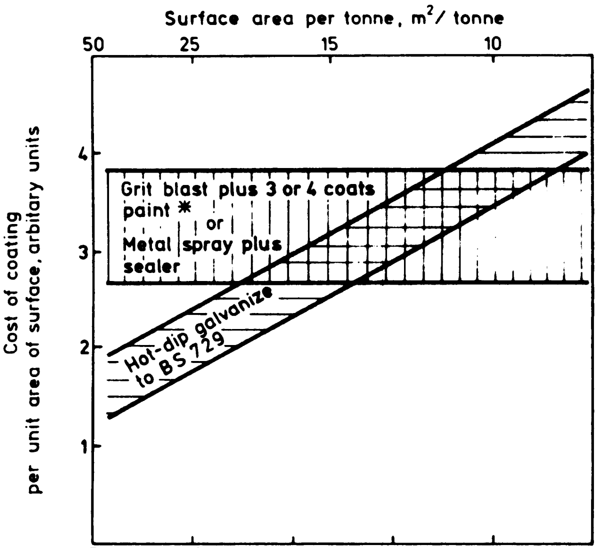
c) Surface preparation for painting is often analysed separately, for its cost frequently amounts to about one-third of the total cost. Acceptance of poor surface preparation may save 20 % or less of the total capital cost, but is likely to reduce the life expectancy of a coating by more than half, so adding more than 100 % to the total life cost. Incorrect choice of blasting equipment (e.g. size of nozzle, grade of abrasive, etc.) will increase the cost of surface preparation and may even double it.

d) In calculating paint quantities, the theoretical dry-film requirement should be increased by up to 50 % to allow for locally thick coatings, wastage, repairs and losses (typically 30 % for air spray, 15 % for airless spray, 10 % for electrostatic spray, 5 % for roller or brush application) etc. Manufacturers should be asked to quote the percentage of solids by volume in their paints to facilitate calculations.

e) Labour costs for the application of paint increase in an approximate ratio in the following order:

airless spray : normal air spray : roller : brush
1 : 2 : 3 : 4

f) Comparative costs, unlike actual costs, change little with time. When labour costs are rising more rapidly than material costs, painting will become slightly more expensive relative to metal coatings and vice versa.



*Except that with paint, the final coat is on site.

Figure 10 — Shop coating costs relative to thickness of steel

Table 13 — Suggested layout of a cost-calculation table

	Competing systems (conforming to systems under same environment and same time to first maintenance in Table 3)		
	First system	Second system	etc.
Extra capital cost (step 1) Add extra transport costs (step 2) Add extra fabricator's mark-up (step 2)			
Total gross extra capital cost Deduct total taxed allowances (step 3)			
Total gross extra capital cost, net of tax allowances, etc. Delay factor (step 4) Maintenance costs (step 5) Disruption factor (step 6)			
Total cost of system, over and above costs common to all systems, and expressed in present-value terms			

g) Sprayed-metal, paint, powder, and tape coatings are usually costed by the area covered, which should be known reasonably accurately. Galvanizing is costed by the weight of steel coated, i.e. by the thickness of steel. Costs also vary by product. The qualitative relation for structural steel is shown in Figure 10.

h) The most economical system for one job is not necessarily the most economical for another, e.g. galvanized steel may be best for a bolted job but not where much site welding is necessary.

i) First costs include access costs, e.g. scaffolding. Surfaces treated before erection do not require scaffolding.

Appendix F
Methods for control of preparation (by blast-cleaning)

Grades of blast-cleaning are selected by the specifier in relation to the conditions of use and the protective system chosen. Specifications for blast-cleaning are given, together with representative photographic examples, in Swedish Standard SIS 05 59 00 and BS 7079-A1, but these can be used for site control only if the lighting is good and the inspectors are highly experienced. Steel coupons blast-cleaned to an agreed standard are better but should be carefully stored and handled to prevent deterioration.

For convenience and to reduce disputes it is best to use instruments which enable figures to be recorded. A light reflectometer, e.g. the Surclean Model 153[14], can be used to assess effectiveness of removal of mill-scale, freedom from rust, and general approach to "white metal" condition. This instrument measures the amount of blue light reflected from the surface compared with that from a standard grey tile. Repeatedly blasting the same area of steel causes an increase in reflection until a steady value $R_{\max}$ is reached corresponding to white metal (dependent on the abrasive and the steel) as shown in Figure 11. The acceptance level should be fixed as a percentage of $R_{\max}$ for BS 7079-A1, Sa2½; the average of all readings on the work should be at least 90 % of $R_{\max}$ and not more than one reading in ten should be below 80 % of $R_{\max}$. When using this control method the value of $R_{\max}$ and the acceptance levels should be agreed by the Inspector, the contractor and other interested parties at the start of the work.

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[14] Supplied by Elcometer Instruments Ltd., Manchester.

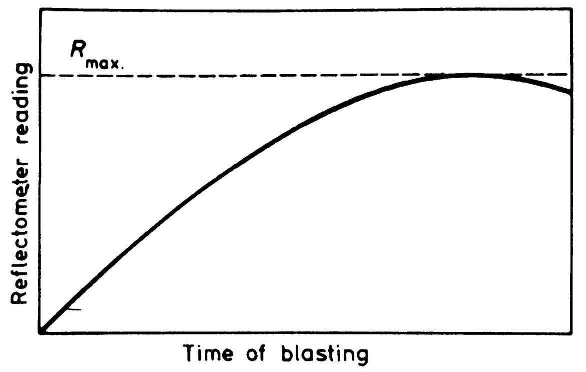

Figure 11 — Assessment of steel cleaning

Appendix G
Test for detecting soluble rust-producing salts remaining on blast-cleaned steel

When blast-cleaning heavily rusted and rust-pitted steel a surface appearance suggesting a standard of cleanness equivalent to white metal or Swedish Standard Sa2½ or Sa3 can be obtained, which, after an hour or two and sometimes after standing overnight, develops rust-spotting at points corresponding to the rust-pitting. In such circumstances it is a serious mistake to apply protective coatings until the cause of the rust-spotting has been eliminated. The cause is the presence of rust-producing soluble salts of iron which are practically colourless and are located at the lowest point of the rust pits. In the presence of moisture they hydrolyse to iron oxides and acids; the acids dissolve more iron to form more iron salts thus producing, in time, large volumes of rust which will break the adhesion bond of protective coatings if applied before the salts are removed.

Using potassium ferricyanide test papers any remaining soluble iron-salt contaminants can be detected as follows.

a) Spray a fine mist of water droplets on to a small area of the blast-cleaned surface using a hand spray (a scent-spray type of bottle if satisfactory).

b) Allow the water droplets to evaporate and at the moment when they have disappeared but the surface is just perceptibly wet apply a small piece of test paper and press with the thumb for 2 to 5 seconds.

If soluble salts remain, these will be drawn by capillary action into the test paper and will react with the potassium ferricyanide to give a characteristic prussian blue complex as blue dots on the paper corresponding to the contaminated pits on the blast-cleaned steel.

Appendix H
Example of use of the code (see clause 3)

The following example is intended to demonstrate, for the inexperienced specifier, the step-by-step approach to selection of a coating system for a particular fabrication, taking all appropriate factors into account.

The protective system to be selected and specified is required for a girder linking a sea-water pontoon to a fixed point on land at a site in the United Kingdom.

It is assumed that the girder has been conceived as a welded box-girder with lightening holes and pin joints at the ends. The pin joints, which are considered to be purpose-made units to be attached to the ends of the girder by site bolts, are not included in the example.

The selection and specification of a coating system		Source of information or location in the code
Step 1	**Acquire an appreciation of what is included in the code and where it is located**	Table of contents and index
Step 2	**Consider if any modification of the design is desirable in the light of the advice in the code**	**45.3** and **A.3**
	In the example it is seen that a box section with lightening holes will not only trap water but will be difficult to maintain internally, so it is decided to redesign the girder as a welded plate girder with lightening holes in the web. This reduces water trapping and makes all surfaces readily accessible.	
	Special attention is paid to the ends to ensure that any water resting on the bottom flange can run off as the pontoon rises and falls.	
Step 3	**Ascertain and list the basic facts concerning the structure by answering the questions in 4.2**	
	In the example, the facts (and assumptions) are tabulated as follows.	
	4.2.1 Function.	
	a) Structure is required to link pontoon to shore.	Design remit
	b) Nil.	
	4.2.2 Life.	
	a) 50 years.	Design remit
	b) Reconsider later.	
	4.2.3 Environment.	Clause **5**
	a) Coastal.	Design remit
	b) Structure is a few feet above salt water and is likely to be covered with spray from time to time.	
	c) At high tide, in storm conditions the under side may be hit by water-borne flotsam, but there is unlikely to be mechanical damage arising from usage or contamination by de-icing salts.	
	4.2.4 Appearance.	
	a) The owning authority requires the colour to be green overall.	Design remit
	b) Yes.	
	4.2.5 Special properties.	
	a) No requirement.	
	4.2.6 Maintenance	
	a) Because of pontoon use, access for maintenance will be possible only in November and December.	Design remit
	b) It is clear that maintenance will be difficult.	Practical experience
	4.2.7 Health and safety.	
	a) No special points requiring attention are apparent at this stage.	
	b) The existence of offices adjacent to the shore connection suggests that limits may be placed on permissible noise and/or dust created during maintenance work.	Section 6 and practical experience
	4.2.8 Tolerance.	
	a) A high standard is essential at this site, requiring works application of initial coatings.	Clause **9**
	b) As a) above. However, site applied coats may need to be tolerant of a lower standard.	Suppliers

<table>
<tr><th colspan="7">The selection and specification of a coating system</th><th>Source of information or location in the code</th></tr>
<tr><td>Step 4</td><td colspan="6">Examine Table 1. Select the description nearest to 4.2.3 above. Turn to the corresponding part of Table 3</td><td>Table 1</td></tr>
<tr><td></td><td colspan="6">In the example, the nearest description is “sea water: splash zone ... frequent salt spray”.</td><td>Table 3, part 9</td></tr>
<tr><td>Step 5</td><td colspan="6">Decide on a life requirement, taking into account the answers to questions 4.2.2, 4.2.4, 4.2.6</td><td>Clause 6</td></tr>
<tr><td></td><td colspan="6">It is clear that a durable protective system is required. However, the decorative coating may be expected to require attention at shorter intervals than would normally apply with a durable protective system. It is decided, therefore, to select a “long life” system to reduce the frequency of maintenance and (incidentally) reduce the likelihood of potentially noisy surface preparation being needed for corroded areas. At the same time a greater frequency of maintenance for the decorative coating is considered acceptable.</td><td>6.2.1
6.2.2
6.3 b)</td></tr>
<tr><td>Step 6</td><td colspan="6">Consider the “long life” systems listed in Table 3, part 9; eliminate any that are thought to be unsuitable. Make preliminary estimates of the approximate cost per square metre and inquire into the suitability (for the actual conditions) of the remaining systems, so far as time permits</td><td>Table 3, part 9. Appendix E</td></tr>
<tr><td></td><td colspan="6">It is clear that some of the systems listed (SB1 + SK5; SB3; SB9; SC3Z; SC6Z; SC10A; SC10Z; SE7; SK8; SL5) will require the decorative finish as an addition; yet there are no immediately obvious reasons for eliminating any of those systems at this stage. Therefore:</td><td></td></tr>
<tr><td></td><td colspan="6">a) if time permits, make inquiries (preferably of the manufacturers) about all of these systems; or</td><td></td></tr>
<tr><td></td><td colspan="6">b) if there is not sufficient time, confine the inquiries to those systems that include a finish that gives or seems to give the required appearance.</td><td></td></tr>
<tr><td>Step 7</td><td colspan="6">On the basis of the conclusions reached in step 6 and any experience or justified preference, select a limited number of systems for detailed examination</td><td></td></tr>
<tr><td></td><td colspan="6">In fact, time is short (step 6 b) applies) so the selection of systems for detailed study is limited to SB9; SC10A; SC10Z; SE7; SL5.</td><td>Table 3, part 9</td></tr>
<tr><td>Step 8</td><td colspan="6">Make a detailed study of the characteristics of the selected systems, asking the questions listed in 4.3</td><td></td></tr>
<tr><td></td><td colspan="6">In this example, this study could have been made as part of step 6 because the time limitation discussed in step 7 was then already known.</td><td>4.3</td></tr>
<tr><td></td><td colspan="6">A check list in the following form may be found useful. It tabulates the answer for each of the five systems against each question.</td><td></td></tr>
<tr><td></td><td colspan="6">4.3.1 Coating systems.</td><td></td></tr>
<tr><td></td><td>a)</td><td>SB9</td><td>SC10A</td><td>SC10Z</td><td>SE7</td><td>SL5</td><td>Table 3, part 9</td></tr>
<tr><td></td><td>b)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Supplier/experience</td></tr>
<tr><td></td><td>c)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Supplier/experience</td></tr>
<tr><td></td><td>d)</td><td colspan="5">Application method to suit material. No apparent limitation.</td><td></td></tr>
</table>

The selection and specification of a coating system						**Source of information or location in the code**
4.3.2 Coating facilities						
	SB9	SC10A	SC10Z	SE7	SL5	
a)	1) Depends on size and shape of structural member	Yes	Yes	Yes	Yes	Supplier/experience
	2) Yes	Yes	Yes	Yes	Yes	Supplier/experience
b)	Very large members may be a problem	Yes	Yes	Yes	Yes	
c)	Yes	Yes	Yes	Yes	Yes	
d)	Yes	Yes	Yes	Yes	Yes	
4.3.3 Compatibility						
	SB9	SC10A	SC10Z	SE7	SL5	Clauses **7** and **8**
a)	Yes	Yes	Yes	Yes	Yes	
b) Not with normal structural steels; check if special steels may be used in the fabrication		No	No	No	No	
c) N.A. (not applicable)						
4.3.4 Delays.						
	SB9	SC10A	SC10Z	SE7	SL5	
a)	N.A.	N.A.	N.A.	N.A.	N.A.	
b)	N.A.	N.A.	N.A.	N.A.	N.A.	
c)	N.A.	N.A.	N.A.	There may be problems of intercoat adhesion.		
d)	N.A.	N.A.	N.A.	There may be problems of intercoat adhesion.		
e) The final coat should be applied as soon as possible after erection in view of possible salt contamination. Ensure adequate pretreatment before applying paint coat.						
4.3.5 Transport, storage, handling (works-applied coats only).						
	SB9	SC10A	SC10Z	SE7	SL5	Experience applied to manufacturer's data
a)	Quite good	Good	Good	Fair	Fair	
b)	Quite good	Good	Good	Fair	Fair	
c)	Good	Good	Good	Doubtful	Doubtful	
d)	N.A.	N.A.	N.A.	N.A.	N.A.	
NOTE These are qualitative, not absolute, terms.						
4.3.6 Experience.						
Assumed reported equal for all systems.						
4.3.7 Export.						
Not applicable.						

The selection and specification of a coating system	Source of information or location in the code
4.3.8 Maintenance.	
Yes, if steel is exposed. Deterioration of finishing coat only is not serious.	
4.3.9 Costs.	
a) 1), 2) It is not practical to quote costs in a hypothetical exercise.	
3), 4), b) So far as can be seen these will be the same for all the systems considered.	
Step 9 Make final selection	
In the example, all five systems examined are of about equal merit. Assuming that there is no large disparity in the Net Present Value of the corrosion protection, it is decided to reduce the choice to the two sprayed-metal systems, since these seem to have some slight advantage.	
Step 10 Review the design in the light of the information now assembled	
No further basic modification of the design seems necessary. However, detailing should ensure adequate access for surface preparation and application of coatings, with provision for slinging.	
Step 11 Draft the Specification for inclusion in the tender documents	
It may be advantageous to permit the contractor to include alternative prices in his tender for different systems where the performance is equal.	
The specifications for these items are based on the recommendations included in this code. The clauses for fabrication, handling, transport, storage and erection of steelwork cover all necessary precautions.	Section 3
Full details of the protective system are given, including references to British Standards; and clauses covering quality of other materials, standards of workmanship and limitations on application environments are included.	Section 2 Section 3
Step 12 Draft the inspection requirements	Section 4
Since undetected or unrepaired damage to the coating system can have serious consequences it is considered necessary to specify “full” level inspection for both works- and site-applied coats.	**4.3.8** Clause **37**
Furthermore, it is required that all inspection reports and other relevant information be kept available for future reference in connection with maintenance.	Clause **39**
Step 13 Final-check	Clause **34**

Appendix J
References and bibliography

J.1 References cited in appendix A

(1) Hudson, J.C., and Stanners, J.F. The effect of climate and atmospheric polution on corrosion. *Journal of Applied Chemistry,* vol. 53, 1953, pp. 86–95.

(2) Sixth Report of the Corrosion Committee. *Special Report No. 66.* London: Iron and Steel Institute, 1959.

(3) Booth, G.H. Microbiological corrosion. London: Mills and Boon, 1971.

(4) Hudson, J.C., and Watkins, K.O. Tests on the corrosion of buried cast-iron and mild-steel pipes. *BISRA Open Report MG/B/3/68.* British Iron and Steel Research Association, 1968.

(5) Romanoff, M. Underground corrosion. *National Bureau of Standards Circular 579.* Washington, D.C.: U.S. Government Printing Office, 1957.

(6) Corrosion of iron and steel by industrial waters and its prevention. *Special Report No. 41.* London: The Iron and Steel Institute, 1949.

(7) Bishop, R.R. Costly car rot can be slowed. London: *New Scientist,* vol. 62, 1974, pp. 380–3.

(8) Butler, G., *et al.* The influence of movement and temperature on the corrosion of mild steel. *Journal of Applied Chemistry,* vol. 10, 1960, pp. 80–93; vol. 15, 1965, pp. 325–8.

(9) Stanners, J.F. Metal coatings on steel at Lighthouse Beach, Lagos. *British Corrosion Journal,* vol. 6, 1971, pp. 197–9.

(10) Scott, D.J. Aluminium sprayed coatings: their use for the protection of aluminium alloys and steel. *Transactions of the Institute of Metal Finishing.* London, vol. 49, 1971, pp. 111–22 and 173–5.

(11) Chandler, K.A., and Kilcullen, M.B. Corrosion-resistant low-alloy steels: a review with particular reference to atmospheric conditions in the United Kingdom. *British Corrosion Journal,* vol. 5, 1970, No. 1, pp. 24–32.

(12) Gates, P.H. Corrosion prevented by humidity control. *Conference on heavy-duty coatings, 1972.* Institution of Corrosion Technology.

(13) Godfrey, G.B. The design and protection of tubular structures. *Symposium on the Protection of Structural Steelwork.* London: Zinc Development Association, 1962.

(14) White, P.E. The selection and use of corrosion resistant fasteners for building construction. *Symposium on Developments in Methods of Prevention and Control of Corrosion in Building.* November 1966, British Iron and Steel Federation.

(15) Waterproofing concrete bridge decks. Paris: O.E.C.D., 1972, obtainable from H.M.S.O.

J.2 Bibliography

Department of Industry. Corrosion prevention directory. London: H.M.S.O., 1975.

Shreir, L.L. (ed.). Corrosion (2 vols). London: Newnes-Butterworths, 2nd edition, 1976.

Evans, U.R. The corrosion and oxidation of metals. London: Arnold, 1960.

Evans, U.R. first supplementary volume. London: Arnold, 1968.

Evans, U.R. second supplementary volume. London: Arnold, 1976.

Barton, K. (translated by J.R. Duncan). Protection against atmospheric corrosion. London: Wiley, 1976.

American Society for Testing and Materials. Metal corrosion in the atmosphere. Philadelphia, Special Technical Publication No. 435, A.S.T.M., 1968 (obtainable from University Microfilms, High Wycombe, England.)

Chatfield, H.W. (ed.). The science of surface coatings. London: Ernest Benn, 1962.

Fancutt, F., *et al.* Protective painting of structural steel. 2nd edition. London: Chapman Hall, 1968.

Morgan, M.A. Cathodic protection. London: Leonard Hill, 1959.

Slunder, C.J., and Boyd, W.K. Zinc: its corrosion resistance. London: Zinc Development Association, 1971.

Zinc Development Association. Galvanizing Guide. London: Zinc Development Association (re-issued at frequent intervals).

Index

In this index references are not to page numbers but to clause, table, figure and appendix numbers. The method of alphabetization used is word-by-word. The use of bold type denotes that the reference is wholly concerned with the subjects to which they refer.

Standards publications referred to

BS 534, *Specification for steel pipes and specials for water and sewage.*

BS 729, *Hot-dip galvanized coatings on iron and steel articles.*

BS 1070, *Black paint (tar-based).*

BS 1133, *Packaging Code.*

BS 1133-6, *Temporary protection of metal surfaces against corrosion (during transport and storage).*

BS 1706, *Electroplated coatings of cadmium and zinc on iron and steel.*

BS 2015, *Glossary of paint terms.*

BS 2091, *Specification for respirators for protection against harmful dusts, gases and scheduled agricultural chemicals.*

BS 2451, *Chilled iron shot and grit.*

BS 2523, *Lead-based priming paints.*

BS 2569, *Sprayed metal coatings.*

BS 2569-1, *Protection of iron and steel by aluminium and zinc against atmospheric corrosion.*

BS 2569-2, *Protection of iron and steel against corrosion and oxidation at elevated temperatures.*

BS 2989, *Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel: wide strip, sheet plate and slit wide strip.*

BS 3294, *The use of high strength friction grip bolts in structural steel work.*

BS 3382, *Electroplated coatings on threaded components.*

BS 3382-1, *Cadmium on steel components.*

BS 3382-2, *Zinc on steel components.*

BS 3416, *Black bitumen coating solutions for cold application.*

BS 3698, *Calcium plumbate priming paints.*

BS 3900, *Methods of test for paints.*

BS 3900-A5, *Large scale brushing test.*

BS 3900-C5, *Determination of film thickness.*

BS 4147, *Specification for bitumen based hot applied coating material for protecting iron and steel including suitable primers where required.*

BS 4164, *Specification for coal tar based hot applied coating materials for protecting iron and steel, including suitable primers where required.*

BS 4275, *Recommendations for the selection, use and maintenance of respiratory protective equipment.*

BS 4479, *Recommendations for the design of metal articles that are to be coated.*

BS 4604, *The use of high strength friction grip bolts in structural steelwork. Metric series.*

BS 4652, *Metallic zinc-rich priming paint (organic media).*

BS 4921, *Sherardized coatings on iron and steel articles.*

BS 5228, *Code of practice for noise control on construction and demolition sites.*

BS 5950, *Structural use of steelwork in building.*

BS 6150, *Code of practice for painting of buildings.*

BS 7079, *Preparation of steel substrates before application of paints and related products.*

BS 7079-A1, *Specification for rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

BS 7079-C1, *Specification for surface profile comparators for the assessment of abrasive blast-cleaned surfaces.*

BS 7079-C2, *Method for the grading of surface profile of abrasively blast-cleaned steel using a comparator.*

BS 7361, *Cathodic protection.*

BS 7361-1, *Code of practice for land and marine applications.*

BS 8110, *Structural use of concrete.*

CP 3012, *Cleaning and preparation of metal surfaces.*

PD 6484, *Commentary on corrosion at bimetallic contacts and its alleviation.*

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