

Guides to Good Practice
in Corrosion Control

Surface Preparation for Coating



NPL 
National Physical Laboratory

Surface Preparation for Coating

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Surface Preparation for Coating

1.0 Introduction

Surface preparation is the essential first stage treatment of a substrate before the application of any coating. The performance of a coating is significantly influenced by its ability to adhere properly to the substrate material. It is generally well established that correct surface preparation is the most important factor affecting the total success of surface treatment. The presence of even small amounts of surface contaminants, oil, grease, oxides etc. can physically impair and reduce coating adhesion to the substrate.

Chemical contaminants that are not readily visible, such as chlorides and sulphates, attract moisture through coating systems resulting in premature failure. In summary, the importance of a chemically clean substrate to provide the best possible contact surface for the applied coating cannot be over-emphasised.

The scope of this guide covers the surface preparation of metallic surfaces for the subsequent application of paint and metal coatings for corrosion protection or the enhancement of surface appearance for both new structures and maintenance treatments.

The adhesion of coating materials such as zinc by hot dip galvanising is particularly good due to the metallurgical alloying with the steel surface. In this process, the molten zinc reacts with the steel to form a series of iron / zinc alloy layers of varying composition to form an intimate bond with the substrate.

Alternatively, metal coatings applied by thermal spraying require a coarse surface profile to maximise the coating bond which is principally by mechanical keying.

Organic paint coatings adhere to the surface mainly by polar adhesion which is aided by mechanical adhesion which is especially important for thick coating films.

For all types of coatings, the surface condition of the substrate is critical in terms of coating performance and durability.

2.0 Preparation of new steelwork (paint and metal coatings)

2.1 General requirements

There is generally more information available for the preparation of steelwork prior to the application of paints and related products than is the case for metal coatings. However, metal coatings require no less attention to the requirements for surface preparation and guidance should be sought from the appropriate standards.

Steelwork to be hot dip galvanized should be prepared according to ISO 1461 'Hot dip galvanized coatings on fabricated iron and steel articles - Specification and test methods, Annex C 1.2'. Surface cleaning is normally achieved by pickling in inhibited acid solutions. Alternatively, abrasive blast cleaning may be specified to achieve a thick galvanized coating. For steelwork to be thermally sprayed, the surface preparation is usually in accordance with BS EN 22063 'Metallic and other inorganic coatings - thermal spraying - Zinc, aluminium and their alloys'. Surfaces to be thermally sprayed are normally abrasive blast cleaned to a high standard of cleanliness.

2.2 General condition

Hot rolled structural steelwork leaves the last rolling pass at a temperature of 1000°C. As it cools, the surface reacts with oxygen in the atmosphere to produce mill scale. This is a complex oxide which appears as a blue-grey tenacious scale completely covering the surface. Mill scale is unstable and with time water in the atmosphere penetrates fissures in the scale and rusting of the steel occurs. The corrosion process progressively detaches the mill scale and produces a variable surface that is generally unsuitable for overcoating.

The amount of rusting is dependent upon the length of time that the steel has been exposed to a damp or wet environment. Four categories of 'rust grades' for new steelwork are described in ISO 8501-1: 1988 (BS 7079 Part A1, 1989) as follows:

A - Steel surface largely covered with adhering mill scale, but little if any rust.

B - Steel surface which has begun to rust and from which mill scale has begun to flake.

C - Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting under normal vision.

D - Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

The majority of new steelwork usually conforms to A and B conditions and occasionally C condition. In either case, the substrates can be prepared to an equally good standard by abrasive blast cleaning.

2.3 Surface contaminants

Residues of oil, grease, marking inks, cutting oils etc. after fabrication operations will seriously affect the adhesion of applied coatings and must be removed. It is erroneous to think that subsequent cleaning operations will remove such contaminants and it is bad practice to permit them to remain on the surface. Failure to remove these contaminants before blast cleaning results in them being distributed over the steel surface and contaminating the abrasive.

Suitable organic solvents, emulsion degreasing agents or equivalents should be applied to remove contaminants in preparation for subsequent descaling treatments. Further guidance can be obtained from BS 7773 'Code of Practice for Cleaning and Preparation of Metal Surfaces'.

2.4 Methods of preparation

Because a mill scaled surface is unsuitable for most modern coatings, it should be removed. Various methods and grades of cleanliness are presented in ISO 8501-1: 1988, (BS 7079, Part 1: 1989), 'Preparation of Steel Substrates Before Application of Paints and Related Products - Visual Assessment of Surface Cleanliness'.

This standard essentially refers to the surface appearance of the steel after abrasive blast cleaning (dry blasting) and gives descriptions with pictorial references of the grades of cleanliness.

(Note: There is a Supplement 1 to this standard that includes pictorial references for 6 different types of abrasives whilst the main standard refers to the condition of the steel after grit blasting only).

The standard grades of cleanliness for abrasive blast cleaning are:

Sa 1	Light blast cleaning.
Sa 2	Thorough blast cleaning.
Sa 2½	Very thorough blast cleaning.
Sa 3	Blast cleaning to visually clean steel.

Cleaned surfaces should be compared with the appropriate reference photograph in the standard according to the treatment specification.

A very wide range of non-metallic (metal slags, aluminium oxide etc) and metallic (steel shot or grit etc) abrasives are available and these are covered in ISO 11124/1 to 4, ISO 11125/1 to 7, ISO 11126/1 to 8 and ISO 11127/1 to 7. New ISO standards for staurolite and garnet abrasives are under development.

The particle size of the abrasive is also an important factor in affecting the rate and efficiency of cleaning. In general terms, fine grades are efficient in cleaning relatively new steelwork, whereas coarse grades may be required for heavily corroded surfaces. The removal of rust from pitted steel is more easily effected by fine grades and, depending upon the condition of the steel surface, a mixture of grades may be required initially to break down and remove mill scale and clean in pitted areas.

2.5 Hand and power tool cleaning (St Grades)

Surface cleaning by hand tools such as scrapers and wire brushes is relatively ineffective in removing mill scale or adherent rust. Power tools offer a slight improvement over manual methods and these methods can be approximately 30% to 50% effective but are not usually utilised for new steel work fabrications.

(More information on hand and power tool cleaning is given in Section 5 - Preparation for Maintenance Painting).

2.6 Abrasive blast cleaning (Sa Grades)

By far the most significant and important method used for the thorough cleaning of mill-scaled and rusted surfaces is abrasive blast cleaning. This method involves mechanical cleaning by the continuous impact of abrasive particles at high velocities on to the steel surface either in a jet stream of

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compressed air or by centrifugal impellers. The latter method requires large stationary equipment fitted with radial bladed wheels onto which the abrasive is fed. As the wheels revolve at high speed, the abrasive is thrown onto the steel surface, the force of impact being determined by the size of the wheels and their radial velocity. Modern facilities of this type use several wheels, typically 4 to 8, configured to treat all the surfaces of the steel being cleaned. The abrasives are recycled with separator screens to remove fine particles. This process can be 100% efficient in the removal of mill scale and rust.



Figure 1. Modern automatic shot blast plant.

2.7 Surface profile/amplitude

The type and size of the abrasive used in blast cleaning have a significant effect on the profile or amplitude produced. In addition to the degree of cleanliness, surface preparation specifications need to consider 'roughness' relative to the coating to be applied. For example, shot abrasives are used for thin film paint coatings such as pre-fabrication primers, whereas thick or high build paint coatings and thermally sprayed metal coatings need a coarse angular surface profile to provide a mechanical key. Inadequate quality control and lack of restriction of large abrasive particle sizes for thin priming coats can lead to peaks of the blast cleaned surface not being adequately covered and may produce rust spots very quickly. The more recently used very high build coatings and thermal-sprayed metal coatings need a large surface area with a high profile in order to ensure that the adhesive bond is greater than the cohesive bond. The difference between these two examples of blast cleaned surfaces is illustrated in the three-dimensional (axonometric) diagrams obtained from a non-contact surface characterisation equipment.

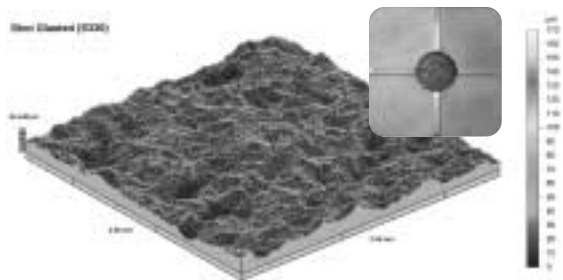


Figure 2. Surface Profile for shot blasted surfaces.

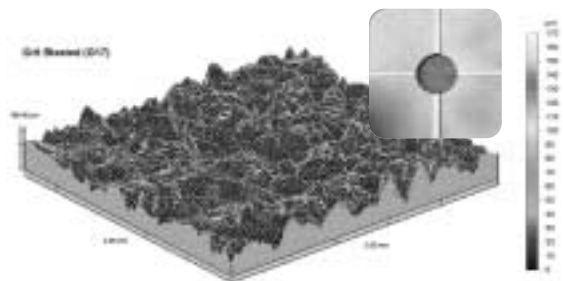


Figure 3. Surface Profile for grit blasted surfaces.

The surface treatment specification therefore should describe the surface roughness required, usually as an indication of the average amplitude achieved by the blast cleaning process.

Several methods have been developed to measure or assess the distance between the peaks and troughs of blast cleaned surfaces. These have included comparator panels, special dial gauges and replica tapes.

To date only the comparator method is referenced as a standard. This method uses a square panel with a central hole surrounded by four segments with different grades of roughness. There is one comparator for grit blasted surfaces and one for shot blasted surfaces. See Figures 2 & 3 (surface profile comparators for grit and shot blasted surfaces). The appropriate comparator is placed against the substrate then visual and tactile comparisons are made. The comparators are referred to in ISO 8503-1 Parts 1 to 4, (BS 7079 Parts C1 to C4), 'Preparation of Steel Substrates before the Application of Paints and Related Products - Surface Roughness Characteristics of Blast Cleaned Steel Substrates'. These standards describe the specification for the comparators, the method of use and two methods for calibration.

The dial gauge and replica tape methods have been commonly used in the UK. For the dial gauge a calibrated

needle gauge is first set to zero on a smooth surface and then the gauge is positioned at several points on the steel surface to measure the depths in the profile. Average readings are obtained.

The replica tape method comprises the use of a two layer plastic film, one compressible, one 50 μm thick incompressible layer and a specially adapted flat anvil dial gauge. The compressible layer is placed on the surface of the blast cleaned steel and is rubbed with a circular ended tool until the surface has conformed to that of the steel, indicated by a uniform dark colouration. The tape is then removed and measured with the dial gauge. The maximum profile can then be calculated by subtracting the thickness of the non-compressible backing, i.e. 50 μm from the dial reading. The replica tape method is relatively easy to use especially on difficult to access surfaces of fabricated components. This method also provides a permanent record of the surface roughness. Commercially available tapes are known as 'Testex, Press - O - Film'. A standard for this method is currently being drafted by an ISO committee.

If an average profile reading is required, this can be obtained using a portable surface roughness meter that traverses a stylus over the cleaned surface for a defined distance, usually 0.8 mm. These instruments, such as the Talysurf 10, can measure either the arithmetic mean roughness (R_a) or the mean 'peak to valley' height (R_z or R_{tm}), however their short traverse length can only provide an indication of the surface roughness. More accurate measurements of surface roughness can be obtained from an instrument with a stylus traverse length of 2.5 mm, e.g. the Talysurf 3+ gauge.

Whichever method is used to measure surface roughness, inevitably there will be rogue peaks that need to be taken into account. These can be defined as peaks of exceptional height in the blast cleaned surface and are not usually representative but can cause 'rust rashing' on primed surfaces where the peaks have projected above the primer coating.

2.8 Surface dust

The blast cleaning operation produces large quantities of dust and debris which must be removed from the abraded surface. Automatic plants are usually equipped with mechanical brushes and air blowers. Other methods can utilise sweeping and vacuum cleaning. However, the effectiveness of these cleaning operations may not be readily visible and the presence of fine residual dust particles that could interfere

with coating adhesion can be checked for using a pressure sensitive tape pressed onto the blast cleaned surface. The tape, along with any dust adhering to it, is then placed on a white background and compared to a pictorial rating. This method is described in ISO 8502 Part 3 1992, (BS 7079 Part B3, 1993), 'Preparation of Steel Substrates before Application of Paints and Related products - Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure Sensitive Tape Method). Although the standard provides a method of checking for dust, there are not recommendations for acceptable levels.

2.9 Surface condition immediately before coating

After the preparation of the surface to an acceptable standard of cleanliness and profile, it is important that the steelwork is not allowed to deteriorate. Re-rusting can occur very quickly in a damp environment and unless the steel is maintained in a dry condition coating of the surface should proceed as soon as possible. Any re-rusting of the surface should be considered as a contaminant and be removed by re-blasting.

2.10 Additional surface treatments

After abrasive blast cleaning, it is possible to examine for surface imperfections and surface alterations caused during fabrication processes, e.g. welding.

Certain surface imperfections introduced during the original processing of the steel may not be detrimental to the performance of a coating in service particularly for structures in relatively low risk environment categories. However, depending upon the specific requirements of the structure, it may be necessary to remove general surface imperfections on welds and cut edges to produce an acceptable surface condition for painting.

Weldments on fabricated structural steelwork represent a relatively small but important part of the structure and can produce variable surface profile and uneven surfaces or sharp projections that can cause premature failure of the coating. Although welded areas are inspected, the requirements for weld quality do not usually consider the requirements for coating. Welds must be continuous and free from pin holes, sharp projections and excessive undercutting. Weld spatter and residual slags should also be removed.

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There is currently under development, a new standard, ISO/DIS 8501-3, 'Preparation of Steel Substrates before the Application of Paints and Related Products - Visual Assessment of Surface Cleanliness - Preparation Grades of Welds, Cut Edges and Other Areas with Surface Imperfections'. The standard is to define the preparation grades of welds, cut edges and general surface imperfections that are not rectified by blast cleaning.

Three preparation grades are described with illustrated examples of relevant imperfections as:

- P1 Light Preparation.
- P2 Thorough Preparation.
- P3 Very Thorough Preparation.

It is proposed that the selected preparation grade be correlated between the environment corrosivity category (C1 to C5 as described in ISO 9223 'Corrosion of metals and alloys-Corrosivity of atmospheres-Classification) as appropriate for the structure.

2.11 Soluble iron corrosion products

Depending upon the condition of the steelwork prior to blast cleaning, there may be surface contaminants present other than mill scale and rust. Initial steel surface conditions of Grades A to C are unlikely to be affected, however Grade D condition (steelwork that is pitted) could contain contaminants within the pits that are not removed by the dry blast cleaning process. The testing for soluble iron corrosion products is not usually required for new steelwork but is sometimes carried out on steelwork which has been stored in an external environment for long periods of time and on existing structures undergoing maintenance treatments. (More information is given in Section 5 - Preparation for Maintenance Painting).

3.0 Preparation of a new metal

3.1 Hot dip galvanizing

The need to carry out surface preparation of a galvanized surface prior to painting is by no means less important than that required for steel substrates. Failure to prepare a galvanized surface correctly will lead to a reduction in life of both the paint and underlying galvanizing.

The first, and most important, treatment is to ensure the complete removal of any oil, grease or other foreign matter from the surface. This can be achieved by the use of suitable degreasing agents (see Section 2.3 - Surface Contaminants). Once a chemically cleaned surface has been achieved one of the following treatments can be applied.

(i) Mordant solution ('T' wash)

Despite the fact that this preparation process has been used for some considerable time with varying degrees of success, it is still generally considered to be the best pre-treatment method. The solution is an acidified solution in methylated spirits containing copper carbonate which reacts with the zinc surface.

The degreased surfaces are treated with 'T-wash', which is best brush applied to ensure that all of the surface is coated. The 'T-wash' reacts with the galvanizing to form a darkened 'conditioned' surface onto which a paint coating can be applied.

The reaction is a visual one and a successful application of T-wash produces a black surface coloration. Where no such colour is observed, further application(s) can be made to ensure that a total reaction takes place. Care should be taken to avoid ponding or puddling of the 'T-wash', and any excess should be removed, by washing with water.

The washing down of treated surfaces is a long debated subject, which some manufacturers specify and others do not.

Washing down with water brings the need to carry out surface drying before applying the paint coating, whereas not washing down can result in some degree of surface contamination as a residue. It is generally recommended that water washing and drying should be carried out.

When hot weather conditions are encountered then 'T-wash' formulated for tropical environments should be used for the pre-treatment process. High temperatures produce flashing off of the 'T-wash' before the reaction process has time to take place, leaving only an apparently reacted surface.

The worst problems attributed to T-wash are not in its use, but as a result of its absence, even though specified as part of a 'duplex' (metal and paint) coating.

(ii) Weathering

The weathering process becomes fully effective after a galvanized surface has been exposed to the atmosphere for a period of approximately twelve months. Preparation of the surface is a fairly simple one. The surface is prepared using either abrasive pads or stiff bristle brushes to remove all loose adherent materials but making sure that a bright zinc surface is not restored. This is then followed by a hot water detergent wash, which in turn is followed by a rinsing off with fresh clean water. Before applying a paint coating the surface must be thoroughly dried.

In marine environments where chloride levels are high, weathering is not the preferred option. Preparation and painting should be carried out either before or shortly after exposure.

(iii) Etch primers

The major disadvantage of etch primers is the absence of any visible colour change after application as is the case with T-wash. Therefore, there can never be complete confidence that all surfaces have fully reacted to the primer. Major differences arise in the surface condition when single-pack and two-pack materials are used, the better quality of surface condition being achieved with the latter. The single-pack primers have lower levels of reactive materials in their formulation, whereas the two-pack products carry higher levels which are activated as a result of the necessary mixing action.

(iv) Sweep blasting

This is the use of low pressure (< 275 kPa / 40 psi) blast-cleaning using a fine grade non-metallic abrasive. It is a process which can be very effective, but only when undertaken with a high degree of expertise. It is used to best advantage on flat surfaces, and when used on more complex configurations can lead to adjacent areas of under-prepared and over-prepared character.

Excessive blasting can remove all the zinc coating and expose bare steel especially on fasteners and edges. Coating integrity can also be affected through excessive blasting on thinner steel sections. This produces a poor surface for the duplex coating with a considerable risk of early localised breakdown and an ultimate need for a reduced protective treatment cycle.

If surface pre-treatment is not carried out or carried out poorly, then there is a very high probability that a paint coating will suffer either early deterioration or even total failure.

3.2 Thermally sprayed coatings

Metal coatings applied by the thermal spray process are usually of zinc or aluminium deposited by either the oxy/gas or electric arc method. Unlike hot dip galvanized coatings, thermally sprayed coatings are not metallurgically bonded to the steel substrate but adhere by mechanical 'keying' as a discontinuous, open and porous structure. Because of the generally open nature of the coating, it is common practice to apply a low viscosity sealer coat whether or not the metal coating is to be overcoated with paint.

Thermally sprayed surfaces must be free from dust and loose particulate matter, free from chemical contamination (chlorides and sulphates) and dry before the application of a sealer coat. Ideally, sealing should be carried out as soon as possible after thermal spraying. Methods of sealer application can vary from brushing to airless spraying. However, it is important that the sealer is fully absorbed into the pores of the coating. This may require more than one application to ensure that this objective is achieved. Application by brush tends to be more successful in filling the pores rather than by airless spraying. Brushing is time-consuming and labour intensive compared with airless spraying, however, there has been a general acceptance of using a combination of both methods; i.e. deposition of the sealer coat by airless spray followed by distribution and 'working in' using brushes.

Sealers are formulated to have low viscosity, low volume solids ratio, medium leafing and non-leafing pigments, low water absorption and inertness to chemical attack. They can be un-pigmented or pigmented with colouring agents or aluminium flake. Coloured sealers enable visual checking for complete coverage during application.

Various sealers may be used according to requirements and compatibility with any subsequently applied coatings. These include vinyl chloride / acetate co-polymers and phenolic resins. Silicone modified alkyls and pigmented silicone resins are used for resistance to high temperatures. Two-pack epoxide may be used or a polyvinyl - butyral 'etch' primer before overcoating.

Where a specification requires painting over a thermally sprayed coating, e.g. in aggressive environments or where

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future maintenance may be difficult, a suitable sealer or etch primer should first be applied to the manufacturers' recommendations to ensure penetration into the pores. This first treatment should then be followed by a compatible chemical resistant paint.

4.0 Fasteners

Often fasteners receive inadequate surface preparation and protection and as such result in early failure of the coatings.

With the presence of many sharp edges and corners on nuts, washers and bolts, the thickness of paint coatings is often relatively thin compared with larger flat surfaces on structural members and the coatings can be easily damaged.

It is, therefore, important that the standards of surface preparation and protective coating of fasteners are compatible with those for the main structure. This can be achieved by either locally blast cleaning black blots and nuts to an acceptable standard of cleanliness followed by the application of a protective treatment as specified for the main structural elements.

More often, pre-treated metal coated fasteners are sourced externally and, depending upon type and thickness of the metal coating, may be adequate without further treatment or may need additional coating.

Electro-plated zinc fasteners have bright thin coatings (7.5 μm) and are sometimes chromate treated to provide passivity during transit and storage. Sherardized (zinc) coated fasteners are matt grey in colour, unless passivated, and have coating thicknesses in the range 15-30 μm , depending whether they are of Class 1 or Class 2 according to BS 4921.

Hot dip galvanized fasteners can have a bright or dull finish depending upon the composition of the steel, and have a coating thickness typically of 43 μm .

Whichever type of metal coating is on the fasteners, the surfaces must be free of grease and oil before any additional protective treatments are applied.

Fasteners that have not been passivated may be etch primed and overcoated with a conventional paint system. Passivated surfaces do not always readily provide a suitable surface for

overpainting and may need to be lightly sweep blasted before overcoating.

5.0 Preparation of previously coated surfaces for maintenance painting

Inevitably, steel structures protected by coatings will require maintenance to reinstate the protective system for structural preservation and cosmetic purposes. The extent of maintenance required depends upon the condition of the initial protective treatment and the effectiveness of any remaining coating. In order to prepare a strategy for maintenance painting, it is important to undertake a survey to determine whether part or full re-painting is required. Where coatings are found to be firmly adherent to the substrate with no indication of breakdown, they can be considered as a suitable base for the maintenance coats.

The surface condition of the existing paint should be thoroughly washed to remove contaminants, and it may then be necessary to abrade the surface lightly especially of hard coatings such as epoxies, to enable good adhesion.

Where the breakdown is localised and the majority of the protective coating is intact and soundly adherent to the substrate, then the small areas of breakdown can be prepared back to the substrate for localised repainting. Ideally, the affected areas should be prepared to a standard suitable for the maintenance paint, e.g. localised blast cleaning or by manual and mechanical methods where blasting is impractical.

The desired standards of surface cleanliness for previously painted (existing) steelwork are defined in ISO 8501-2: 1994 (E), 'Preparation of Steel Substrates before Application of Paints and Related Products - Visual Assessment of Surface Cleanliness - Preparation Grades of Previously Coated Steel Substrates after Localised Removal of Previous Coatings'. The levels of visual cleanliness are related to the common methods that are used prior to painting. This standard is based upon experience that complete removal of all previous paint coatings is not always necessary and that localised treatment is sufficient.

In such situations it is assumed that the remaining intact coating is making a useful and durable contribution to the maintenance coating system and that during the preparation

of the locally corroded area down to the substrate, the surrounding coating is not irreparably or significantly damaged.

Each preparation grade is designated as 'Sa' and 'St' as in ISO 8501-1, (BS 7079 Part A1) for original treatments (see Section 2). However there is an additional grade of 'Ma' for machine abrading. All of these grades are prefixed by the letter 'P' to indicate that they refer to the localised removal of previously applied paint coatings;

Localised blast cleaning

- P Sa 2 Through localised blast cleaning.
- P Sa 2 Very thorough localised blast cleaning.
- P Sa 3 Localised blast cleaning to visually clean steel.

Localised hand and power tool cleaning

- P St 2 Through localised hand and power tool cleaning.
- P St 3 Very thorough localised hand and power tool cleaning.

Localised machine abrading of previously coated surfaces

- P Ma Localised machine abrading.

The standard does not consider the presence of soluble salts and invisible contaminants, which should be checked for according to methods described in ISO 8502. Similarly, surface roughness characteristics should also be considered by reference to ISO 8503.

5.1 Dry abrasive blast cleaning

Where possible, the use of abrasives is preferred to achieve a high standard of surface cleanliness to accept the maintenance coating.

Until recently, open blast cleaning was widely used for maintenance but has now become environmentally unacceptable because of the dust and pollution it creates during the operation.

More often is it necessary to provide some form of containment or encapsulation for collection of spent abrasives, dust and hazardous paint material removed from existing structures.

Dry abrasive blast cleaning can achieve a high standard of surface cleanliness using versatile blast cleaning equipment at relatively low cost. The additional costs associated with the need for containment and disposal of spent abrasives and

removed paint can be disproportionately high.

By means of specially adapted equipment, it is now possible to enclose and recover abrasives and particulate matter within an enclosed vacuum system. The equipment enables a fairly dust-free surface to be produced and the recycling of the abrasive.

By changing the blast head and brushes it is possible to clean in corners and along edges although large flat surfaces are easier to clean.

The main advantages of the vacuum system are the low waste and clean-up costs particularly for lead based paints on old structures.

Dry abrasive blast cleaning does not remove all soluble salts contained in heavily corroded surfaces. The presence of residual contamination should be checked by special test methods (see Section 5.5 - Surface contaminants).

5.2 Wet abrasive blast cleaning

The introduction of water into an abrasive blast stream contributes to the reduction of the dust hazard, particularly when removing old lead based paints and the removal of water-soluble contaminants. Several methods of using water with abrasives have been developed. Conventional wet abrasive blast cleaning uses the same pressures as for conventional dry blasting and uses similar equipment. The water is usually introduced immediately behind the nozzle so that it is atomised and accelerated through the nozzle orifice along with the air and abrasive. Water can also be introduced in controlled amounts at the base of the blast pot and is then mixed with the air and abrasive as it passes along the blast hose.

There is a low pressure system in which water is injected into the air stream which then shrouds the air/abrasive mixture and prevents dust escaping during the blasting operation. The air/water pressure at the nozzle is relatively low; up to 7.0 kgF/cm² (100 lbF/in²). Because of the low water to air ratio of the system fine particulates of abrasive can remain on the steel surface and need to be removed by water washing. This method can produce a high visual standard of cleaning and is effective in removing a high proportion of soluble salts.

Some wet abrasive processes use inhibitors in the water to prevent rusting of the cleaned surface. It is important to

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establish whether any remaining traces of such inhibitors will be compatible with the paint coating to be applied subsequently. Generally, where inhibitors are not used, any surface rusting after wet abrasive blasting is usually removed by final light dry blast cleaning.

5.3 Ultra-high pressure water jetting

Ultra-high pressure water jetting over 172 kPa (25,000 psi) is gaining in popularity, partly because of its ability to remove high percentages of soluble salts from the steel surface. It has the advantage of not generating spent abrasive and not incurring the cost of abrasive disposal. Also, at the higher pressures, lower volumes of water are used, and this makes disposal costs lower than with traditional water blasting methods. Ultra-high pressure water jetting leaves a warm surface from which traces of residual water quickly dry, but does not generate sufficient heat to cause thermal stress in the steel surface.

The removal of a high proportion of soluble salts from the steel surface is seen to be the major advantage of ultra-high pressure water jetting. Rust and coatings are sheared and lifted from the surface relatively easily compared with other blasting methods. Soluble salts are removed more effectively because the steel profile generally remains unchanged.

Injecting small amounts of abrasive into the water stream can induce a rougher surface profile but can also increase operating costs.

At present, there are no international standards for ultra high pressure water jetting, although the Steel Structures Painting Council (SSPC) have prepared a joint standard with NACE as SSPC standard No. 12. The American Society of Testing and Materials is considering the need for a national and, thereafter, international standard.

Ultra-high pressure water jetting is an extremely versatile and effective method of removing paint and metal coatings, soluble salts and other contaminants from steel surfaces. It is environmentally friendly and, although at present costly compared to traditional blast cleaning methods, it is considered to be an emerging technology which will, in the near future, rival and possibly replace traditional open abrasive blast cleaning methods.



Figure 4. Ultra-high pressure water jetting of steel barrier gates.

5.4 Mechanical hand and power tool cleaning

Where it is not possible to clean by abrasive blasting, hand and power tool methods may be the only acceptable alternative methods, although flame cleaning may also be considered. Flame cleaning uses an oxy/gas flame that is passed over the steel surface. The sudden heating causes rust scales to flake off as a result of differential expansion between the scales and the steel surface. All loose rust can then be removed by scraping and wire brushing followed by dust removal. Flame cleaning is not an economic method and may damage coatings on the reverse side of the surface being treated. Also the technique is not very effective in removing all rust from steel.

Modern power tooling has been developed not only to achieve a good standard of surface cleanliness and profile but also to provide near total containment of all dust and debris generated. New equipment is now available to use percussive reciprocating needles, rotary abrasive coated flaps and right-angle grinders, all within a vacuum shroud to enable on-site surface preparation to be environmentally acceptable.

At present there are no International or European standards for power tool cleaning although in 1987 the Steel Structures Painting Council (SSPC) recognised the advances in power tool cleaning and introduced a Surface Preparation number 11 (SP11) for power tool cleaning to bare metal. This specification requires that power tool cleaning should produce a bare metal surface and retain or produce a surface profile suitable for the specified paint system. Additionally, the SSPC SP11 specification differs from the ISO 8501-1 St. 3 standard that only requires the removal of loosely adherent material.

5.5 Surface contaminants

Previous sections have discussed methods for the removal of millscale and rust. Reference has also been made to the need to remove other contaminants such as oil grease and dust before undertaking surface preparation to achieve a required degree of surface cleanliness and profile.

In maintenance painting operations after surface cleaning of the substrate, even by dry blast cleaning to Sa 2½ standard, there may be contamination with salts produced by the corrosion process. Old steel structures that are pitted by corrosion are more likely to have salts of ferrous sulphate and iron chlorides retained within the pitted areas and their presence may need to be determined, particularly if the maintenance painting specification requires all such salts to be absent from the surface prior to painting.

In general terms, the salts are usually referred to as 'soluble iron corrosion products' and can sometimes be seen by the use of a magnifying glass. However, visual examinations are not always a reliable indication as to the presence of such salts and a number of chemical tests have been developed to detect their presence.

The most commonly used test is the potassium ferricyanide test in which freshly-prepared filter papers soaked with potassium ferricyanide are placed over the blast cleaned steel surface moistened with distilled water. The impregnated filter paper is pressed on to the damp surface for several seconds after which time the paper is examined for blue spots which indicate the presence of soluble iron salts.

The test is not a standard method and does not provide an indication of the type of salts present and requires a degree of skill and experience to obtain a meaningful result.

Experience and judgement are then required to determine the significance of the amount of blue spotting in relation to the specification and whether re-blasting is necessary.

Another test method is commonly known as the 'Merckoquant test'. Unlike the potassium ferricyanide test, it does not identify discrete spots indicating the position of soluble salts but provides an average measure of their concentration per unit area. It is therefore a quantitative or, more correctly, allowing for the limitations of the method, a semi-quantitative test, unlike the qualitative nature of the potassium ferricyanide method.

The following procedure is commonly used:

- (1) An area of approximately 250 mm x 100 mm is marked out on the blast-cleaned surface of the steel.
- (2) A pure cotton wool swab (about 1 g in weight) is soaked in a receptacle containing 50 ml distilled water. It is then used to swab the test area for about 2 minutes. It is subsequently placed into a fresh dry container.
- (3) The swabbing with water is repeated, the swab being placed in the container.
- (4) The area is then dried with another piece of cotton wool, which is placed in the container.
- (5) The remaining water in the first container is transferred to the second container and the cotton wool swabs are thoroughly stirred in the water.
- (6) A strip of suitable indicator paper is dipped into the solution in the container.

If soluble iron salts have been removed, there will be a colour change on the indicator paper and this is compared with coloured references giving the concentration of ferrous salts present. If the volumes and areas noted above are used, the ferrous iron concentration indicated on the reference slips is twice the concentration of ferrous ions on the steel surface, expressed in milligrams per square metre.

For on-site testing, a plastic bag may be used as the container. To prevent additional contamination of the surface, operators should wear clean disposable plastic gloves. The test strips should be kept in dry, tightly closed containers when not in use. One strip should be checked with a test solution of known ferrous iron concentration, stabilised with dilute sulphuric acid. When stored in a plastic bottle, not a glass bottle, the solution should remain stable for about 4 weeks.

A standard method for the assessment of chloride containing salts that are readily soluble in water and present on a steel surface is described in ISO 8502-2: 1992, (BS 7079 Part B2 1996), 'Preparation of Steel Substrates before Application of Paints and Related Products - Tests for the Assessment of Surface Cleanliness - Laboratory Determination of Chloride on Cleaned Surfaces'. This standard describes the assessment of salts that have been introduced by the cleaning operation or that have been deposited on the surface before or after cleaning. The method requires a defined area of the cleaned steel to be water washed and then the chloride content is determined by a titration method.

Surface Preparation for Coating

A way of obtaining a sample for analysis of chloride and soluble salt contamination from a prepared surface is described in ISO 8502-6: 1995, (BS 7079 Part B6 1996), 'Preparation of Steel Substrates before Application of Paints and Related Products - Tests for the Assessment of Surface Cleanliness - Extraction of Soluble Contaminants for Analysis - The Bresle Method'. This standard describes a method of extracting for analysis soluble contaminants from a surface using flexible cells in the form of adhesive patches which can be attached to any surface. It is particularly suitable for use on existing structures. The self-adhesive patch is attached to the cleaned surface and distilled water is injected into and withdrawn from the patch by a hypodermic syringe. The process is repeated several times to provide agitation to increase recovery of any soluble salts.

The most recently introduced procedure for on-site determination is by the conductometric method. A recently introduced standard ISO 8502-9 (BS 7079 Part B9), 'Preparation of Steel Substrates before Application of Paints and Related Products - Tests for the Assessment of Surface Cleanliness - Field Method for Conductometric Determination of Water Soluble Salts'. This standard describes an on-site method for the assessment of total surface density of various water soluble salts (mostly chlorides and sulphates) on steel surfaces before and / or after surface preparation.

Any salts on a given area of steel surface are dissolved in distilled water by the Bresle method (ISO 8502-6). The conductivity is then measured with a conductometer and the total surface density of the salts within the test area is calculated by equation. There are no pass / fail criteria associated with this test at present.

5.6 Conductivity

Samples of liquid obtained from blast cleaned surfaces can also be used for detecting water soluble contamination by conductivity measurements using a conductivity meter. The Bresle patch method is particularly suited to sampling for conductivity in that it minimises the risk of additional contamination during handling, etc.

A salt contamination meter (SCM 400) has been developed in the UK to check the conductivity of a wet filter paper after application to the cleaned surface.

Conductivity measurement includes all forms of water soluble contamination and does not distinguish between the ions

present that cause an increase in the conductivity. At present there are no standards for the measurement of conductivity and generally no agreed limits of acceptability.

5.7 Condensation

The presence of water in the form of condensation on cleaned surfaces can affect the adhesion and performance of any paint coating applied. Site maintenance work is exposed to a wide variation in atmospheric conditions and it is often difficult to determine whether the conditions are likely to favour condensation on the surface to be painted. Many factors have an influence on the possibility of condensation including heat conduction of the structure, solar radiation on the surface, air flow around the structure and the presence of hygroscopic substances on the surface.

It has for some time been recognised that steel surface temperature generally should be 3°C above the dew point before painting is commenced, unless the paints are described as being moisture tolerant.

By means of a suitable instrument to measure air humidity and both air and surface temperatures, the dew point can be determined. The minimum surface temperature (above the dew point) that is needed to avoid condensation can then be estimated. A standard that gives guidance on the estimation of the probability of condensation is ISO 8502-4 1993, (BS7079Part B4: 1993), 'Preparation of Steel Substrates before Application of Paints and Related Products Part B4 - Guide to the Estimation of the Probability of Condensation on a Surface to be Painted'.

6.0 Preparation for maintenance painting of metal coatings

Metal coatings eventually require maintenance, usually by paint coatings. Previously unpainted hot dip galvanized coatings corrode away to leave a mixture of zinc and iron alloy layer, with rusting from the substrate. Zinc corrosion products can be removed by manual cleaning methods. Where there is extensive rusting of the steel substrate, abrasive blast cleaning is the preferred method of surface preparation prior to painting. Painted galvanized steel, where no breakdown of the zinc coating has occurred, can be treated similar to that for paint coatings on steel substrates.

Thermally sprayed coatings, if mainly intact but with surface corrosion products, can be treated by light blast cleaning to remove the corrosion products and any paint if present. Wet blasting is not recommended unless the metal coating is to be removed completely because of the difficulty in ensuring a completely dry surface being painting.

Where there is extensive deterioration of a thermally sprayed coating, it needs to be removed by abrasive blast cleaning, although it may be difficult to completely remove a thermally sprayed aluminium coating.

7.0 Inspection and quality control

Consistent with the requirements of a quality controlled system for any protective coating treatment operations, it is essential that the inspection of surface prepared substrates receives the same attention. Without control to ensure a properly treated substrate, the value of subsequent operations is reduced. Good surface preparation is the foundation for durability and should not be underestimated.

Before any treatments to remove millscale and rust are applied, the surface to be treated should be visually free from oil, grease and other contaminants.

After the removal of millscale and rust by either manual / mechanical methods or abrasive blast cleaning, it is necessary to check that the required level of cleanliness (and surface profile, if appropriate) have been achieved by reference to the relevant standards. The profile of abrasive blast cleaned steel can be assessed by reference to visual comparators or by the use of surface profile gauges or replica tapes to ensure that it is neither too smooth nor too coarse for the protective coating. Generally, smooth shot blasted surfaces would be specified for thin film paint coatings, e.g. pre-fabrication primers and coarse grit blasted surfaces would be produced for high build paints or thermally sprayed coatings.

Similarly, the treatment of specific surfaces e.g. welds, edges, holes, etc. should be inspected for preparation to a suitable condition to receive the protective coating.

Immediately before the application of the protective coating, a final check should be carried out to ensure that the surface is free from dust and loose particulate matter and has not been re-contaminated. There may also be a requirement to check

for the presence of residual contaminants (soluble salts) especially on existing structures where maintenance painting is being carried out.

Metal coatings including hot dip galvanizing and thermal spraying should be checked for adequate preparation if they are to be over-painted. The use of mordant ('T-wash') treatments for hot dip galvanized coatings should be monitored to ensure that the application is compliant with the manufacturers data sheets and that the treatment has been effective with the treated surface free from residual solution and thoroughly dry. Thermally sprayed coatings should be sealed immediately after application to avoid the formation of corrosion products from the coating material or, especially in the case of aluminium, the appearance of red rust from the substrate.

In all aspects of surface preparation and the application of a protective coating system, it is desirable, as a minimum requirement, to employ appropriately qualified personnel to an approved and recognised standard to check that the work is executed according to the specification and good industrial practice. Further guidance can be found in ISO 12944 Part 7 'Paints and Varnishes - Corrosion Protection of Steel Structures by Protective Paint Schemes - Execution and Supervision of Paint Work'.

8.0 Additional reference standards and further sources of information

8.1 Standards

There are many national, European and international standards concerned with the preparation of metallic surfaces for subsequent coating. These documents may be referred to in surface treatment specifications for surface cleanliness, profile and methods checking for contaminants. Those standards currently available are listed below and new standards for the determination of surface moisture, oil and grease, solvent cleaning, hydro blast cleaning, surface profile measurement by Testex tape and acceptable limits for test result methods of surface contaminants are in the process of development.

Surface Preparation for Coating

Published ISO surface preparation standards (March 1999)

ISO 8501/1: 1988 (BS 7079: Part A1)

Preparation of steel substrates before application of paints and related products.

Visual assessment of surface cleanliness.

Specification for rust grades and preparation grades of uncoated steel substrates after overall removal of previous coatings.

ISO 8501/2: 1995 (BS 7079: Part A2)

Preparation of steel substrates before application of paints and related products.

Visual assessment of surface cleanliness.

Preparation grades of previously coated steel substrates after localised removal of previous coatings.

ISO TR 8502/1: 1991 (BS 7079: Part B1)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Field test for determination of soluble iron corrosion products.

ISO 8502/2: 1992 (BS 7079: Part B2)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Laboratory method for determination of chlorides on cleaned surfaces.

ISO 8502/3: 1992 (BS 7079: Part B3)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method).

ISO 8502/4: 1993 (BS 7079: Part B4)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Guide to the estimation of the probability of condensation on a surface to be painted.

ISO 8502/5: 1998 (BS 7079: Part B5)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Chloride measurement - Ion detection tube method

(Not to be duelled as a British Standard).

ISO 8502/6: 1995 (BS 7079: Part B6)

Preparation of steel substrates before application of paints and related products.

Methods for the assessment of surface cleanliness.

Extraction of soluble contaminants for analysis (the Bresle method).

ISO 8502/9: 1998 (BS 7079: Part B9)

Preparation of steel substrates before application of paints and related products.

Tests for the assessment of surface cleanliness.

Field method for the conductometric determination of water soluble salts.

ISO 8503/1: 1988 (BS 7079: Part C1)

Preparation of steel substrates before application of paints and related products.

Surface roughness characteristics of blast cleaned steel substrates.

Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces.

ISO 8503/2: 1988 (BS 7079: Part C2)

Preparation of steel substrates before application of paints and related products.

Surface roughness characteristics of blast cleaned steel substrates.

Method for the grading of surface profile of blast cleaned steel - comparator procedure.

ISO 8503/3: 1988 (BS 7079: Part C3)

Preparation of steel substrates before application of paints and related products.

Surface roughness characteristics of blast cleaned steel substrates.

Method for the calibration of ISO surface profile comparators and for the determination of surface profile - focusing microscope procedure.

ISO 8503/4: 1988 (BS 7079: Part C4)

Preparation of steel substrates before application of paints and related products.

Surface roughness characteristics of blast cleaned steel substrates.

Method for the calibration of ISO surface profile comparators and for the determination of surface profile - stylus instrument procedure.

ISO 8504/1: 1992 (BS 7079: Part D1)

Preparation of steel substrates before application of paints and related products.

Surface preparation methods - general principles.

ISO 8504/2: 1992 (BS 7079: Part D2)

Preparation of steel substrates before application of paints and related products.

Surface preparation methods - abrasive blast cleaning.

ISO 8504/3: 1993 (BS 7079: Part D3)

Preparation of steel substrates before application of paints and related products.

Surface preparation methods - hand and power-tool cleaning.

ISO 11124/1: 1993 (BS 7079: Part E1)

Preparation of steel substrates before application of paints and related products.

Specifications for metallic abrasives - general introduction and classification.

ISO 11124/2: 1993 (BS 7079: Part E2)

Preparation of steel substrates before application of paints and related products.

Specifications for metallic abrasives - chilled iron grit.

ISO 11124/3: 1993 (BS 7079: Part E3)

Preparation of steel substrates before application of paints and related products.

Specifications for metallic abrasives - high carbon cast steel shot and grit.

ISO 11124/4: 1993 (BS 7079: Part E4)

Preparation of steel substrates before application of paints and related products.

Specifications for metallic abrasives - low carbon cast steel shot.

ISO 11125/1: 1993 (BS 7079: Part E6)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - sampling.

ISO 11125/2: 1993 (BS 7079: Part E7)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of particle size distribution.

ISO 11125/3: 1993 (BS 7079: Part E8)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of hardness.

ISO 11125/4: 1993 (BS 7079: Part E9)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of apparent density.

ISO 11125/5: 1993 (BS 7079: Part E10)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of percentage defective particles and of microstructure.

ISO 11125/6: 1993 (BS 7079: Part E11)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of foreign matter.

ISO 11125/7: 1993 (BS 7079: Part E12)

Preparation of steel substrates before application of paints and related products.

Test methods for metallic abrasives - determination of moisture.

ISO 11126/1: 1993 (BS 7079: Part F1)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - general introduction and classification.

ISO 11126/3: 1993 (BS 7079: Part F3)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - copper refinery slag.

ISO 11126/4: 1993 (BS 7079: Part F4)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - coal furnace slag.

ISO 11126/5: 1993 (BS 7079: Part F5)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - nickel refinery slag.

ISO 11126/6: 1993 (BS 7079: Part F6)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - iron furnace slag.

Surface Preparation for Coating

ISO 11126/7: 1993 (BS 7079: Part F7)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - fused aluminium oxide.

ISO 11126/8: 1993 (BS 7079: Part F8)

Preparation of steel substrates before application of paints and related products.

Specifications for non-metallic abrasives - olivine sand.

ISO 11127/1: 1993 (BS 7079: Part F11)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - sampling.

ISO 11127/2: 1993 (BS 7079: Part F12)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - determination of particle size distribution.

ISO 11127/3: 1993 (BS 7079: Part F13)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - determination of apparent density.

ISO 11127/4: 1993 (BS 7079: Part F14)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - assessment of hardness by a glass slide test.

ISO 11127/5: 1993 (BS 7079: Part F15)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - determination of moisture.

ISO 11127/6: 1993 (BS 7079: Part F16)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - determination of water-soluble contaminants by conductivity measurement.

ISO 11127/7: 1993 (BS 7079: Part F17)

Preparation of steel substrates before application of paints and related products.

Test methods for non-metallic abrasives - determination of water-soluble chloride.

8.2 Other standards

BS 7773:1995

Code of practice for cleaning and preparation of metal surfaces.

BS EN ISO 12944-4:1988

'Paint and varnishes - Corrosion protection of steel structures by protection paint systems. Part 4 Types of surface and surface preparation'.

BS 4921:1988

Specification for Sherardised Coatings on Iron and Steel.

8.3 Further sources of information

National Corrosion Service National Physical Laboratory

Queens Road
Teddington
Middlesex TW11 0LW
Tel: 020 8943 6142
Fax: 020 8943 7107

The Institute of Corrosion

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

Paint Research Association

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

The Water Jetting Association

3 East Street
Hemel Hempstead
Hertfordshire HP2 5BN
Tel: 01442 246605
Fax: 01442 246970



The National Corrosion Service

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

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

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

National Physical Laboratory, Queens Road,
Teddington, Middlesex TW11 0LW

NPL's Web Page can be found at:
www.npl.co.uk or Email: enquiry@npl.co.uk
Tel: 020 8943 6880 Fax: 020 8943 6458