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 4232. 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 4232 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 two) 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 two, 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 anti-corrosion 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 : Part 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* materials to a satisfactory finish on completion of the wrapping.

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 unnecessary 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

*Petrolatum is petroleum jelly used for impregnation.

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)	Thermo-plastic	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	Thermo-plastic	Not relevant		Pour Gun	No	−10 to 70	5 to 20	0.7 to 1.7	10 to 30	<1	1.0

preparation. Preliminary surface preparation may include removal of oil and grease, initial blasting, chipping, wire-brushing, etc.

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 six).

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 : Parts 1 and 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 two).

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.