

Transport of Radioactive Material Code of Practice

Finishing Systems for
Transport Containers

Produced by the Transport Container Standardisation Committee

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FOREWORD

This Code of Practice is based around the requirements of the International Atomic Energy Agency's (IAEA) Regulations for the Safe Transport of Radioactive Material, TS-R-1.

The purpose of this Code of Practice is to advise designers and users on the range of protective systems available for the coating of Transport Containers.

This code represents a standard of good practice and takes the form of recommendations only. It should be noted that the word "shall" denotes a requirement the word "should" denotes a recommendation; and the word "may" denotes permission, neither a requirement nor a recommendation. Imperative statements also denote requirements. To conform with this code of practice, all operations shall be performed in accordance with its requirements, but not necessarily with its recommendations.

1 GENERAL

1.1 Scope

This document provides general and specific advice to designers and users on the choice of protective systems available for the coating of transport containers manufactured from a variety of materials and subject to a range of environmental conditions. Particular emphasis is placed on the selection of both the appropriate protective system and the required degree of surface preparation for particular construction materials.

Information is provided on systems providing maximum corrosion protection under various environmental conditions commensurate with other factors including contamination, decontamination, resistance to chemicals and solvents and long term decorative properties.

It is intended that the user of this guide can, if so desired, select from the section covering the appropriate construction material, a protective coating system meeting pre-determined criteria. It is not an essential prerequisite that the user should be familiar with all the information contained in Section 1 which serves to provide useful background information but reference to it will aid understanding.

1.2 Related Documents

The following specifications and standards are listed as providing background information on the topic of protective systems although not specifically referred to in other parts of the document.

ASTM B449-93	Standard Specification for Chromates on Aluminium.
BS 3987	Specification for Anodic Oxidation Coatings on Wrought Aluminium for External Architectural Applications.
BS 4247 - 1	Surface materials for use in radioactive areas. Methods of measuring and evaluating the decontamination factor.
BS 4247 - 2	Surface materials for use in radioactive areas. Guide to the selection of materials.
BS 4842	Specification for Liquid Organic Coatings for Application to Aluminium Alloy Extrusions, Sheet and Preformed Sections for External Architectural Purposes and for the finish on aluminium alloy extrusions, sheet and preformed sections coated with liquid organic coatings.
BS 4921	Specification for Sheradized Coatings on Iron or Steel
BS 6150	Painting of Buildings. Code of Practice
BS 6338	Specification for Chromate Conversion Coatings on Electroplated Zinc and Cadmium Coatings.
BS 6496	Specification for Powder Organic Coatings for Application and Stoving to Aluminium Alloy Extrusions, Sheets and Preformed Sections for External Architectural Purposes and for the finish on aluminium alloy extrusions, sheet and preformed sections coated with powder organic coatings.
BS 7079	General Introduction to Standards for Preparation of Steel substrates before application of Paints and related Products.
BS 7773	Code of practice for cleaning and preparation of metal surfaces

BS 7956	Specification for primers of woodwork.
BS 8110 – 1	Structural use of concrete. Code of practice for design and construction
BS 8118-1	Structural Use of Aluminium. Code of practice for design.
BS 8118-2	Structural use of aluminium. Specification for materials, workmanship and protection.
BS EN 927 –1	Paints and varnishes. Coating materials and coating systems for exterior wood. Classification and selection.
BS EN 2101	Specification for Chromic Acid Anodising of Aluminium and Wrought Aluminium Alloy.
BS EN 10143	Continuously hot-dip metal coated steel sheet and strip. Tolerances on dimensions and shape.
BS EN 12373 -1	Aluminium and aluminium alloys. Anodizing. Method for specifying decorative and protective anodic oxidation coatings on aluminium.
BS EN 12476	Phosphate conversion coatings of metals. Method of specifying requirements.
BS EN 12540	Corrosion protection of metals. Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and copper plus nickel plus chromium.
BS EN 22063	Metallic and other inorganic coatings. Thermal spraying. Zinc, aluminium and their alloys.
BS EN ISO 1461	Hot-dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods.
BS EN ISO 2081	Corrosion protection of metals. Electrodeposited coatings of zinc with supplementary treatment on iron or steel.
BS EN ISO 2082	Corrosion protection of metals. Electrodeposited coatings of cadmium on iron or steel.
BS EN ISO 4527	Metallic Coatings. Autocatalytic (Electro less) Nickel Phosphorous alloy coatings. Specifications and test methods.
BS EN ISO 4618	Paints and varnishes. Terms and definitions for coating materials. General terms.
BS EN ISO 8501 - 1	Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. Rust grades and Preparation grades of uncoated steel substrates and steel substrates after overall removal of previous coatings.
BS EN ISO 8503-1	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.

BS EN ISO 12944 -1-8	Paints and varnishes. Corrosion protection of steel structures by protective paint systems.
BS EN ISO 14713 - 2	Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures. Hot dip galvanizing.
COSHH Regulations Guidance Note EH40	Control of Substances Hazardous to Health (COSHH) regulations Guidance Note EH40, Occupational Exposure Limits.
DEF-STAN 03-2	Cleaning and Preparation of Metal Surfaces.
DEF-STAN 03-3	Protection of aluminium alloys by sprayed metal coatings
DEF-STAN 03-6/2	Guide to Flame Spraying Processes.
DEF-STAN 03-11	Phosphate Treatment of Iron and Steel.
DEF-STAN 03-18	Chromate Conversion Coatings (Chromate Filming Treatments) Grades. Standard and Brushing for Aluminium and Aluminium Alloys.
DEF-STAN 03-20	Electro-deposition of Zinc
DEF-STAN 03-24	Chromic Acid Anodising of Aluminium and Aluminium Alloys.
DEF-STAN 03-25	Sulphuric Acid Anodising of Aluminium and Aluminium Alloys.
Federal Specification, TT-C-490	Cleaning Methods for Ferrous Surfaces and pre-treatment for Organic Coatings.
Swedish Standard SIS 05 59 00 (BS EN ISO 8501-1)	Pictorial Surface Preparation Standards for Painting Steel Surfaces.
SSPC SP2, SP3 & SP8	Steel Structures Painting Council (SSPC) Processes Nos. SP2 (Hand Tool Cleaning, SP3 (Power Tool Cleaning) and SP8 (Pickling).

Note. *It is the reader's responsibility to ensure that the current version of any standard listed in this document is consulted.*

1.3 Definitions

1.3.1 Anodising

An anodising process occurs when aluminium is anodically polarised in sulphuric, chromic or other acid electrolytes to produce a thickened oxide layer on the surface. It is an electrolytic bath immersion process and may be carried out in sulphuric, phosphoric, chromic or oxalic acids and less commonly boric acid. Sulphuric acid anodising produces harder, denser and more wear resistant films and the resulting coating is colourless and transparent on aluminium and most alloys which do not contain manganese and silicon. Although the sulphuric acid process is the preferred industrial process, it has the major disadvantage that it cannot be used on fabricated or riveted assemblies, as trapped electrolyte results in corrosion of the substrate. There is considerable loss of metal during the process due to solution in the electrolyte.

Chromic acid anodising produces thin, dense deposits with excellent chemical resistance. The film is opaque and not particularly decorative. Because aluminium is relatively insoluble in chromic acid little metal is lost during the process and this lack of solubility means that the process is highly suitable for the treatment of fabricated parts where trapped electrolyte is unlikely to lead to corrosion. The corrosion resistance of the chromic acid films is dependent to some extent on the composition of the base alloy, and the high copper alloys (over 4%) are less easy to chromic acid anodise and the anodic films deposited are generally poor. The only other anodic process of any commercial significance is the oxalic acid process

which offers no advantage over sulphuric or chromic acid processes other than the appearance of the film.

It is essential that whichever anodising process is used as a protective coating in its own right, the deposited anodic film is sealed either by immersion in boiling water or a cobalt acetate/nickel acetate/boric acid solution or sodium dichromate solution. Although the latter produces unsightly coloured anodic films, the corrosion resistance of a chromic acid sealed film is outstanding.

Anodic films produce an excellent base for subsequent paint coatings providing excellent adhesion and a very high degree of protection against corrosion, although in this case the film is normally left unsealed. Anodic films may also be deposited on magnesium alloys and titanium, although in the case of magnesium it is more commonly used as a cleaning process for castings, and as a decorative coating on titanium.

1.3.2 Blasting (grit blasting)

A process in which a surface is bombarded with abrasive particles. The most effective method of preparing surfaces prior to the application of paint by removal of rust, mill-scale and previously applied coating material is by blast cleaning with grit, shot or sand under pressure or water under high pressure. Variants on dry blast cleaning are dry processes such as centrifugal blasting, vacuum blast cleaning and compressed air blast cleaning. Wet processes include high pressure water cleaning using pressures up to 900kg/cm² and low pressure humidified abrasive blast cleaning.

Several international standards are commonly used, the more usual of which are:

	British Standard 7079	Swedish Standard SIS-05-5900	USA Specification SSPC
White Metal	Sa.3	Sa3	SSPC-SP5
Near White Metal	Sa.2½	Sa2½	SSPC-SP10
Commercial Blast	Sa.2	Sa2	SSPC-SP6
Brush Off Blast	-	Sa1	SSPC-SP7

The grade of blasting required for a particular application depends on a variety of factors including the type of coating system selected, the substrate and the service requirements.

Surface profile or the degree of surface roughness is important and depends on the abrasive used, the technique employed and the air pressure. Too low a profile will result in an insufficient key for the applied coating, too high a profile may cause insufficient coverage over the peaks resulting in premature breakdown.

The typical abrasives and resulting profiles are shown below:

Abrasive	Mesh Size	Profile Height
Very fine sand	80	40 microns
Coarse sand	12	70 microns
Iron shot S390	14	90 microns
Copper slag	-	100 microns
Iron grit No. G16	12	200 microns

1.3.3 Carbonation

The defect arising from the penetration of carbon dioxide into concrete thereby reducing the alkalinity and allowing corrosion of the reinforcing steel.

1.3.4 Chalking

The defect arising from ultra-violet attack on a paint resin binder causing photochemical breakdown of the surface layer and resulting in white powder or chalk on the surface.

1.3.5 Coating

The material which when applied to a substrate is in direct contact with the environment. It may take the form of any one or combination of the materials described in this document. It may also refer to the process of applying a protective system.

1.3.6 Coating System

A combination of materials and/or processes used in combination and applied or deposited on a substrate.

1.3.7 Contamination

Radioactive contamination is the presence of radionuclides on, or at a small indefinite depth below a surface. For porous or fissured materials the surface may include those of the pores and fissures. When applied in a more general way it is the presence of unwanted materials or detritus on a surface, the presence of which is detrimental to the process to be carried out, e.g. oils, greases, waxes, swarf, welding slag etc, which will materially downgrade the performance of organic coatings, and, in extreme cases lead to total loss of adhesion.

1.3.8 Compatibility

If the coatings used previously have performed satisfactorily it is advisable to use materials of a similar type for maintenance. Generally no problems should be encountered in applying successive coatings of a similar type. Difficulties may, however, be experienced with some combinations of existing and new coatings of dissimilar type. Problems with compatibility of old and new coatings can occur, e.g.

- a) Specialist coatings with strong solvents over alkyds can lead to solvent strike-back problems.
- b) Alkyd coatings over zinc products can lead to saponification causing premature adhesion failure and should therefore be avoided.
- c) Water based coatings over alkyd coatings because of poor adhesion.

Where there is any doubt on compatibility a trial area should be carried out on site and it's adhesion assessed prior to a final decision being made.

If a pronounced colour change is to be made, especially from dark to a light shade, additional coats may be required.

1.3.9 Conversion Coatings (Chromate Coatings)

Conversion coatings are non-electrolytic coatings consisting of complex mixtures of chromium compounds and are usually applied only to carbon steel, aluminium, cadmium and zinc, they fall into three basic groups.

Chemical Oxide Coatings. Alkaline chromate processes, which operate at elevated temperatures under immersion conditions and are therefore factory applied processes, depositing a coating of mixed aluminium and chromium oxides on the surface. The films vary in colour from green to brown-green and coating weights from 1 to 5g/m² and have good bare corrosion resistance. They can also be used as a pre-treatment prior to painting. Suitable for castings and fabricated components.

Chromium Phosphate Coatings (Green Chromate). Containing phosphoric acid, chromic acid, or a chromate/fluoride, they can be applied by tank immersion, spray or brush, although the former processes are preferred. They deposit a coating of mixed hydrated chromium phosphate and hydrated chromium oxide together with aluminium salts. The green colour of the film depends on the aluminium content of the bath. Coating weights vary between 0.1 to 1g/m² for maximum bare corrosion resistance and decorative properties. They are suitable for sheet, castings and fabricated components, although drainage may be a problem in the latter.

Chromium Chromate Coatings (Yellow Chromate). In general a factory applied immersion process the coatings consist of hydrofluoric acid, chromic acid or chromates and an accelerator consisting of potassium ferricyanide, selenium or molybdenum salts. Recent developments have led to the introduction of spray applied coatings. The deposited film is thought to consist of chromium chromate with hydrated aluminium oxide. Coatings may range in colour from iridescent light yellow to brown depending on the proprietary brand used and the film weight deposited. Coating weights range from 0.3g/m² to 2.0g/m². Heavier films tend to be powdery and less corrosion resistant. They are suitable for use as a base for painting and for bare corrosion resistance which is excellent. Chromium chromate coatings are considered to be essential for obtaining good adhesion of powder coatings.

1.3.10 Decontamination

The process by which radioactive contamination is removed or reduced in level. It may involve aggressive physical and chemical processes using strong solvents and acids together with mechanical abrasion and will, in many cases, result in damage to the applied coating. In extreme cases the process may result in, or require, the removal of a surface layer. If ease of decontamination is important then either the protective system selected should have good resistance to the likely decontaminants or the decontaminating agent(s) should be limited to those unlikely to cause damage. Most coating systems will be resistant to mild detergent solutions and organic acids but strong solvents will dissolve certain coatings and concentrated inorganic acids will damage many others.

1.3.11 Decontamination Factor (DF)

A dimensionless number which is the ratio of the initial to final concentration of unwanted radioactivity after a decontamination process. The same instrument should be used for both initial and final measurements. In practice it is normally measured by the test method described in BS 4247 - 1 Method A. In the same standard, Method B is a specific test designed to measure the contamination and decontaminability of a coating system or material under conditions closely allied to those of the proposed use in terms of environmental conditions, contaminant and decontaminant expected in service.

1.3.12 Dry Film Thickness (dft)

The measured or recommended thickness of the applied film of paint. It is a particularly important parameter in protective technology which uses organic surface coatings, and minimum dry film thicknesses are essential to achieve long service life and maximum protection. The paint manufacturer's recommendation should always be sought and adhered to. The measured dft should always be the minimum thickness, i.e. that over asperities and on sharp edges.

1.3.13 Ease of Decontamination (ED)

A term used to classify a surface which is related to the DF according to the following table and described fully in BS 4247-2.

Measured DF	Corresponding ED
More than 1000	Excellent
From 100 to 1000	Good
From 10 to 100	Fair
Below 10	Poor

1.3.14 Etch Primer (Wash Primer)

A lightly pigmented two pack primer based on polyvinyl butyral and containing phosphoric acid. Used to achieve good adhesion on metals which are 'difficult' to paint.

1.3.15 Explosive Limit

Upper and lower explosive limits are defined as the highest and lowest concentrations of flammable solvent vapours between which an explosion can occur in ambient air.

1.3.16 Flash Point

The lowest temperature at which a flammable material will flash if a flame or spark is present.

1.3.17 Finish

The final coat or layer in a protective system. The finishing or topcoat provides the required colour, gloss and general decorative properties and is designed to be smooth and to have good mechanical properties and weathering resistance. Finishes may also be formulated to have specific properties such as chemical resistance, ease of decontamination and resistance to decontaminants. It is usual to describe topcoats in terms of the resin binder, e.g. epoxy, polyurethane etc. The term is also used in a general way to describe the overall appearance of a painted surface.

1.3.18 Galvanized Steel (Galvanizing Process)

Galvanized steel is low carbon mild steel coated with zinc which may or may not contain small amounts of aluminium. Two methods of galvanizing are employed, electrogalvanizing using a plating solution of the acid sulphate type and zinc anodes and hot dip galvanizing in which the steel is dipped into a bath of molten zinc.

Electrogalvanized steel sheet has a zinc thickness of about 2.5 microns and is almost invariably phosphated or chromated and coated with an organic coating as its corrosion resistance is relatively poor in the untreated condition.

Hot dip galvanized steel has a zinc thickness between 20 microns and 120 microns and is classified into grades determined by the weight of deposited zinc per unit area. The

spangled appearance of hot dip galvanized sheet is due to the presence of other metallic impurities in the deposit. Hot dip galvanized coatings have excellent corrosion resistance except in acidic environments which can be improved by phosphate or chromate treatment.

1.3.19 Hot-Dip Coatings

Hot-dip coatings are those applied, usually to steel, by immersion in molten metal baths. The deposited metal may be zinc (as in galvanizing) tin (as in tinplate), lead or aluminium. Hot dipped lead coatings may contain up to 25% of tin and are known as 'terne' coatings. It is important that all hot-dipped coating layers are free from porosity and pin-holes otherwise heavy local pitting can occur. The choice of deposit coating is dependent on the corrosive environment and on cost.

1.3.20 Mastics (Sealants)

Mastics and sealants are flexible polymeric materials formulated on epoxy, polyurethane, silicone, butyl rubber, and polysulphides are used to fill gaps, accommodate movement in structures and insulate dissimilar metals from contact to avoid galvanic corrosion. Although some formulations are known to have good ease of decontamination most do not and DF's in the range 10-100 are common, particularly in polysulphide compositions. If the DF is not known it would be prudent to overcoat them with a paint system although this is unnecessary if ease of decontamination is not required, most formulations have excellent exterior weathering properties. Overcoating can be a problem with many formulations and failure to cure, cracking and flaking of the applied finishing system are common defects.

1.3.21 Workplace Exposure Limit (WEL)

WEL's are concentrations of hazardous substances in the air, averaged over a specified period of time. Two time periods are used: long term (8 hours) and short term (15 minutes). WEL replaces MEL (maximum exposure limits) and OES (occupational exposure standard). A list of WEL's is shown in Table 1 of COSHH document EH40 – "List of approved workplace exposure limits".

1.3.22 Metal Spray

Metal sprayed coatings are metallic coatings applied from either gas fired or electric spray pistols using wire or powder. The coatings are applied to increase the corrosion resistance to atmospheric condition and/or the appearance of the base metal. The more common sprayed metal coatings are aluminium and zinc separately or in combination. The deposited thickness is dependent on the metal and the environment. Aluminium coatings average 100 microns, zinc coatings 50 microns.

1.3.23 Montreal Protocol Substances

A group of chlorinated and fluorinated solvents including 1.1.1 trichloroethane used for solvent degreasing, the use and production of which are being phased out by international agreement.

Pretreatment

Pretreatment is a term used for a process which chemically modifies a substrate by the deposition of a surface film and in this important respect varies from a surface preparation which mechanically or chemically removes a film from the substrate and modifies the surface topography or morphology. A pretreatment is usually carried out as a basis for a subsequent protective system although some pretreatment notably anodised films and chromate conversion coatings may constitute a protective system in their own right.

The pretreatment will depend on both the substrate to be processed and the subsequent protective system to be applied. The most common substrate to be pretreated is probably

cold rolled steel, then zinc coated steel, either hot-dip galvanized or electrozinc, followed by aluminium. Other metals which may require pretreatments are cadmium and magnesium alloys.

The usual pre-treatments are:

- Anodising
- Chromate conversion coatings
- Phosphating

1.3.24 Phosphating (Heavy Phosphating)

A term applied to the deposition of a heavy phosphate layer which is then impregnated with oil, wax or proprietary stains. Heavy phosphating is usually only applied to mild steel and may be carried out using ferrous phosphate, manganese phosphate and zinc phosphate processes. Manganese phosphate is generally accepted as giving the best corrosion protection. Manganese phosphate processes are usually accelerated by the incorporation of nitrate salts or nitroguanidine, the latter being preferred where fabricated structures or substrates which may trap process residues are being treated. Nitrate ions are likely to accelerate corrosion, nitroguanidine residues will not. Coatings of this type must always be sealed and are not regarded as being pretreatments for paint but rather as protectives for steel plate or castings.

Phosphating (Light or Amorphous) Usually applied to steel, zinc and aluminium these coatings deposited from solutions of alkali metal phosphates produce a layer of fine microcrystalline mixed iron phosphate and iron oxide on the surface when applied to steel. The coatings which vary in colour depending on the nature of the bath and the base metal provide an excellent base for subsequent organic coatings but have limited corrosion resistance without further coating. The coating weight is between 0.2 and 0.7g/m². As they do not contain heavy metals they are among the most environmentally friendly coatings in use and for disposal. They are sometimes called alkali metal phosphate or lightweight iron phosphate processes but should not be confused with the true iron phosphate processes based on ferrous phosphate. They may be applied by dip or spray.

1.3.25 Primers

Primers are formulated to have good wetting properties and to give excellent adhesion to the substrate and provide a key for subsequent coats. They represent the first line of anti-corrosion defence and provide a barrier system. They frequently, but not invariably, contain an inhibitive pigment present to chemically passivate surface or to act as a reservoir of inhibitive ions. Provided they are applied over a correctly prepared surface and at the manufacturers recommended dry film thickness (dft) protection is afforded against corrosion creep at points of mechanical damage. A special case is that of zinc rich primers which contain a high level of metallic zinc and afford protection by galvanic action, functioning as sacrificial anodes. It is the usual practice to describe a primer in terms of the inhibitive pigment it contains e.g. zinc phosphate.

However it should be clearly recognised that the organic binder present, whether epoxy, alkyd or polyurethane is important and a material specified as a zinc phosphate primer is both insufficiently and misleadingly described. The correct choice of primer is central to the success of the complete system as a corrosion resistant barrier and it is essential to match the type of primer to both the substrate and the rest of the coating system.

1.3.26 Required Air Quantity (RAQ)

The volume of air in m³/litre of solvent to dilute flammable vapours to 10% of the LEL (lower explosive limit).

1.3.27 Sherardizing

A zinc diffusion process for the protection of ferrous metals. Similar in properties to galvanizing but produces only minor dimensional changes.

1.3.28 Surface Preparation

Any process carried out to modify or alter the surface topography by the removal of undesirable material without depositing a further layer on the surface. Undesirable materials may be oils, greases, waxes, rust or other corrosion products.

1.3.29 Undercoats

Undercoats are formulated to have high opacity and maximum solids content to enhance the overall corrosion protection of the system and provide good intercoat adhesion. They may contain inhibitive pigments to ensure that local areas not covered by the primer are protected and the permeability to water and oxygen may be improved by the incorporation of lamellar pigments such as mica, aluminium flake or micaceous iron oxide.

1.4 Selection of Protective Systems

In the selection of a protective system there are many factors which must be taken into consideration all of which have a considerable bearing on the effectiveness, life and cost of the coated object. These include the type of substrate, the properties required of the protective system, the environment(s) to which it is to be exposed, the possible methods of surface preparation and the application techniques available or possible. Value for money will depend on a correct choice having been made on the basis of a critical assessment of these factors taken in combination.

1.4.1 The Substrate

In the selection of a suitable protective system, the first important point to consider is the material, or materials of construction, since this will, to a large extent, govern the choice of protective systems, in that it may limit the options available or reduce the necessity to consider a spectrum of options. The choice of stainless steel as a substrate for example will both reduce the number of available choices and at the same time reduce the need for any protective system.

It should be noted that a factor to consider in the selection of substrate is that a fully protected relatively cheap substrate may have the same service life at a lower cost as a more expensive substrate not requiring the use of a protective system. An example of this is the use of painted or galvanized steel to replace stainless steel.

Some substrates, notably aluminium, brass, copper, lead and low alloy corrosion resistant steels may not require protection under many conditions of use, particularly under interior exposure situations where the environment is either completely benign or almost so.

Conversely carbon steels will require to be protected under almost all conditions of use. In considering the corrosion resistance of a particular metal it is essential to consider the complete gamut of hostile agencies and associated environments to which it may be exposed and not just the obvious factors such as water, oxygen, contaminants, decontaminants and specific chemicals. Some metals, notably zinc and lead, are readily corroded by organic vapours particularly acetic and formic acids which may arise from wooden containment or associated paint products which contain vegetable oil residues.

The most reactive metals, e.g. carbon steel require the most attention to the choice of protective system and careful consideration must be given to surface preparation and the type of primer used.

1.4.2 Protective Systems

For convenience these may be separated into two groups, organic coatings and inorganic coatings, the former embraces most of the paints and varnishes and the latter such coatings as anodic films and chromate conversion coatings although zinc rich priming paints based on potassium silicate are completely inorganic in composition.

There are vast numbers of organic paint systems available for the coating and protection of every type of substrate and each paint company will have its own brand names and basic systems. However, most paint coatings will be based on a limited number of polymeric binder resins, and coating systems are frequently described in these generic terms, e.g. epoxy, polyurethane etc., further qualified by the type of pigmentation, e.g. zinc phosphate, micaceous iron oxide. They are also frequently described as being single pack or two pack. Only a full descriptive title, e.g. Two Pack Zinc Phosphate Polyamide Cured Epoxy will provide sufficient information to enable the correct material to be used. An indication of the available organic finishing systems is shown in table 1.

There is a limited number of inorganic protective systems most of which are either factory applied e.g. anodising and hot dip galvanizing, or require special equipment or techniques e.g. metal spraying. The choice of inorganic system is largely determined by the substrate, the nature of which considerably limits the selection, thus hot dip galvanizing is only suitable for use on steels and anodising on aluminium and its alloys. The protection afforded by inorganic systems varies from a few months under hostile conditions to decades in benign conditions. Few inorganic systems can be regarded as decorative and the method of application limits their use in many applications. An indication of the available inorganic coating systems is shown in table 2.

A guide to the initial selection of protective finishes is shown in table 3.

**TABLE 1
GUIDE TO AVAILABLE ORGANIC FINISHES**

TYPE	AVAILABILITY		APPLICATION
Alkyds and modified alkyds Epoxies polyamide amine amine adduct phenolic solventless solvent free water based Polyurethanes aromatic cured aliphatic cured moisture curing	Air drying Chemically cured Chemically cured Chemically cured Chemically cured Chemically cured Chemically cured Chemically cured Chemically cured Chemically cured Moisture cured	- single pack - twin pack - twin pack - twin pack - twin pack ¹ - twin pack - twin pack - twin pack - twin pack - twin pack - single pack	Brush, spray, roller Brush, spray, roller Brush, spray, roller Brush, spray, roller Brush, airless spray Airless spray, roller Airless spray, roller Brush, spray, roller Brush, spray, roller Brush, spray, roller Brush, spray, roller
Elastomers	Chemically cured	- twin pack	Hot airless or airless spray only
Powder Coatings Polyester Epoxy	Elevated temperature Elevated temperature	- powder - powder	Factory applied Factory applied
Nylon and other thermoplastics	Elevated temperature	- powder	Factory applied
Plastisols	Evaporation	- single pack	Factory applied

Note

1. Some proprietary brands may be triple pack

TABLE 2
GUIDE TO AVAILABLE INORGANIC FINISHES

TYPE		APPLICATION
Anodic	- Chromic acid	Factory applied, electrolytic process.
Anodic	- Oxalic acid	
Anodic	- Phosphoric acid	
Anodic	- Sulphuric acid	
Chromate	- Phosphate (Green)	Spray or dip. Generally a factory applied process. Non-electrolytic.
Chromate	- Chromium (Yellow)	Spray or dip. Generally a factory applied process. Non-electrolytic.
Galvanizing	- Electrogalvanizing	Factory applied electrolytic process
Galvanizing	- Hot dip 'Zinc'	Factory applied non-electrolytic process.
Metal Spray	- Aluminium	May be applied in situ or as a factory applied process and may be in combination.
Metal Spray	- Zinc	
Phosphate	- Iron	Factory immersion or spray applied processes. Non-electrolytic
Phosphate	- Manganese	
Phosphate	- Zinc	
Plating	- Cadmium	Factory applied electrolytic process.
Plating	- Chromium	
Plating	- Nickel	
Plating	- Zinc	

TABLE 3

GUIDE TO INITIAL SELECTION OF PROTECTIVE FINISHES

Finish	Ease of Decontamination	Resistance to Decontaminants	Corrosion Resistance	Chemical Resistance		Solvent Resistance	Weathering Resistance and Decoration	Mechanical Damage Resistance
				Acid	Alkali			
Organic Coatings								
Polyurethane	Good to excellent	Excellent	Excellent	Good	Good	Excellent	Excellent	Good
Epoxies	Good to excellent	Excellent	Excellent	Moderate	Excellent	Excellent	Moderate to good	Good
Alkyds	Good	Poor	Good	Poor	Poor	Poor	Good	Poor
Powder Coatings								
Thermoset	Good to excellent	Excellent	Excellent	Excellent	Excellent	Good to excellent	Excellent	Excellent
Thermoplastic	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
	Fair to good	Fair to good	Poor to good	Poor to good	Poor to good	Poor to fair	Excellent	Excellent
Inorganic Coatings								
Galvanizing (Electro)	)	Excellent	Excellent	Poor	Poor	Excellent	Excellent	Excellent
Galvanizing (Hot Dip)	)	Excellent	Good	Poor	Poor	Excellent	Good	Excellent
Anodic Films	)	Fair to good	Good to excellent	Good	Good	Excellent	Good	Good
Metal Spray	)	Fair to good	Excellent	Good	Good	Excellent	Excellent	Excellent
Plating(s)	)	Fair to good	Good to excellent	Good to excellent	Good to excellent	Excellent	Good	Good
Chromate (Conversion)	)	Poor to fair	Good	Good	Poor	Excellent	Good	Poor
Phosphate	)	Poor to fair	Good	Good	Good	Excellent	Fair	Fair

1.4.3 Decoration

In considering the need for initial decoration and long term maintenance of appearance, the degree of gloss of the finish, freedom from chalking when exposed to ultra-violet radiation, freedom from marked colour change and light mechanical damage in the form of scuffing and minor surface scratching may be important. Many of the coating systems which may be selected for long term corrosion protection are neither initially decorative nor remain decorative for extended periods of exterior exposure. Epoxy based paints for example show rapid chalking and associated loss of gloss on exterior exposure but aliphatic isocyanate cured polyurethane paints show remarkable gloss retention and resistance to chalking. Between these two extremes are the alkyds, urethane alkyds and acrylics which show good initial gloss and can maintain their appearance for several years.

Inorganic systems cover a wide spectrum of decorative properties and it is not easy to generalise. Galvanized surfaces, and metal sprayed surfaces have poor initial appearance and show rust staining and zinc degradation products relatively early in their service life. Anodised surfaces, unless dyed, are only moderately decorative, particularly chromic acid anodising, and soon show deterioration in decorative properties unless regularly cleaned. Plated surfaces, particularly chromium and copper are decorative although the appearance of copper plated surfaces deteriorates relatively rapidly.

The rate at which the decorative properties of all protective systems deteriorate depends on the environmental exposure and the exposure period. In general decoration is far less important than protection.

1.4.4 Identification

Organic coatings are frequently used for colour coding and identification of pipe-lines, specific hazards etc and the important factors are long term colour retention, adhesion and compatibility with the substrate or existing coating system. It is perhaps self evident that a coating which discolours either by fading or excessive chalking to such an extent that identification becomes doubtful, should not be used. Adhesion is important for long life and the identification paint should be regarded as the top coat in a complete system and the appropriate primer used. This is particularly important on zinc, lead and copper substrates where reaction of the degradation products of the paint with the base metal is possible. Chloride free paints or other products, e.g. adhesive tapes, must be used on stainless steel particularly under conditions in which stress corrosion cracking could occur.

1.4.5 Corrosion Protection

In considering the possible protective systems for use on a particular substrate it is necessary to decide what the substrate is being protected against, in other words what are the corrosive agencies involved and will they damage the chosen substrate. If there are no corrosive agencies or the substrate is resistant and decoration or decontamination are not required then there is no need to protect. The less hostile the environment is, the less protection is required. Protection is expensive.

Hostile agencies include atmospheric gases and contaminants, ultra-violet radiation (in the case of wood), water, solvents, chemicals (acids/alkalis/decontaminants) and the environments may be exterior (rural, marine or industrial), interior, or immersion, either continuous or intermittent. Protection against some or all of these destructive environments may be required. The ability to clean, inspect and maintain protected structures or substrates is a major factor to consider and if this is not possible, and a long service life is required, then the best possible protective system involving protection in depth is required. In these cases the use of a combined or duplex system, e.g. hot dip galvanizing plus a multi-coat organic paint system is required.

Because of the many possible environments, hostile agencies and substrate combinations which need to be considered, all of which are specific to an end use, only general statements can be made in this section and reference must be made to Sections 3 - 15 for

particular substrates. Potential elevated temperature use complicates the situation. A general guide to corrosion resistance is given in table 4.

**TABLE 4
GUIDE TO SELECTION FOR CORROSION RESISTANCE**

COATING SYSTEM	ENVIRONMENT				
	External Rural	External Industrial	Internal	Immersion	Chemical*
Alkyd	+	#	+	x	x
Urethane alkyd	+	+	+	x	+
Epoxies	+	+	+	+	+
Phenolic epoxies	+	+	+	+	+
Powder coatings	+	+	+	+	+
Polyurethane	+	+	+	+	+
Galvanizing (Electro)	+	x	+	x	x
Galvanizing (Hot Dip)	+	#	+	#	x
Anodic films	+	#	+	#	#
Metal spray	+	+	+	+	#
Plating	+	#	+	x	#
Chromate	+	#	+	x	x
Phosphate	+	+	+	x	x

+ Recommended

May be suitable

x Not recommended

* Resistance to strong oxidising acids will be poor

The most versatile protective systems are the organics provided that the correct surface preparation has been carried out, the correct primer used and a sufficient dry film thickness (dft) applied. The greatest protection is afforded by the cross-linked coatings; epoxies and polyurethanes. The organic systems based on alkyds are the least protective. The thicker the coating system the better the protection under most conditions of use and resistance to the most hostile agency likely or present should dictate choice.

Inorganic systems are less versatile as they are more substrate specific and may themselves require protection against a particular corrodent. Duplex systems of inorganic and organic materials provide the best overall corrosion protection and although expensive to apply are less costly over long periods as they require less maintenance. Examples of duplex systems with excellent all-round protection include chromate conversion coatings with powder coatings and galvanizing with micaceous iron ore pigmented epoxy.

1.4.6 Mechanical Damage

For practical purposes mechanical damage may be defined as minor, covering surface defects such as abrasion marks, shallow or deep scratches and minor chipping which affect the decorative properties of a system, and major, covering large chipouts and flaking which expose the substrate to hostile agencies. Any form of mechanical damage will affect the ease of decontamination of an organic system and major damage will shorten the protective

life or time to first maintenance. Even some minor damage will allow accelerated penetration of the protective film resulting in corrosion and exfoliation.

The best resistance to mechanical damage will be provided by tough firmly adherent coatings, powder, polyurethanes and epoxies in the case of organic systems and hot dip galvanizing in the case of inorganics. If resistance to mechanical damage is an important consideration, organic systems which can be repaired easily are a first choice.

1.4.7 Chemical Resistance

Of the many properties required of a protective system, chemical resistance is the most difficult to define in general terms as the factors involved are so varied and numerous. These factors include the specific chemical or chemicals, the concentration, the temperature and the degree of exposure. In general the most aggressive environments will be immersion in a concentrated chemical solution at elevated temperature which will attack most, if not all protective coatings, conversely the same chemical at low concentration at room temperature may cause little damage.

It is essential to seek advice on specific applications from the paint manufacturer, as both the nature of the chemical and the concentration present are important factors.

1.4.8 Maintenance and Repair

The maintenance of painted or otherwise protected structures is a complex subject and the specification of remedial procedures is correspondingly difficult particularly where the exact nature of the existing system is unknown. Two considerations are apparent, one to maintain before breakdown occurs and the second after some degree of breakdown is apparent. Some coating manufacturers provide guidance on "life to first maintenance" based on the need to maintain when a structure shows corrosion conforming to Re2 degree of rusting, but this is only applicable to ferrous metals. The time at which a protected structure requires maintenance will depend on the substrate, the type of coating system applied, the dft of the applied system and the service environment. The longest life to first maintenance will be provided by a fully cross-linked epoxy or polyurethane system applied at a dft of 200+ microns to aluminium and subjected to a non-hostile environment (or mild chemical fumes) at ambient temperature or painted galvanized iron. In this former case a life to first maintenance of 10+ years is readily achievable and in the second, 25+ years. At the opposite extreme a thinly applied low quality coating applied to mild steel and subjected to immersion conditions might fail in a few months.

If the existing protective system is inorganic, e.g. anodising, chromating or galvanized etc, that is a factory applied system, it cannot usually be maintained by repeating or replacing it with the same system, and the only practical course is to use an organic coating system, the need to maintain the protective system may well decide the nature of the protective system selected in the first case. The need to maintain a system may be governed by a perceived need for good decorative properties or by a local or general breakdown of the system allowing corrosion of the substrate. Although the former is the easier to maintain it is essential that in both cases the nature or composition of the existing system is known if a repetition of the original failure is to be avoided, this is particularly so for organic coatings (see Clause 1.3.8 Compatibility).

Cases of premature or catastrophic failure are likely to arise due to either poor surface preparation of the substrate or an inappropriate choice of coating for the service environment. In either case a repetition must be avoided by reselection. It is generally considered that a surface showing failure by blistering, flaking or corrosion over more than 25% of the area should be completely renewed.

If a painted structure is to be recoated for decorative purposes, i.e. the finish shows pronounced colour change, chalking, mildew or loss of gloss, then the surface preparation required may be confined to the removal of surface contamination (radioactive or non-active) by high pressure washing with a solution of detergent in water, or mild bleach in the case of mildew, followed by washing with clean water. Hard, glossy or tough surfaces should be

abraded by hand or power tool. A single coat of the original finish may then be applied by the most convenient method. In the case of some epoxies and phenolic epoxies the original manufacturer should be consulted.

If the structure is to be recoated because the finish shows blistering, cracking, peeling or flaking or corrosion of the substrate the surface will require a more stringent surface preparation, a minimum of light sweep blasting to remove defective but uncorroded areas. Where corrosion has occurred this must be removed to bright metal over a larger area than the observed corrosion by high pressure water blasting, spot blast cleaning or power tool. Disc sanding is particularly useful for removing small areas of corrosion.

It is invariably preferable, and potentially less expensive to maintain coatings before corrosion of the substrate has occurred.

1.4.9 Surface Preparation

Many of the surface preparation methods required for particular protective systems, either to achieve maximum service life or because the chosen system cannot be applied without a specific surface preparation can only be carried out under factory conditions, this is frequently the case for the inorganic protective systems. This type of preparation may require tank immersion at elevated temperature or the use of chemicals which cannot be discharged to atmosphere or allowed to contaminate ground water. Examples are toxic solvents and solutions containing chromates. If, therefore, the component or structure to be protected cannot be factory treated, then many of the inorganic protective systems cannot be considered as an option. Protective systems of this type consist of galvanizing, anodising, plating and chromate conversion coatings. The use of thin gauge sheet material may also preclude the use of some forms of surface preparation, e.g. blast-cleaning.

The degree of surface preparation will depend on the nature of the substrate, the presence or otherwise of contaminants and the type of coating to be applied. In general the greater the service life expectancy, the more hostile the service conditions and the more sophisticated the protective system, the more stringent the surface preparation required. It is imperative with organic coatings that if maximum service life is to be achieved and costly adhesion failures avoided, the supplier's recommendations on surface preparation or pretreatment are followed, failure to do so will result in premature failure without legal redress. The most common single cause of premature coating failure is inadequate surface preparation.

The basic methods of surface preparation in order of increasing severity and effectiveness are:

- degreasing
- hand tool cleaning
- power tool cleaning
- pickling
- blast-cleaning

although not all surface preparations are applicable to all substrates. See Sections 3 to 15 covering specific substrates and Section 2 on Surface Preparation Methods. Unlike surface pretreatment surface preparation modifies the surface topography without depositing a modified compositional layer on the surface, surface preparation removes surface layer. In its simplest form a surface preparation may only remove a layer of grease or oil from the surface without changing the surface profile.

Degreasing: Is applicable to all metallic substrates. It is essential that all oils, greases, waxes and cutting oils are removed from a surface prior to any other surface preparation. Failure to do so will result in the organic contamination being spread over a wider area and residues remaining after any other treatment. Usually carried out by solvent washing followed by wiping with clean rags in the field, factory processes include hot liquid immersion, solvent vapour, or hot spray with chlorinated solvents and hot liquid immersion in

proprietary aqueous or solvent emulsion cleaners. Steam cleaning is also effective. It should be noted that many of the chlorinated solvents used for degreasing are covered by the provisions of the Montreal Protocol, which seeks to eliminate them.

Hand Tool Cleaning: Is usually only applied to steel substrates to remove loosely adherent mill-scale and rust, and carried out using wire brushes, abrasive cloths and/or scrapers. This is a relatively inefficient method as it leaves rust on a steel surface and fails to clean pitted areas.

Power Tool Cleaning: Is carried out using grinders, sanders, rotary brushes or needle guns on steel, this method is more effective than hand tool cleaning but will not remove tightly adherent millscale and rust. It is preferable to hand tool cleaning but far less effective than blast cleaning.

Pickling: Is only used on steel and preferably under factory conditions. It involves the use of strong mineral acids.

Blast-cleaning: Is applicable to most substrates and can be used to remove surface corrosion products and contaminants and modifies the surface profile to a marked extent. It is by far the most efficient non-factory method of surface preparation but care must be taken with thin gauge section and non-ferrous metals by using non-metallic abrasives.

1.4.10 Application of Surface Coatings

The most universal methods of applying organic coatings are brush, roller, conventional spray and airless spray although factory processes include dipping, curtain coating and electrostatic spray. Airless spray is the most efficient and convenient method of applying high performance, high build coatings. Coatings are generally formulated to be applied by a specific method of application and either the manufacturers recommendations must be followed or a coating ordered for a chosen method of application. The method of application will have a marked effect on the rate of application, economy of paint use, dry film thickness and service life.

Brushing: Is a slow application method usually reserved for applying conventional decorative paints to small areas or where the use of a spraying method would cause over-spray or dry-spray problems. Skill is required to prevent brush marks, the presence of which may result in inadequate local film thickness. Brush application is generally unsuitable for coatings curing by solvent evaporation where the speed of drying is rapid and pick-up or lifting of previously applied coats may be a problem. In general high and uniform film thicknesses cannot be achieved by brush.

Roller application: Although faster than brush application, is generally only suitable for large flat areas and dry film thickness is difficult to control. The correct choice of roller type with regard to material and pile length is essential if a good surface finish is to be achieved.

Conventional Spray: Is a simple method of application in which low pressure is used to atomise the paint. Skill is required to avoid excessive paint loss from both over-spray and bounce-back from the surface. Over application can result in runs and sags in the dry film and over pressure may result in pin holes in the surface. The solid content of paints suitable for application by conventional spray is low and multiple coats are required to achieve high dry film thickness.

Airless Spray: Is a method using very high pressure air (2,000-3,000 psi) to pump the paint through specially designed nozzles. The major advantages of this technique are that high throughput speeds are possible using high solids content, high viscosity paints with a

consequent rapid build up of film thickness. Overspray and bounce-back are much reduced leading to economy of paint use.

Variations on airless spray are hot airless spray in which the paint is preheated to reduce the application viscosity and speed up the cure rate and twin nozzle sprays in which twin streams of base and curing agent are mixed in the paint stream. Airless spray is now recognised as the most efficient and convenient method of applying high performance, high build coatings.

1.4.11 Design Considerations

In designing any metal structure which is required to be protected against corrosion, attention to detail at the design stage is important if premature failure of the protective system is to be avoided with consequent costly maintenance. It is generally recognised that between 10 and 15% of the area of a given structure may be subject to enhanced risk of corrosion due to sharp edges, imperfect or incomplete welds and water and dirt traps. In particular, riveted or bolted structures or those with intermittent welding are difficult to protect. Protective systems of whatever type may show cracking, shrinking or peeling from these areas. Sharp edges almost invariably cause thin areas in the protective system due to surface tension effects. Paint systems are notoriously prone to this defect.

Structures composed of mixed metals should be avoided whenever possible as galvanic corrosion may occur in the presence of an electrolyte resulting in saponification of a paint system or rapid loss of adhesion. If the use of dissimilar metals cannot be avoided then provision must be made for the use of mastics and sealants to prevent electrical contact. Openings and blind holes which prevent access for painting or trap water or moisture retaining dirt should be avoided.

The connections between round or curved sections and flat surfaces should be filled by welding or sealant, as should the junction between facing plates. Connections between vertical and sloping sections should be made in such a manner that water or other liquids can drain away and all sharp edges should be ground either flat or be rounded off and the overall design of the structure should recognise the need for maintenance coatings. Attention to these details will minimise the possibility of premature breakdown.

1.4.12 Contamination

If contamination is likely to be an important issue or a practical problem, the need for minimum pick-up of radioactivity under the conditions of use will need to be assessed in terms of the nature of contaminant ions, whether particulate or in solution, and the solution pH. If only light non-abrasive particulate contamination is involved then a conventional smooth glossy relatively impermeable coating of the alkyd or modified alkyd type will be suitable. If, however, the contaminant is in solution, particularly at high or low pH, then a heavy duty coating system of the polyurethane or epoxy type will be required. It may follow therefore that if a coating system has a high radioactive pick-up and a poor ease of decontamination it will need to have a high resistance to decontaminants. Conversely if it has a low pick-up and excellent ease of decontamination, its resistance to decontaminants need not necessarily be high. Practical experience indicates that where contamination by a liquid contaminant is concerned surfaces which have the highest pick-up are the most difficult to decontaminate.

Unfortunately there is little published information on actual levels of pick-up either under laboratory test conditions or in service, but all surfaces will retain contaminants under ionic conditions and particulates will be retained by rough surfaces. It is more usual to categorise surfaces in terms of their ease of decontamination rather than their contaminability.

1.4.13 Decontamination

Decontamination may require the use of a range of methods ranging from a simple detergent wash (for particulates) to a prolonged abrasive treatment using strong chemicals or even total removal of the surface layer. The BS 4247 - 1 Method A test provides an indication of

the relative ease with which surfaces may be decontaminated from specific radionuclides applied under standard laboratory conditions and removed under specific conditions. To this extent the test indicates the potential for contamination/decontamination at the time of test on a perhaps unrealistic substrate prepared under laboratory conditions. It may therefore have only a limited bearing on the actual decontaminability of a surface under practical application and service conditions. A more practical test in which the actual contaminant to which the surface will be exposed in service under conditions closely allied to those of the proposed area of usage is provided by Method B of BS 4247 - 1.

Information on the ease of decontamination of surfaces is largely confined to surface coatings, which have been shown to have Decontamination Factors (DFs) ranging from below 10 to 5000-8000 depending on the product evaluated. Some indication of the range of DFs for various generic types of coating is shown in table 5. The only other type of substrate which is known to have been tested and reported is stainless steel which has been found to have a DF highly dependent on the surface finish. Further information on this substrate may be obtained from the Testing Laboratory, Building 109/B32, Decontamination Centre, AEEW.

**TABLE 5
DECONTAMINATION FACTORS OF AVAILABLE COMMERCIAL PAINTS
(BS 4247 Method A)**

PAINTS	DF RANGE
Alkyds (Various)	400-600
Epoxies	22-8110
Nitrocellulose	2200
Polyurethanes	280-4600

In the absence of test data for other surfaces it is difficult to make predictions on the ease of decontamination of specific surfaces and it will be necessary to have selected candidate surfaces tested for ease of decontamination by either method A or B of BS 4247 - 1.

However it is clear that rough surfaces, on either the micro or macro scale are likely to retain the most contamination and have poor ease of decontamination with associated low DFs. Substrates and surfaces falling into this category are those which have been galvanized, phosphated, chromated, hot dipped or metal sprayed. Surfaces which may be expected to react with a liquid contaminant at any pH are also likely to have a low DF. Substrates in this category are uncoated aluminium, brass, copper, steel and zinc and those surfaces which have been anodised or metal sprayed. If ease of decontamination is a major factor in the use of a container, then in the light of present knowledge, only organic surface coatings are known to be entirely suitable until the data base has been expanded. As mentioned earlier stainless steel may be sufficiently decontaminable providing it has the required surface finish, but any scratches or surface abrasions arising from service or earlier decontamination will adversely affect the subsequent ease of decontamination.

Published work on organic surface coatings exposed to a variety of environmental conditions including exterior weathering and water immersion suggests that the ease of decontamination of polyurethanes, epoxies and alkyds changes considerably with age and exposure conditions, in many cases decontaminability is improved. This general statement is not applicable to the phenomena of 'sweating' peculiar to some coatings immersed in liquids containing caesium 137, which may be regarded as a special case of ageing.

1.4.14 Health and Safety Considerations

The use of organic surface coatings presents several potential health and safety hazards and it is essential that the Paint manufacturers' safety data sheets are both available and consulted before a particular coating system is chosen or used. In extreme cases the potential hazard may eliminate a coating as a candidate material.

Most surface coatings, apart from solvent free and water based systems, contain organic solvents which are flammable and may have a low flash point. If the flash point is lower, or close to the application temperature, there is a major risk of fire or explosion in close proximity to a source of ignition, or even some considerable distance away from such a source. In enclosed or badly ventilated areas the lower explosive limit, LEL, may be exceeded. Explosions may be prevented by correct ventilation practices which reduce the concentration of flammable vapours below the LEL. It is the usual practice to ventilate to 10% of the LEL, the quantity of air required, referred to as the required air quantity, RAQ, is expressed in m³/litre of paint. It should be noted that this quantity of air (or degree of ventilation) is much less than the air required to ventilate to below the occupational exposure limit, OEL, quoted in ppm or mg/m³. The RAQ to ventilate to below the OEL varies considerably from coating to coating but the more coating being applied the greater the ventilation required. The presence or absence of odour should not be taken as indicating the presence of toxic or flammable vapours as the olfactory sense is quickly swamped by many organic vapours. Monitoring should be carried out to determine the presence of hazardous or flammable vapours. Where possible the flash point of a coating should be above ambient temperature.

Certain paints are regarded as being particularly hazardous to health. Polyurethane paints in particular contain isocyanates which are respiratory sensitisers and some epoxy phenolic coatings contain small amounts of isocyanate and aromatic amines which are also sensitisers. Once sensitised a worker will suffer reoccurring symptoms at progressively lower exposures. Many commonly used solvents are hazardous to health and exposure by inhalation, ingestion or skin contact must be avoided by the use of the appropriate protective clothing. If it is not possible or practical to ventilate to below the OEL then an air fed mask or hood must be worn and it is important to wear the appropriate type of mask for the hazard likely to be encountered. Some masks will remove vapours or particulate and droplets but not both. Solvents and other constituents of paints may be skin irritants and cause dermatitis, skin contact should be avoided.

More detailed information on all safety aspects should be obtained from the paint manufacturer but the Health and Safety at Work Act 1974, and the Control of Substances Hazardous to Health Regulations (COSHH) require both the employee and the employer to safeguard health and safety. Written procedures and instructions are essential.

1.4.15 Specialised Organic Coatings

1. Intumescent Coatings

These are coatings which swell on exposure to heat to form a thick voluminous carbon char which protects the substrate and package contents against elevated temperatures. The coatings may become activated at temperatures of 200-300°C. It is important that the char remains firmly adherent during exposure to heat and the degree of surface preparation and choice of primer are important if the intumescent coating is to perform satisfactorily. Care should therefore be taken in the choice of the complete finishing system and the manufacturers recommendations closely followed. Intumescent coatings should not be applied over unknown existing paint systems as premature detachment may occur.

Certain intumescent coatings contain water sensitive blowing agents and carbon-forming ingredients and may have a limited service life without the application of a protective finishing coat. An important reason for overcoating is that coatings of this type are heavily loaded and are unlikely to be easily decontaminable and it may therefore be necessary to overcoat them with a suitable decontaminable finish. In this case it is particularly important that the finish selected should be compatible and not cause damage to the intumescent coating by lifting or dissolution or cause it to fail to intumesce. The manufacturers recommendations must be followed in these situations.

2. Strippable Coatings

These are coatings which have only a temporary life and are removable by mechanical stripping or dissolution in aqueous or non-aqueous solvents. They may be applied over existing paint systems to prevent initial contamination, to tie down existing contamination on a temporary basis or to remove particulate contamination from a surface. Because they contain strong solvents they may cause lifting or blistering of the existing paint and a compatibility test is essential before selecting or applying a strippable coating. It is also essential that if a soluble type is used the existing system should not be damaged by the solvent it contains.

Care must be exercised in ensuring that a sufficient dry film thickness is applied to ensure that a strippable coating can be readily removed, an insufficient dry film thickness will result in incomplete or difficulty in removal. It is general experience that strippable coatings frequently fail to strip when required and frequently strip when not!

3. Heat Resistant Coatings

Most organic coatings have a finite operating temperature above which they will fail rapidly and completely, and unless specially formulated will have a service life dependent on the service temperature. The higher the temperature the shorter the service life. A combination of high service temperature and exposure to strong chemicals will almost invariably cause rapid breakdown of most organic coatings. Some indication of the dry heat resistance of coatings is shown in table 6. It should be noted that specific coatings from a particular manufacturer might have a greater or lesser recommended service temperature which will be highly dependent on the working environment. If high temperature resistance is a prerequisite then the choice of systems is limited to inorganic zinc rich primers and silicones.

TABLE 6
DRY HEAT RESISTANCE OF GENERIC COATING TYPES

COATING	MAXIMUM SERVICE TEMPERATURE* °C
Organic Types	
Alkyds	80
Alkyd (aluminium pigmented)	160
Epoxies	150
Epoxy (aluminium pigmented)	170
Polyurethanes	120
Powder Coating	150
Silicones	450-600
Inorganic Types	
Anodising	100
Chromate Conversion	60
Galvanizing	200-275
Metal Spray	200-275
Plating	Variable, depends on plating metal and substrate
Zinc Silicate	400

*Will depend on environmental factors and advice must be sought on specific conditions of use.

1.4.16 Factors Which May Affect Performance

Environmental conditions during paint application and cure

In addition to the environmental conditions that a coated structure may be required to resist causing eventual breakdown, the environmental conditions prevailing at the time of application and subsequent cure may seriously affect the service life of protective systems which have not been applied under controlled ambient conditions, by immersion, electrolytic or other factory processes. Important factors in the application and cure of organic coatings are temperature and humidity.

Painting should only be undertaken when the ambient temperature is equal to or above the lower limit recommended by the paint supplier. In general this will be 5°C or above for epoxies and polyurethanes. As a general rule the temperature of the substrate to be painted should be at least 3°C higher than the dew point. High temperatures above 40-45°C may cause rapid loss of solvent causing voids, pinholes, bubbles or dry spray.

Surfaces must be free from condensation initially and when there is no likelihood of condensation occurring during cure. High humidity, above 90% RH, can adversely affect the cure of two pack epoxy and polyurethane paints and may cause bubbling in the latter. The water content of concrete, plaster and other porous surfaces must not exceed that recommended by the paint supplier or adhesion failure is likely.

1.4.17 Effect of Substrate on Surface Finish

It should be clearly understood that the pick-up of radioactivity, the ease of decontamination and the resistance to corrosion of a structure are dependent to a large extent on the properties of the substrate/coating system combination. This is particularly the case with contamination and decontamination where, even when a BS 4247 -1 Method A test has indicated a high DF for a coating system, the practical achievement may be considerably inferior to that indicated by the measured DF.

In practice good ease of decontamination may be difficult to achieve due to the surface porosity and roughness or profile of the substrate. This is particularly the case with concrete substrates where the presence of blowholes and asperities on the surface cause the applied coating to be of variable thickness. In extreme cases the local measured dft may be less than 10% of the general dft.

On metal substrates there is less of a problem, with the possible exception of steel which has been gritblasted to give a maximum profile for paint application. In this case it is important to ensure a minimum thickness over the peaks on the metal surface. This will require the recommended dft to be very much greater than this minimum value.

2 SURFACE PREPARATION METHODS

It is important that the surface preparation chosen is both appropriate and adequate for the finishing system to be applied and the manufacturer, supplier or processor must be consulted before specifying a detailed method. It is also important to recognise that some finishes may be recommended and used as surface pretreatments for other finishing systems where particularly arduous or corrosive conditions are to be experienced. Examples of this are the use of chromate conversion coatings on aluminium and zinc phosphating and galvanizing on steel as pretreatments for organic finishes.

Where organic finishes are to be applied either in the field or at a fabricator's premises, the surface preparation specified should be that stated by the paint supplier. In the case of factory applied finishes, particularly where electrolytic processes such as anodising or immersion techniques as in hot dipping are being employed, the finishing contractor will have well defined and standard surface preparation schedules which are essential parts of the whole process. In these situations it will be unnecessary to specify the surface preparation method in detail, particularly where a BS or DEF-STAN process is involved.

As a general rule the method of surface preparation should be the mildest of those available consistent with obtaining the degree of cleanliness and/or surface profile required for optimum adhesion and corrosion protection particularly where thin metal sections are being prepared. The objective must always be as near complete removal of corrosion products and soluble contaminants as possible and in this context the removal of corrosion products from zinc and aluminium surfaces is at least as important as removing rust from ferrous metals.

Method 1 - Solvent Degreasing

Degrease by the use of solvents applied by brushing, wiping, immersion or vapour degreasing.

Note : The choice of solvent will depend on the method of degreasing chosen and COSHH considerations but it should be noted that many chlorinated and fluorinated solvents are covered by the Montreal Protocol (see section 1.3.23).

DEF-STAN 03-2, Methods A1 to A6 provide further detail.

Method 2 - Aqueous Degreasing

Degrease by the use of aqueous commercial products by dipping or spraying followed by a clean water rinse.

DEF-STAN 03-2, Methods B1 to B3 provide further detail.

Method 3 - High Pressure Fresh Water Treatment

Spray wash with clean fresh water at high pressure, some abrasion may be necessary.

Method 4 - Nitric Acid/Sodium Dichromate

For cleaning and passivation of low alloy steels immerse in:

	pbw
Nitric acid (SG 1.4)	200
Sodium dichromate (Na ₂ Cr ₂ O ₇ .2H ₂ O)	25
Cold water wash	
Ferritic and Martensitic steels require immersion in a solution of:	
sodium dichromate	50g/l
DEF-STAN 03-2 Process M provides further detail.	

Method 5 - Steam Clean**Method 6 - Light Mechanical Abrasion**

Sandpaper or Scotchbrite or other non-metallic abrasives to remove surface oxide or corrosion spots followed by clean water washing. Silicon carbide abrasives are not recommended for use on aluminium and aluminium alloys.

DEF-STAN 03-2 Method D3 provides further detail.

Method 7 - Wire Brush (Hand Tool Cleaning)

Only effective on loose millscale but leaves a layer of tightly adherent rust on the surface. SSPC-SP2 provides further detail.

Method 8 - Power Tool Cleaning

Generally more effective than method 7, may be carried out by power wire brush, disc grinders and sanders and needle guns.

SSPC-SP3 provides further detail.

Method 9 - Sweep Blasting (Fine Abrasive Blasting)

Sweep blast with non-metallic abrasive such as aluminium or glass beads to Swedish Standard SIS-05-5900 Sa.2 for steel surfaces.

DEF-STAN 03-2 Method D2 provides further detail.

Method 10 - Coarse Abrasive Blasting

Wet or dry blasting with chilled iron grit, alumina or other coarse abrasive comparable with Grade G17 of BS 7079 or larger to achieve Swedish Standard SIS-05-5900, Sa.2½ .

Note: Only alumina should be used on aluminium or aluminium alloys. The process is unsuitable for thin sheet or where a fine surface finish is required. Swedish Standard SIS-05-5900 is not suitable for non-ferrous metal surface evaluation.

DEF-STAN 03-2, Method D1 and DEF STAN 03-3 and BS EN 22063 provide further details.

Method 11 - For Chromate Coating and Anodising of Aluminium

- Solvent degrease
- Non-silicate aqueous alkaline clean
- Water rinse
- Aqueous alkaline dip
- Water rinse
- Nitric acid desmutt
- Water wash

DEF-STAN 03-2 Process O and P provide further detail.

Method 12 - For Plating Aluminium

- Solvent degrease
- Water rinse
- Non-silicated aqueous clean
- Water rinse
- Nitric acid desmutt
- Water rinse
- Zincate treatment
- Water rinse

Method 13 - T-Wash for Zinc Surfaces

	% by mass
Phosphoric acid	9.0
Ethyl cellosolve	16.5
Methylated spirits	16.5
Water	57.0
Copper Carbonate	1.0

Any zinc salt formed as a result of moisture attack must be removed using stiff bristle brushes before subsequent painting.

Method 14 - Pickling (For Carbon Steel)

Immersion processes using hydrochloric, sulphuric or phosphoric acid, either cold or at elevated temperature, are essentially factory processes. An example of a proprietary process is the Footner Duplex.

DEF-STAN 03-2 and SSPC-SP8 provide further details. Water washing to remove acid traces is essential.

Method 15 - Pickling (For Stainless Steel)

Immersion in nitric acid or nitric/hydrofluoric acid mixture. Water washing to remove acid traces is essential.

Method 16 - Proprietary Chemical Treatments

These include Bonderite, Parker, Granodine, Walterising and many others. Used to clean and to provide a modified surface layer. The manufacturer must be consulted.

Note: Iron must be free from copper additions.

Method 17 - Phosphating for Iron and Steel

To DEF-STAN 03-11

Method 18

Prepare to BS 8110 –1

Method 19 - Sealing for Wood

Lightly abrade and coat all knots and areas of exudation with Shellac Knotting after wiping with acetone.

3 FINISHING SYSTEMS FOR ALUMINIUM AND ALUMINIUM ALLOYS

3.1 General

Commercially pure aluminium and aluminium alloys with a low alloying content are relatively corrosion resistant except under saline and alkaline conditions, but show surface roughening and local pitting with associated dirt retention on long exposure to exterior weathering. All alloys show improved mechanical properties but are less corrosion resistant than pure aluminium, particularly when the alloying elements are copper and zinc. Where these are present it is almost invariably better to chemically or anodically oxidise the surface if it is to be exposed to highly corrosive environments and even here it is usually found necessary to apply organic coatings over these treatments, using them as a surface preparation.

Some form of surface finish is essential if good decorative properties and ease of decontamination are to be maintained or high pH decontaminants are to be used. Aluminium and aluminium alloys are generally regarded as ‘difficult’ metals to paint and adhesion failures are common if the surface preparation is inadequate and the correct inhibitive primer is not used. It is essential that an etch wash primer is applied as the first coat in the system if the surface has not been chromated. The choice of protective systems is wide and the final choice will depend on such factors as the design of the structure, the service environment, the expected life and cost.

The possible options for the treatment and protection of aluminium include surface coatings, conversion coatings, anodic coatings and a variety of plated coatings. The latter option is not considered to be necessary or desirable for most applications.

3.2 Organic Systems

A large number of organic paint systems will provide excellent protection to aluminium particularly if they are applied over chromate conversion coatings or anodic films although this type of surface pretreatment/preparation is not essential for other than the most extreme exposures or when a powder coating is to be used. If the surface is not to be chemically modified before coating, then the use of an etch (wash) primer together with an inhibitive primer containing zinc phosphate is highly desirable. It should be noted that the use of chromate pigments and the paints containing them are coming under increasing pressure on health grounds.

3.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation – Section 2 Methods 1,2,3,6,9			
Finishing System O-1			dft
Pretreatment	Etch (Wash) Primer		10 microns
Primer	Two Pack Zinc Phosphate Epoxy Primer		70-75 microns
Finish	Two Pack Solvent-free Epoxy		100-125 microns
Total dft			180-210 microns

This system will provide maximum corrosion resistance against environmental conditions including exposure to marine, industrial atmospheres and immersion at a range of pHs. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product with a BS 4247 Certificate showing a DF of 1000+. The system will have excellent mechanical properties including scratch and abrasion resistance but this will be achieved at the expense of decorative properties. On exterior exposure the system will show chalking and loss of gloss and in this characteristic it is inferior to the aliphatic isocyanate cured polyurethane top coat recommended in System O-3. Maintenance will be moderate to difficult and depend to a marked extent on the degree of surface preparation carried out to achieve good intercoat adhesion.

This system is moderately expensive but note that high film build will be achieved with low volumes/weights of finish.

3.2.2 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 1,2,3,6,9			
Finishing System O-2			dft
Pretreatment	Etch (Wash) Primer		10 microns
Primer	Zinc Phosphate Two Pack Amine Adduct Cured Modified Phenolic Epoxy		45-55 microns
Finish	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Topcoat		90-110 microns
		Total dft	145-175 microns

This system will provide maximum chemical resistance to a wide range of organic and inorganic acids, alkalis and organic solvents and will be resistant to most decontaminants except high concentrations of oxidising acids, e.g. nitric acid. The decorative properties of this system will be poor to moderate as it will show pronounced chalking and loss of gloss on exterior exposure and in this respect is inferior to an aliphatic isocyanate cured polyurethane topcoat recommended in O-3. The system will have good mechanical properties including scratch and abrasion resistance but is unlikely to have more than a Fair rating in the BS 4247 - 1 Method A test. DFs are likely to be in the 150-300 range. It will provide good general corrosion protection against a range of environments including marine, industrial and intermittent immersion. The components of the finishing system are moderately expensive and therefore, the total applied price of System O-2 may be greater than System O-1 as the lower solids content of the finish may demand the application of more than one coat. COSHH requirements are likely to be more exacting than for System O-1 but less so than System O-3.

3.2.3 For Maximum Corrosion Resistance, Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 1,2,3,6,9			
Finishing System O-3			dft
Pretreatment	Etch (Wash) Primer		10 microns
Primer	Two Pack Zinc Phosphate Epoxy		45-55 microns
Undercoat	Two Pack Epoxy		45-55 microns
Finish	Two Pack Aliphatic Isocyanate cured Polyurethane Topcoat		45-55 microns
		Total dft	145-175 microns

This system will provide excellent corrosion resistance against most environmental conditions including marine, industrial and immersion, it will only be marginally inferior to System O-2. The decorative properties of the system are outstanding and little or no chalking or loss of gloss will occur on exterior exposure over very long periods. An ease of decontamination rating of Excellent, DF 1000+, can be readily achieved by selection of the appropriate manufacturer. The mechanical properties, particularly abrasion resistance, are excellent. Maintenance will be moderate to difficult and depend on the degree of surface preparation carried out to achieve good intercoat adhesion. The system is expensive to apply and COSHH regulations will be onerous as isocyanates are known respiratory sensitisers. For spray application an air fed mask is mandatory.

3.2.4 General Purpose System(s) with Good Corrosion, Chemical Resistance and Ease of Decontamination

Surface Preparation - Section 2 Method 1,6,9			
Finishing System O-4			dft
Pretreatment	Etch (Wash) Primer		10 microns
Primer	Zinc Phosphate Alkyd Primer		25-35 microns
Undercoat	Alkyd		25-35 microns
Finish	Alkyd		25-35 microns
		Total dft	85-115 microns

This system is an alkyd based system that can be used as a general purpose system to provide moderate corrosion protection in many environments but not continuous immersion. The mechanical properties of this system are only moderate and the scratch and abrasion resistance is inferior to that of the other recommended systems. Maintenance will be relatively easy with no essential surface preparation for good intercoat adhesion.

3.2.5 For All-round Excellence

Surface Preparation - Section 2 Method 11	
Finishing System O-5	
Proprietary Powder Coating	
As recommended by the supplier	

This system uses a proprietary powder coating used in conjunction with chromium phosphate/chromium chromate conversion coatings to DEF-STAN 03-18 and represents the ultimate in terms of corrosion protection and chemical resistance and has excellent mechanical properties including scratch, impact and abrasion resistance. The decorative properties are excellent. As this system is factory applied and cured at high temperature it has limited application on containers as distortion of thin fabricated sections is likely to occur. The expense of this system indicates that it should only be used where ambient conditions are particularly hostile. Maintenance will be difficult as the system can only be repaired using coatings other than powder coatings.

3.3 Inorganic Systems

A relatively small number of inorganic processes are available for the protection of aluminium and aluminium alloys. In general they are not as versatile as the organic systems shown in Section 3.2 and find their main use as decorative coatings on architectural wrought aluminium components, as a paint base to improve corrosion resistance and adhesion, or for specific specialist applications. Chromium chromate conversion coatings for example are electrically conducting. All the systems are either factory applied or where they can be applied in situ are best applied under factory conditions. The quality and properties, particularly the corrosion resistance of inorganic finishes are particularly dependent on the composition of the aluminium alloy to which they are applied. Alloys containing large amounts of copper and silicon are especially difficult to protect, particularly with conversion coatings. It is unlikely that any of the inorganic finishes will have a high ease of decontamination although there is no actual test data available, for this reason the following systems are not recommended if ease of decontamination is a requirement.

3.3.1 For Maximum Corrosion Resistance, Mechanical Properties and Decoration for Non-Fabricated Parts

Surface Preparation - Section 2 Method 11
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Finishing System I-1

Sulphuric acid anodising to DEF-STAN 03-25 will provide excellent exterior and interior corrosion resistance for marine and industrial environments together with excellent abrasion and scratch resistance. It has good decorative properties when dyed as part of the sealing process. For maximum corrosion protection high film thicknesses are required. The chemical resistance of this treatment will be good to organic solvents and aqueous chemicals at neutral pH and moderately so in the range 4.0 to 8.5, but poor outside these limits. The performance on high copper and silicon alloys will be inferior to that on aluminium and low impurity alloys.

Because this treatment is a factory applied process it is **not** suitable for use on prefabricated structures where trapping of residual electrolyte can occur and cause corrosion. Maintenance will be limited to regular washing and repair to touch up with either a chromium chromate conversion coating to DEF-STAN 03-18 or organic finishing systems.

3.3.2 For Maximum Corrosion Resistance and Mechanical Properties for Fabricated Parts

Surface Preparation - Section 2 Method 11
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Finishing System I-2

Chromic acid anodising to DEF-STAN 03-24 will provide excellent interior and exterior corrosion resistance for marine and industrial environments although it is considerably less abrasion resistant than sulphuric anodising to DEF-STAN 03-25. It has poor decorative properties, producing an opaque or semi-opaque finish with a pronounced yellow colour which cannot be readily dyed. Sealing is essential for maximum corrosion resistance. The thickness of the anodic film will be dependent on the alloy being processed. The chemical resistance of System I-2 will be similar to that of System I-1 at neutral pH and moderately so in the range 4.0 to 8.5 but poor outside these limits. The performance on high copper and silicon alloys will be superior to that of System I-1.

The system is a factory applied process and is suitable for use on fabricated structures/parts as the process electrolyte is non-corrosive towards the base alloy. It should be noted that chromium salts are facing increasing pressure from the COSHH regulations. Maintenance will consist of regular washing and repair with System I-4 or organic finishing systems.

3.3.3 For Good Corrosion Resistance and Decorative Properties

Surface Preparation - Section 2 Method 11
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Finishing System I-3

Thinner chromium phosphate, (green chromate) conversion coatings to DEF-STAN 03-18 at 0.1-1.0 g/m², provide an excellent base for organic coatings particularly powder coatings, enhancing both the adhesion and the corrosion resistance of the duplex system. For bare corrosion resistance coating weights up to 5.0 g/m² are required. The coating varies in colour from light iridescent green to emerald green depending on coating weight and the base alloy. The coating provides good corrosion resistance against exterior, marine and industrial atmospheres and has good chemical resistance particularly to aqueous materials and strong acids. It is not suitable for use under immersion conditions. The corrosion resistance and chemical resistance is highly dependent on alloy compositions and high copper alloys are more difficult to protect with this system. Its mechanical properties are only moderate and it is relatively easily scratched.

The system is a factory applied process. It is extremely unlikely to have good ease of decontamination. Maintenance will consist of regular washing and repair with System I-4

3.3.4 For Good Corrosion Resistance

Surface Preparation - Section 2 Method 11
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Finishing System I-4

Unlike System I-3, this system of chromium chromate (yellow chromate) conversion coating to DEF-STAN 03 -18 can be applied in the field as well as being a factory applied process. The system provides an excellent base for subsequent organic coating systems, particularly powder coatings. Thin coatings, up to 1.0 g/m² are suitable for paint coating and thicker films up to 2.0 g/m² are required for bare film resistance. The colour of the coating varies from almost colourless at a coating weight of 0.25 g/m² to yellow at 1.0 g/m² and brown above this figure. The chemical resistance is similar to that of System I-3 and the bare corrosion resistance slightly superior depending on the base alloy. It is not suitable for use under immersion conditions.

The system has only moderate mechanical properties and is easily scratched and abraded. The major advantage of this system over System I-3 is that although it is desirable to carry out the process under factory immersion conditions, it is not absolutely essential although only lower coating weights will be achieved. It is unlikely to have good ease of decontamination. Maintenance will consist of regular washing and repair with the same system.

3.3.4 For Improved Resistance to Alkalis

Surface Preparation - Section 2 Method 12
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Finishing System I-6

Brass plating is carried out primarily to improve the decorative properties of aluminium, the resistance to mechanical damage and resistance to alkalis. In practice good adherent plated films are difficult to achieve due to the firmly adherent quick-forming oxide on the metal, the presence of intermetallics (in alloys), gassing due to occluded gases and the difference in the coefficients of thermal expansion of the base metal and the plated film. This is a proprietary factory process with uncertain results and in view of the attendant difficulties attention should be paid to changing the substrate rather than utilising the system. Maintenance is likely to be difficult.

4 FINISHING SYSTEMS FOR BRASS(ES)

4.1 General

Brass or brasses are essentially alloys of copper and zinc, containing between 10 and 45% zinc, but many other metals may be present including tin, aluminium, iron, lead and manganese. They thus represent a class of copper alloys but as they may present characteristic corrosion problems in certain environments they have been addressed separately (See Section 8 for Copper). Brasses have a high degree of resistance to atmospheric corrosion, salt and fresh water, and most inorganic acids and alkalis at moderate concentrations. However, under some conditions of service, particularly immersion conditions in high chloride content water at high temperatures, the phenomena known as de-zincification can occur. When de-zincification occurs some or all of the zinc is removed to leave a porous low strength copper mass. This is unlikely to occur except under the extreme conditions cited and only then with high zinc content brasses.

It is generally unnecessary to protect brass except to prevent tarnishing, and varnishing or lacquering may be sufficient. It is advisable to select a varnish which does not contain vegetable oil residues as long-term adhesion may be a problem due to reaction with the substrate. Proprietary varnishes may contain corrosion inhibitors.

4.2 Organic Systems

There are many types of organic coatings which could be used on brass if a coating were to be required or thought desirable but as previously stated there are strictly limited requirements for protection.

4.2.1 For General Decorative Use to Avoid Tarnishing

Surface Preparation – Section 2 Methods 1,2, 6		
Finishing System O-6		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		30-50 microns
Note:	It may be necessary to apply a further thin coat to avoid pinholes or holidays	

This lacquer will provide an excellent long term decorative effect under all interior conditions, be readily decontaminable and highly abrasion resistant. For exterior use it will require regular maintenance consisting of either re-coating if undamaged, or local abrasion to remove damaged areas and recoating.

4.2.2 For Maximum Corrosion Resistance to High Chloride Solutions

Surface Preparation – Section 2 Methods 1,2,6		
Finishing System O-7		dft
Primer	Zinc Phosphate Two Pack Amine Adduct Cured Modified Phenolic Epoxy	40-50 microns
Finish	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Topcoat	90-110 microns
		Total dft
		130-160 microns

This system will provide maximum corrosion protection against de-zincification in high chloride solutions at temperatures up to 50°C and will also provide excellent general protection and excellent mechanical properties but only moderate ease of decontamination. Maintenance will be moderately difficult depending on the surface preparation required.

4.3 Inorganic Systems

There are no recommended inorganic protective systems.

5 FINISHING SYSTEMS FOR CARBON STEEL

5.1 General

Mild steel is a relatively cheap and mechanically strong substrate readily fabricated by a wide variety of methods but some form of surface finish is absolutely essential if corrosion in even the mildest environments is to be avoided. General corrosion will occur in rural environments and pronounced pitting leading to rapid perforation will occur in industrial and marine environments. This corrosion attack will lead to complete loss of decorative properties and the exposed surface will be impossible to decontaminate by anything less than a method capable of removing metal. Fortunately low carbon steel can be protected against the most aggressive atmosphere by a wide variety of protective systems provided that the required degree of surface preparation appropriate to the protective finish is carried out. The performance of any coating and particularly that of organic coatings is completely dependent on correct and thorough surface preparation prior to coating. Failure to prepare the surface will result in premature failure no matter what coating system is applied. In general the more sophisticated the system the more important the surface preparation.

The choice of protective systems is wide and the final choice will depend mainly on the service environment together with the need for decorative properties, the expected life and cost. Many paint systems are designed for application to structural steel where decorative appearance is not important and these systems containing micaceous iron oxide are based on epoxy or polyurethane resins and are available in only a limited range of colours. Where long term decorative properties are a prerequisite such systems although providing excellent protection, should be avoided.

The possible options for the treatment and protection of mild steel include organic surface coatings, metal spray, hot dip galvanizing, phosphating and a variety of plated coatings. In some cases a duplex system, of, for example, galvanizing and organic coating may be required or thought desirable. An inorganic coating selected for maximum corrosion resistance may have to be coated with a paint system to improve the decorative properties and/or ease of decontamination.

5.2 Organic Systems

A very large number of organic paint systems will provide excellent protection to mild steel provided the necessary care is taken with the surface preparation, a suitable inhibitive primer is used, and a sufficiently high dft of paint is applied. If a full protective organic paint system is applied over an inorganic treatment, i.e. hot-dip galvanizing or metal spray, then a long protective life under almost all service conditions is assured. The degree of surface preparation required will be dependent on the form of the mild steel, cold rolled thin section plate will be easier to prepare than hot rolled plate covered, or partially covered, with mill scale, but badly pitted steel requires extra attention. Blast cleaning to Sa.2½ is generally the best option although pickling may be recommended for pitted surfaces.

Zinc coated surfaces should not be placed in contact with, or stored in sealed containers constructed from acidic woods such as sweet chestnut, red cedar, douglas fir or oak.

5.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation - Section 2 Methods 10,16,17			
Finishing System O-8			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		200-250 microns
		Total dft	245-300 microns

This system will provide maximum corrosion resistance against most environmental conditions including exposure to marine, industrial and immersion conditions and will afford some measure of protection at points of mechanical damage where the base metal is exposed. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has very good mechanical properties including scratch and abrasion resistance and the zinc rich primer will minimise corrosion undercutting at points of damage. This protection will be achieved at the expense of decorative properties as on exterior exposure the finish will show chalking and loss of gloss. In this respect it is inferior to the aliphatic isocyanate cured polyurethane topcoat recommended in System O -10. Maintenance will be moderate to difficult and the original zinc rich primer will be unsuitable for use in general maintenance. Successful maintenance will depend on the degree of surface preparation carried out to remove all corrosion products and to improve intercoat adhesion.

This system is expensive but note that high film build will be achieved with low volume/weights of finish as the coating is 100% solids.

5.2.2 For Maximum Chemical Resistance

Surface Preparation - Section 2 Methods 1,2,5,6,7,8,10,16,17			
Finishing System O-9			dft
Primer	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Primer		90-100 microns
Undercoat	Two Pack High Build Amine Adduct Cured Modified Phenolic Epoxy Undercoat		90-100 microns
Finish	Two Pack High Build Amine Adduct Cured Epoxy Topcoat		90-100 microns
			Total dft
			270-300 microns

This system will provide maximum resistance to a wide range of chemicals, acids, alkalis, solvents, fatty acids and most decontaminants except high concentrations of strong oxidising acids, e.g. nitric acid, and is suitable for use under immersion conditions. The decorative properties of this system are only moderately good and it will show yellowing on interior exposure and pronounced loss of gloss and chalking on exterior exposure. The ease of decontamination will be poor to good depending on the product chosen but the mechanical properties will be excellent. Maintenance will be moderately easy.

5.2.3 For Maximum Corrosion Resistance, Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 10,16,17			
Finishing System O-10			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Undercoat	Two Pack High Build Epoxy Undercoat		125-130 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-40 microns
			Total dft
			205-220 microns

This system will provide outstanding corrosion and weathering resistance in most environments including marine, industrial and immersion conditions. The chemical and solvent resistance is excellent except to highly concentrated oxidising acids but in this respect it is marginally superior to many epoxy coatings. The decorative properties of this system are outstanding as it has a high initial gloss which is maintained on exterior exposure, the chalking rate is extremely low. The mechanical properties, particularly

abrasion resistance, are excellent. Maintenance will be moderate to difficult and care must be taken to achieve good intercoat adhesion.

The system is expensive and COSHH regulations will be onerous as isocyanates are known respiratory sensitizers. For spray application an air fed mask is mandatory.

5.2.4 General Purpose System with Good Corrosion, Chemical Resistance and Ease of Decontamination

Surface Preparation – Section 2 Methods 1,2,5,6,7,8,10,16,17			
Finishing System O-11			dft
Primer	Zinc Phosphate High Build Alkyd Primer		65-75 microns
Undercoat	Alkyd Undercoat		65-75 microns
Finish	High Build Alkyd Topcoat		65-75 microns
		Total dft	195-225 microns

The recommended dft should not be exceeded or the cure of the system will be impaired.

This system will give long lasting protection to mild steel under most conditions of service but is not recommended for continuous immersion in water or aqueous chemicals. The chemical resistance is only moderate and it will be attacked by acids, alkalis and many strong solvents.

The initial decorative properties are good but it will show chalking and loss of gloss on exterior exposure and its mechanical properties are only moderate as it will be relatively easily scratched. Maintenance will be easy and the system can be overcoated with most conventional paints, but not two pack systems or those containing strong solvents.

5.2.5 For All-round Excellence

Finishing System O-5
Proprietary Powder Coating
As recommended by the supplier

This system in combination with conversion coatings to DEF-STAN 03-18 used as a surface pretreatment represents the ultimate in terms of corrosion protection and chemical resistance, has excellent mechanical properties including scratch, impact and abrasion resistance. The decorative properties are excellent. It should be noted that this system is factory applied. It has limited application on thin gauge fabricated containers as distortion may occur. The expense of this system coupled with the factory application indicates that it should only be applied where ambient conditions are particularly hostile and a long service life is required. Maintenance will be difficult as the system can only be repaired using coatings other than powder coatings.

5.3 Inorganic Systems

A relatively small number of inorganic processes are available for the protection of mild steel and which can be regarded as 'stand alone' protective systems, i.e. without application of an organic coating system; these include hot dip galvanizing, thick hot dip galvanizing, and zinc spray. In general they are not as versatile as the organic systems which find their main use on structural steel for exterior exposure under adverse conditions.

None of the inorganic coatings will have good ease of decontamination and must be overcoated with an appropriate organic system if this property is required. It should be noted that the general comments in Section 10 on the corrosion resistance of zinc should be consulted.

5.3.1 For Maximum Exterior Corrosion Resistance

Steelwork to be hot dipped galvanized to BS EN ISO 1461, (factory applied)

Finishing System I-8

This system will provide excellent corrosion for long periods, up to 30+ years, depending on the environment and the area of the country in which the galvanized surface is exposed. Corrosion rates of zinc in the United Kingdom vary between 10 g/m²/pa in rural areas to 34 g/m²/pa in a few industrial/coastal areas. The system has high mechanical strength and toughness and is resistant to abrasives.

5.3.2 For General Purpose Use Including Cold Water Immersion

Steelwork to be hot dipped galvanized to BS EN ISO 14713 - 2, (factory applied)

Finishing System I-9

This system will provide adequate protection for periods up to 20+ years, depending on the environment when used as a 'stand alone' protective system and for longer periods when used for interior protection. As most waters contain scale forming salts which coat the immersed zinc surface the life expectancy under immersion conditions can be as high as 40 years, greater if overcoated. The mechanical strength, toughness and abrasion resistance are very good.

5.3.3 For Use where Overcoating with an Organic System is Required

Continuous galvanizing to BS EN 10143 (factory applied) or sheradizing to BS 4921 (factory and in situ applied)

Finishing System I-10

Both systems provide an excellent base for subsequent organic coatings and are recommended in preference to Systems 5.3.1 and 5.3.2 as the adhesion characteristics of the substrate are considerably superior. The mechanical properties particularly abrasion resistance will depend on the choice of organic coating system.

5.3.4 For the Protection of Small Components Under Mild Corrosion Conditions

Zinc plating to DEF-STAN 03-20 (factory applied)

Finishing System I-5

This system is recommended for use on small components such as fasteners etc. which are to be used in relatively benign conditions. The corrosion resistance of plated coatings, due in part to the thinness of the deposit and the possibility of pin-holes, is considerably less than that of the other inorganic systems. The mechanical properties of the deposit are very good. All the inorganic systems quoted are less expensive to apply than the organic systems and are cheaper to maintain until they show breakdown when maintenance becomes expensive.

5.3.5 For Decoration and Appearance

Chromium Plating to BS EN 12540

Finishing System I-7

This system will provide an excellent decorative appearance for long periods under many interior and exterior conditions as chromium is almost inert in most atmospheres. The deposit will have good mechanical properties with excellent wear resistance. Maintenance, other than regular cleaning will be difficult.

6 FINISHING SYSTEMS FOR CAST IRON

6.1 General

The principal feature of cast iron which distinguishes it from steel is a carbon content in excess of 1.7%. Cast iron is a generic title given to a range of ferrous alloys that exist in many types, white, grey, nodular or ductile and malleable. Grey iron is usually the form referred to as 'cast' and is the most commonly used. In general the corrosion resistance of cast iron in rural, industrial and marine exterior environments is greater than that of low carbon steels, corrosion of cast iron is not usually considered to be a serious problem due to the heavy cross-sections used. However the corrosion rate of the cast iron, particularly in industrial atmospheres is too high to allow the use of thin sections without protection. Grey cast iron has a peculiar corrosion mechanism in that the alloying elements, mainly carbon in the form of graphite, phosphorous in the form of iron phosphide and silicon remain as a non-metallic graphitic corrosion product retaining the true shape and appearance of the original cast iron but with only negligible strength.

The chemical resistance of cast iron is poor and unalloyed white or grey cast iron has no useful resistance to dilute mineral acids, particularly to hydrochloric acid, and to a lesser extent dilute nitric acid. The resistance to strong solutions is considerably greater. Dilute alkali solutions do not corrode cast iron but dilute solutions of organic acids readily attack the metal.

The presence of corrosion products on the surface of cast iron suggests that unprotected surfaces will be difficult to decontaminate and will be far from decorative. Cast iron is not considered to be a difficult metal to protect and a wide variety of organic coating systems having an inhibitive primer as the first coat will afford excellent protection. In this respect the protection of cast irons can be considered identical to that of low carbon steels and the four main types can be considered to be the same for all practical purposes.

6.2 Organic Systems

All the coating systems recommended for Carbon Steel in Section 5, are suitable for use on cast iron and will perform at least as well on this substrate and probably better than on carbon steel. Powder Coatings are not considered to be necessary on cast iron.

6.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation – Section 2 Methods 10, ,16, 17			
Finishing System O-8			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		200-250 microns
		Total dft	245-300 microns

This system will provide maximum corrosion resistance against most environmental conditions including exposure to marine, industrial and immersion conditions and will afford some measure of protection at points of mechanical damage where the base metal is exposed. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has very good mechanical properties including scratch and abrasion resistance and the zinc rich primer will minimise corrosion undercutting at points of damage. This protection will be achieved at the expense of decorative properties as on exterior exposure the two pack solvent free epoxy top coat will show chalking and loss of gloss. In this respect it is inferior to a system culminating in a two pack aliphatic isocyanate cured polyurethane top coat in system O-10. Maintenance will be moderate to difficult and the original zinc rich primer is unsuitable for

use in general maintenance. Successful maintenance will depend on the degree of surface preparation carried out to remove all corrosion and to improve intercoat adhesion.

The system is expensive but note that high film build will be achieved with low volume/weights of finish as the coating is 100% solids.

6.2.2 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 1,2,3,5,7,8,10,16			
Finishing System O-9			dft
Primer	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Primer		90-100 microns
Undercoat	Two Pack High Build Amine Adduct Cured Modified Phenolic Epoxy Coating		90-100 microns
Finish	Two Pack High Build Amine Adduct Cured Epoxy Topcoat		90-100 microns
		Total dft	270-300 microns

This system will provide maximum resistance to a wide range of chemicals, acids, alkalis, solvents, fatty acids and most decontaminants except high concentrations of strong oxidising acids e.g. nitric acid and is suitable for use under immersion conditions. The decorative properties of this system are only moderately good and it will show yellowing on interior exposure. The ease of decontamination will be poor to good depending on the product chosen but the mechanical properties will be excellent. Maintenance will be moderately easy.

6.2.3 For Maximum Corrosion Resistance, Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 10,16, 17			
Finishing System O-10			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Undercoat	Two Pack High Build Epoxy Undercoat		125-130 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-40 microns
		Total dft	205-220 microns

This system will provide outstanding corrosion and weathering resistance to most environments including marine, industrial and immersion conditions. The chemical and solvent resistance is excellent except to highly concentrated oxidising acids but in this respect it is marginally superior to many epoxy coatings. The decorative properties of this system are outstanding as it has a high initial gloss which is maintained on exterior exposure, the chalking rate is extremely low. The mechanical properties, particularly abrasion resistance are excellent. Maintenance will be moderate to difficult and care must be taken to achieve good intercoat adhesion.

The system is expensive and COSHH regulations will be onerous as isocyanates are known respiratory sensitisers. For spray application an air fed mask is mandatory.

6.2.4 General Purpose Systems with Good Corrosion and Chemical Resistance and Ease of Decontamination

Surface Preparation - Section 2 Methods 1,2,3,5,7,8,10,16			
Finishing System O-11			dft
Primer	Zinc Phosphate High Build Alkyd Primer		65-75 microns
Undercoat	Alkyd Undercoat		65-75 microns
Finish	High Build Alkyd Topcoat		65-75 microns
		Total dft	195-225 microns

The recommended dft should not be exceeded or the cure of the system will be impaired.

This system will give long lasting protection under most conditions of service but is not recommended for continuous immersion in water. The chemical resistance is only moderate and it will be attacked by acids, alkalis and many strong solvents.

The initial decorative properties are good but it will show chalking and loss of gloss on exterior exposure and its mechanical properties are only moderate as it can be easily scratched. Maintenance will be easy and the system can be overcoated with most conventional paints but not two pack systems or those containing strong solvents.

6.3 Inorganic Systems

Although inorganic protective systems would be suitable for the protection of cast iron, the thick sections used and the generally good corrosion resistance render the use of heavy duty inorganic systems unnecessary or inappropriate.

7 FINISHING SYSTEMS FOR CONCRETE

7.1 General

It is generally not required to coat concrete for most interior or external exposures except to improve the decorative properties, unless it is used under immersion conditions or where penetration of a permeant is undesirable. If, however, the concrete is in the form of reinforced concrete in which steel rebars are present, painting is highly desirable in all environments and considered essential in some.

The major threat to the long term behaviour of reinforced concrete on exterior exposure is primarily due to carbonation of the concrete in which carbon dioxide penetrates into the alkaline concrete reducing the pH from 12.5-13 to ~8 by the formation of calcium carbonate. In this low alkaline environment the reinforcing bars are not protected; corrosion occurs with a build up of corrosion product leading to expansion and exfoliation with flaking of the concrete. The rate at which this occurs is dependent on the porosity of the concrete, the concrete layer over the steel and the environmental conditions. Coatings having a low permeability to carbon dioxide are required to prevent carbonation and specialist advice is necessary in selecting appropriate systems.

Where concrete is used under immersion conditions and either the leachants from the concrete will contaminate the liquid, or the liquid will penetrate the concrete, some form of organic coating is essential. This is particularly the case where radioactive contamination and the need to decontaminate are concerned. There are a wide choice of organic coatings suitable for use on concrete, the selection of coating is dependent on whether it is required for immersion, as an anticarbonation coating or for ease of decontamination.

Concrete is not a particularly difficult substrate to paint, but it is essential to remove alkaline low cohesive strength surface laitence together with surface dust and other contaminants prior to painting. This is best done by open or vacuum blasting which also exposes blow holes and other sub-surface defects that are not always apparent on visual inspection.

Where site regulations or safety requirements do not permit abrasive blasting the surface laitence may be removed by rotary grinding or scabbling although it should be noted that the latter method may result in a very rough finish.

It is important to realise that concrete presents a rough surface and the dry film thickness of an applied coating will be considerably lower over the asperities than over the general area. Application of an adequate dry film thickness over the entire area is essential where liquid contaminants/permeants are present and ease of decontamination is important. Blow holes on surfaces which have been blasted must be filled and made smooth before coating systems are applied using either a water based epoxy surfacer for fine defects or a solvent free epoxy filler for larger defects.

Where maximum ease of decontamination is required the concrete should preferably be prepared to the dictates of BS 8110 –1.

7.2 Organic Systems

7.2.1 For Maximum Ease of Decontamination under Non-immersion Conditions

Surface Preparation – Section 2 Method 18.			
Finishing System O-12			dft
Primer	Two Pack Water Based Epoxy Primer		25-30 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		100-125 microns
Total dft:			125-155 microns

For minimum radon permeability a second coat of finish will be required.

This system will provide a heavy duty, decorative system having excellent ease of decontamination providing that a product having a BS 4247 Certificate is chosen. The

system will have excellent mechanical properties including scratch and abrasion resistance but may show some yellowing or discolouration on long term exposure to artificial light. It will withstand routine cleaning and decontamination with all normal detergents and decontaminants other than moderate to strong acids. Applied in sufficient dry film thickness it will provide a good radon barrier in monolithic concrete structures. Maintenance will be moderate to difficult and depend to a marked extent on the degree of surface preparation carried out to achieve good intercoat adhesion.

7.2.2 For Maximum Ease of Decontamination under Immersion Conditions

Surface Preparation – Section 2 Method 18			
Finishing System O-13			dft
Primer	Two Pack Solvent Based Epoxy Primer		25-30 microns
Undercoat	Two Pack Solvent Free Epoxy Undercoat		100-125 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		100-125 microns
		Total dft	225-280 microns

This system will provide a heavy duty coating with excellent ease of decontamination and long term water resistance under immersion conditions at pHs in the 5-8 range. A BS 4247 Certificate with a DF of 1000+ is required. It has excellent mechanical properties and is highly abrasion resistant. The very best surface preparation is required if a long immersed life is to be obtained. Maintenance will be difficult and expensive. Note that for cooling pond use it is essential to pay attention to previous experience in this specialised field as failures in application or service have not been uncommon.

7.2.3 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 8,9,10			
Finishing System O-14			dft
Primer	Two Pack Solvent Based Epoxy Primer		25-30 microns
Undercoat	Two Pack Amine Adduct Cured Modified Phenolic Epoxy		45-55 microns
Finish	Two pack Amine Adduct Cured Modified Phenolic Epoxy Topcoat		90-110 microns
		Total dft	160-195 microns

This system will provide maximum chemical resistance to a wide range of organic and inorganic acids, alkalis and organic solvents and will be resistant to most decontaminant solutions except high concentrations of oxidising acids e.g. nitric acid. The decorative properties of this system will be poor to moderate as it will show yellowing and discolouration on exposure to artificial light. The system will have good mechanical properties including scratch and abrasion resistance but is unlikely to have more than a good rating in the BS 4247 -1 Method A test. It will provide a good general finish. Maintenance will be moderate to easy and the system is moderately expensive to apply.

7.2.4 For Carbonation Protection - Exterior Use

Surface Preparation - Section 2 Methods 6,7,8,9
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This is a particularly specialised requirement and the advice of a supplier specialising in concrete protection should be sought. Low carbon dioxide permeable coating systems based on a wide variety of binders having excellent decorative and mechanical properties are commercially available.

7.2.5 For General Purpose Decoration - Interior and Exterior Use**Surface Preparation** - Section 2 Methods 6,7,8,9

Almost any organic paint will be suitable for use on interior concrete providing that the alkaline laitence is removed and a suitable alkaline resistant primer is used. Suitable systems include water based emulsion paints, water based epoxy and acrylated rubber masonry paints. All will provide a smooth, semi-gloss to gloss finish with adequate mechanical properties, the appearance of which will be largely dependent on the general smoothness of the concrete and the freedom from cavities and blow holes.

The choice of a particular paint system will depend on such factors as colour, gloss level, ease of application and price and no special guidance other than the manufacturers instructions are required.

8 FINISHING SYSTEMS FOR COPPER AND COPPER ALLOYS

8.1 General

Copper and most copper alloys have excellent resistance to atmospheric corrosion due to the formation of protective layers of corrosion products, the composition of which depends on the exposure environment and the length of time. The typical green patina formed on copper after long periods of exposure consists initially of basic copper sulphate $CuSO_4.Cu(OH)_2$ which increases in basicity to become $CuSO_4.3Cu(OH)_2$. It is also resistant to sea and fresh water and most dilute mineral acids and relatively strong alkalis but is attacked by some organic acids e.g. acetic and the lower fatty acids. Bare copper in contact with steel in the presence of an electrolyte will cause accelerated pitting corrosion of the latter, particularly under oxygen free conditions.

Because of the generally excellent corrosion resistance of copper it is not usually necessary to protect it or its alloys unless copper staining is objectionable (copper salts are highly coloured) or maintenance of a high quality finish is required. Copper was formerly considered to be a difficult metal to paint as early coatings became embrittled and failed by cracking and flaking. This is no longer the case as different types of coatings have been developed.

8.2 Organic Systems

Because copper is normally regarded as being corrosion resistant in most environments there is no need to apply an inhibitive primer or provide protection in depth, and the finishing coat may be applied direct to the metal surface. It is usually sufficient to lacquer or varnish the metal unless a specific colour is required for decorative purposes or ease of decontamination is considered essential. No protective system is required for aqueous immersion conditions.

8.2.1 For Maximum Decoration and Ease of Decontamination

Surface Preparation – Section 2 Methods 1,2,6,9		
Finishing System O-15		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
	Total dft	35-50 microns

This system will provide maximum decorative properties over long periods of internal and external exposure and will be free from discolouration. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has excellent mechanical properties including scratch and abrasion resistance. Maintenance will be moderate to difficult and the COSHH regulations will be onerous as isocyanates are known respiratory sensitisers. For spray application an air fed mask is mandatory.

8.2.2 For General Anti-Tarnishing Resistance

Surface Preparation – Section 2 Methods 1,2,6,9.		
Finishing System O-6		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Note: It may be necessary to apply a further thin coat to avoid pinholes or holidays		

OR

Finishing System O-16		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Note : It may be necessary to apply a further coat depending on the porosity of the substrate. Measurement of the dft will be difficult, if not impossible. The manufacturers recommendations should be followed.	Total dft	70 –100 microns

Systems O-6 and O-16 will provide a high gloss finish with very good mechanical properties and adequate resistance to many chemicals.

9 FINISHING SYSTEMS FOR CORK

9.1 General

Cork is almost invariably used in the form of fabricated sheet incorporating a polymeric binder or as pressed sheet the physical properties of which are dependent on the grade used and the sheet thickness. It is not necessary to overcoat cork for most uses as materials treated for fire retardance, mould resistance, water permeation and decorative properties are readily available and the manufacturers advice should be sought on the appropriate grade for use in particular environments. Subsequent painting should not be necessary where this has been done.

If however the conditions of use or the environmental exposure are particularly severe or the surface is required to be decontaminable, to have increased resistance to permeation, be abrasion resistant or have its chemical resistance enhanced then overcoating will be required. Any coating used must be sufficiently flexible to withstand substrate deformation under load and this is best achieved by the use of a clear lacquer rather than a pigmented paint coating. This will both provide the necessary flexibility and abrasion resistance and leave the natural appearance of the cork unimpaired. Surface pretreatment other than dust removal is unnecessary as the natural permeability of the material will allow surface penetration of the coating.

9.2 Organic Systems

A large number of coatings are suitable for use on cork and will provide excellent mechanical protection and resistance to spills although water based systems should be avoided. It is advisable to apply a trial patch of the chosen system to check that the solvents in the coating do not attack any organic binder present in the cork composition. Pigmented coatings are not recommended.

9.2.1 Decontamination

Surface Preparation - No surface preparation required		
Finishing System O-16		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Note : It may be necessary to apply a further coat depending on the porosity of the substrate. Measurement of the dft will be difficult, if not impossible. The manufacturers' recommendations should be followed.	Total dft	70-100 microns

This system will provide excellent abrasion resistance and ease of decontamination but it should be noted that the maximum ease of decontamination will require the system to be applied in a sufficient number of coats to completely seal the surface. The chemical resistance of this system to all but strong oxidising acids and alkalis will be very good as will the solvent resistance. The ultra-violet radiation resistance of this system is excellent. Application should preferably be by brush to avoid droplet inhalation and COSHH regulations may be onerous as isocyanates are respiratory sensitisers.

9.2.2 For Excellent Chemical Resistance

Surface Preparation - No surface preparation required.		
Finishing System O-17		dft
Two Pack Polyamide Cured Epoxy Varnish		35-50 microns
Two Pack Polyamide Cured Epoxy Varnish		35-50 microns
Note: It may be necessary to apply a further coat depending on the porosity of the substrate. Measurement of the dft will be difficult, if not impossible. The manufacturers' recommendations should be followed.		Total dft 70-100 microns

This system will provide a coating having slightly better resistance to strong acids and alkalis but marginally lower abrasion resistance. Application of this system will be less hazardous than System O-16 as polyamide cured epoxies are not respiratory sensitisers and its use may be preferred for this reason.

9.2.3 For Use as a General Purpose Decorative System

Surface Preparation - No surface preparation required.		
Finishing System O-18		dft
Urethane Alkyd Varnish		35-50 microns
Urethane Alkyd Varnish		35-50 microns
Note:	It may be necessary to apply a further coat depending on the porosity of the substrate. Measurement of the dft will be difficult, if not impossible. The manufacturers' recommendations should be followed.	Total dft 70 –100 microns

This system will provide a coating with excellent decorative properties with good ease of decontamination, moderate chemical resistance, except to alkalis and strong solvents and adequate abrasion resistance. It presents no special hazards in application providing the manufacturers recommendations are adhered to and is considerably cheaper than Systems O-16 and O-17.

9.2.4 For Use as a Fire Retardant System

This is a difficult requirement and the advice of a company specialising in fire retardant coatings should be sought.

9.3 Inorganic Systems

There are no inorganic finishes for use on cork.

10 FINISHING SYSTEMS FOR GALVANIZED IRON AND ZINC

10.1 General

Zinc used for construction/fabrication purposes is invariably in the form of a relatively thin coating applied to a base metal, usually steel. This zinc coating may be applied by hot dip galvanizing, centrifugal galvanizing, electrogalvanizing, zinc spray, or zinc plating, the deposits varying in thickness from two to three microns for zinc plate to 130 microns for thick hot dip galvanizing. The life of the zinc coating will depend to a marked extent on the service environmental conditions but as a rule of thumb the thicker the coating the longer life under any given set of conditions.

Zinc coatings on steel have the major advantage that they offer cathodic (sacrificial) protection to the substrate, and thus protect at points of film discontinuity or mechanical damage and prevent undercutting from the initial point of damage. In highly acidic industrial areas and under saline conditions subject to industrial pollution the rate of zinc loss from a surface can be as high as 34g/m²/pa whilst in rural areas the loss could be as low as 10g/m²/pa. Zinc coatings used under immersion conditions can result in bimetallic corrosion in contact with other metals. Direct contact with very acidic woods such as oak and sweet chestnut should be avoided. Zinc coatings are capable of withstanding continuous exposure to temperatures up to 200°C with occasional excursions to 275°C. Inorganic zinc rich primers are capable of withstanding temperatures up to 400°C.

A protective zinc film will become progressively rougher, rust stained and discoloured and show a pronounced white zinc salt deposit although still functioning as an effective corrosion barrier. To avoid this, some form of surface finish is essential if good decorative properties are to be maintained and a longer protective life achieved. For many applications it is totally unnecessary to overcoat hot dip, thick hot dip or centrifugal galvanizing and zinc spray unless the environmental conditions are particularly hostile or a decorative or decontaminable finish is required. If ease of decontamination is required then overcoating with an organic finish is essential particularly if highly acidic decontaminants are to be used.

Zinc is a difficult metal to paint and therefore the choice of coating is particularly important if long term adhesion is to be maintained. Research has shown that the pre-treatment adopted is vital to achieving the above. Three pre-treatments are recommended, i.e. blasting with non-metallic abrasive, etch primer or using T wash. All proposed coatings for painting pre-treated galvanized steel must have been thoroughly tested on this substrate prior to adoption. It is unwise to rely on weathering or age to produce a zinc surface which will retain paint and appropriate surface pretreatment or priming system is important if the duplex system is not to show early failure. Organic coatings are considered to be the only option for the protection of zinc.

10.2 Organic Systems

A large number of organic paint systems will provide excellent protection to zinc coated surfaces which in themselves are excellent anti-corrosion systems for mild steel. A duplex system will provide a longer life than that of the lives of a zinc coating or an organic coating on their own i.e. the components are synergistic.

If the surface shows signs of breakdown then an appropriate primer should be applied.

10.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation - Section 2 Methods 1,2,3,9			
Finishing System O-28			dft
Primer	Etch (Wash) Primer		10 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		100-125 microns
		Total dft	110-135 microns

This system will provide maximum corrosion resistance against a wide range of environmental conditions including exposure to marine, industrial and immersion at a range of pHs. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a BS 4247 test certificate showing a DF of 1000+. The system will have excellent mechanical properties including scratch and abrasion resistance but this will be achieved at the expense of decorative properties. On exterior exposure this system will show chalking and loss of gloss and in this characteristic it is inferior to the aliphatic isocyanate cured polyurethane top coat recommended in System O-36.

10.2.2 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 1,2,3,9.			
Finishing System O-29			dft
Primer	Etch (Wash) Primer		10 microns
Finish	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Topcoat		90-110 microns
		Total dft	100-120 microns

This system will provide maximum chemical resistance to a wide range of organic and inorganic acids, alkalis, organic solvents and will be resistant to most decontaminants except high concentrations of oxidising acids e.g. nitric acid. The decorative properties of this system will be poor to moderate as it will show pronounced chalking, yellowing and loss of gloss on exterior exposure. The system will have good mechanical properties including scratch impact and abrasion resistance but is unlikely to have more than a Fair rating in the BS 4247 -1 Method A test. DFs are likely to be in the 150-300 range. It will provide good general corrosion resistance against a range of environmental conditions including marine, industrial and intermittent immersion.

10.2.3 For Maximum Corrosion Resistance, Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 1,2,3,9.			
Finishing System O-30			dft
Primer	Etch (Wash) Primer		10 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		45 -55 microns
		Total dft	55 -65 microns

This system will provide excellent corrosion resistance against most environmental conditions including marine, industrial and immersion. The decorative properties of the system are outstanding and little or no chalking, loss of gloss or discolouration will occur on exterior exposure over very long periods. An ease of decontamination rating of Excellent with a DF of 1000+ can readily be achieved by selection of the appropriate manufacturer. The mechanical properties, particularly abrasion resistance are excellent.

10.2.4 For Maximum Corrosion Resistance

Surface Preparation - Section 2 Methods 9,13			
Finishing System O-31			dft
Primer Finish	Two Pack Polyamide Cured Epoxy Primer Two Pack Micaceous Iron Oxide Polyamide Cured Epoxy Topcoat		45-55 microns 150-200 microns
		Total dft	195-255 microns

This system will provide maximum corrosion resistance at the expense of decorative appearance and ease of decontamination. The duplex system of galvanizing and organic coating should provide protection in excess of 15 years under most environmental conditions except continuous immersion.

10.3 Inorganic Systems

There are no inorganic systems recommended.

11 FINISHING SYSTEMS FOR LEAD AND LEAD ALLOYS

11.1 General

Because lead forms a series of relatively insoluble lead compounds which, providing they are retained at the lead surface, restrict or prevent further reaction in corrosive environments, it has good overall corrosion resistance. It is not normally used in the pure form but in a series of alloys containing either small amounts (below 0.25%) of copper, tin, antimony and bismuth or larger amounts (up to 6 to 12%) of antimony and lesser amounts of tin. The important point here is that although the working properties of the alloys are superior to those of pure lead, the corrosion resistance decreases with increasing alloying metal content.

The presence of a protective surface film, the composition of which depends on the specific environment, gives lead excellent corrosion resistance to atmospheric corrosion even in the presence of SO₂, SO₃ and H₂S. This protective film also renders the lead electrically non-conducting and considerably reduces the chance of galvanic corrosion. Lead has excellent resistance to sea water but has a slight but significant solubility in pure water. Its chemical resistance ranges from excellent to poor depending on the chemical in contact. Its resistance to sulphuric and phosphoric acids is excellent but it is readily attacked by nitric and hydrochloric acids. It has high resistance to alkalis but is less resistant to chloride and nitrate solutions.

The resistance of lead to certain organic acids, notably acetic, formic, propionic, and lactic acids, is poor and attack is rapid. Due to this poor organic acid resistance lead has often been regarded as being a difficult metal to paint as adhesion failures have been common. Rapid failure occurs due to the reaction of the fatty acid decomposition products reacting with the lead to form brittle and water soluble compounds at the metal/paint interface even in the presence of the protective surface layer which has to be removed to ensure good adhesion of paints free from fatty acid decomposition products. It is not general practice to protect lead except where some measure of decoration is required or contact with organic acid vapours is likely. Storage of lead components in contact with acidic woods, or in sealed containers where acidic vapours are present from either wood or air drying paint systems will result in rapid corrosion. Lead and its alloys are unlikely to be readily decontaminated without recourse to hostile reagents unless painted.

11.2 Organic Systems

A variety of organic paint systems can be used on lead but the use of air drying paints containing vegetable oil residues is not recommended. Because lead and lead alloys are normally regarded as corrosion resistant in all but the most hostile environments it is not usual to paint them unless for ease of decontamination or for decorative purposes as part of a mixed metal construction. There is no need for the use of inhibitive primers or protection in depth.

11.2.1 For Maximum Decoration and Ease of Decontamination Section

Surface Preparation - Section 2 Methods 1,2,3,6.		
Finishing System O-15		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-50 microns
	Total dft	35-50 microns

This system will provide maximum decorative properties over long periods of internal and external exposure and will be free from discolouration. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has excellent mechanical properties including scratch and

abrasion resistance. Maintenance will be moderate to difficult and the COSHH regulations will be onerous as isocyanates are known respiratory sensitisers.

11.2.2 For Maximum Chemical Resistance

Surface Preparation - Section 2 Methods 1,2,3,6.		
Finishing System O-19		dft
Two Pack Amine Adduct Cured Modified Phenolic Epoxy Topcoat		45-55 microns
	Total dft	45-55 microns

This system will provide maximum chemical resistance to a wide range of organic and inorganic acids, alkalis and will be resistant to most decontaminants except high concentrations of oxidising acids e.g. nitric. The decorative properties of this system will be poor to moderate as it will show pronounced chalking and loss of gloss on exterior exposure. In this respect it is inferior to System O-15. The system will have good mechanical properties including scratch and abrasion resistance but is unlikely to have more than a Fair rating in the BS 4247 - 1 Method A test. Maintenance will be moderate to easy. It will be moderately expensive to apply.

11.3 Inorganic Systems

There are no inorganic finishes for lead and lead alloys.

12 FINISHING SYSTEMS FOR LOW-ALLOY STEELS

12.1 General

Low-alloy steels known also as low-corrosion steels are low or medium carbon steels to which low concentrations (below 5% in total) of chromium, copper, silicon, aluminium, manganese or phosphorous have been added to improve their tensile strength. In many, but not all, cases the alloying process produces a marked increase in corrosion resistance, particularly to atmospheric corrosion. This improvement is used to best advantage when the steels are exposed unprotected under exterior exposure conditions where they show considerably greater corrosion resistance than normal carbon steels.

The improved corrosion resistance arises from the nature of the corrosion product (rust) formed which is firmly adherent and protective, the rust formed is generally darker in colour, of finer grain size, denser and less porous than the rust formed on low carbon steels. This is normally only the case where exterior exposure is involved and there appears to be little advantage in the use of low-alloy steel under interior, immersion or soil burial conditions. Chemical resistance is similar to that of carbon steels.

Low-alloy steels show a major advantage in situations where, having been coated with a protective paint system, the protective system is not adequately maintained or mechanical damage is likely. In these cases the compact rust formed under the paint or at film discontinuities, being of low volume, is less likely to cause film rupture or edge spalling. There are many coatings which are capable of providing long-term protection to this type of steel, the combination of paint coating and a low corrosion substrate being likely to perform much better than the same paint system on carbon steel. Low-alloy steels present no special problems in surface preparation and are not regarded as difficult substrates to paint. There are no recommended inorganic protective systems for low-alloy steels. Such treatments as galvanizing or metal spray would perform equally well on carbon steel and where protection of this type is considered necessary carbon steel should be used.

12.2 Organic Systems

A very large number of organic paint systems will provide excellent protection to low-alloy steels provided the necessary care is taken with the surface preparation, a suitable inhibitive primer is used and a sufficiently high dft is applied. The degree of surface preparation required will be dependent on the degree of corrosion attack present. Pitted surfaces will require extra preparation and blast cleaning is the best option in this case.

12.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation – Section 2 Methods 9,10			
Finishing System O-8			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Finish	Two Pack Solvent Free Epoxy Topcoat		200-250 microns
			Total dft
			245-300 microns

This system will provide maximum corrosion protection against most environments including exposure to marine, industrial and immersion conditions and will afford some measure of protection at points of mechanical damage where the base metal is exposed. Excellent decontamination will be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has very good mechanical properties including scratch and abrasion resistance and the zinc rich primer will minimise corrosion undercutting at points of damage. This protection will be achieved at the expense of decorative properties and on exterior exposure the finish will show chalking and loss of gloss. In this respect it is inferior to a two pack aliphatic isocyanate cured polyurethane top

coat recommended in System O-3. Maintenance will be moderate to difficult and the original zinc rich primer is unsuitable for use in general maintenance. Successful maintenance will depend on the degree of surface preparation carried out to remove all corrosion and to improve intercoat adhesion.

This system is expensive but note that high film build will be achieved with low volume/weights of finish as the coating is 100% solids.

12.2.2 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 1,2,3,4,5,7,8,9,10			
Finishing System O-9			dft
Primer	Two Pack Amine Adduct Cured Modified Phenolic Epoxy Primer		90-100 microns
Undercoat	Two Pack High Build Amine Adduct Cured Modified Phenolic Epoxy Coating		90-100 microns
Finish	Two Pack High Build Amine Adduct Cured Epoxy Topcoat		90-100 microns
		Total dft	270-300 microns

This system will provide maximum corrosion resistance to a wide range of chemicals, acids, alkalis, solvents, fatty acids and most decontaminants except high concentrations of strong oxidising acids e.g. nitric acid.

12.2.3 For Maximum Corrosion Resistance, Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 9,10			
Finishing System O-10			dft
Primer	Two Pack Zinc Rich Epoxy Primer		45-50 microns
Undercoat	Two Pack High Build Epoxy Undercoat		125-130 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-40 microns
		Total dft	205-220 microns

This system will provide outstanding corrosion and weathering resistance to most environmental conditions including marine, industrial and immersion conditions. The chemical and solvent resistance is excellent except to highly concentrated oxidising acids but in this respect it is marginally superior to many epoxy coatings. The decorative properties of this system are outstanding as it has a high initial gloss which is maintained on exterior exposure, the chalking rate is extremely low. The mechanical properties, particularly abrasion resistance are excellent. Maintenance will be moderate to difficult and care must be taken to achieve good intercoat adhesion.

The system is expensive and COSHH regulations will be onerous as isocyanates are known respiratory sensitisers. For spray application an air fed mask is mandatory.

12.2.4 General Purpose System with Good Corrosion and Chemical Resistance and Ease of Decontamination

Surface Preparation - Section 2 Methods 1,2,3,4,5,7,8,9,10			
Finishing System O-11			dft
Primer	Zinc Phosphate High Build Alkyd Primer		65-75 microns
Undercoat	Alkyd Undercoat		65-75 microns
Finish	High Build Alkyd Topcoat		65-75 microns
		Total dft	195-225 microns

The recommended dft should not be exceeded or the cure of the system will be impaired.

This system will give long lasting protection to low alloy steel under most conditions of service but is not recommended for continuous immersion in water. The chemical resistance is only moderate and it will be attacked by acids, alkalis and many strong solvents.

The initial decorative properties are good but it will show chalking and loss of gloss on exterior exposure and its mechanical properties are only moderate as it will be moderately easily scratched. Maintenance will be easy and the system can be overcoated with more conventional paints but not two pack systems or those containing strong solvents.

12.2.5 For All-round Excellence

System O-5 - In combination with conversion coatings to DEF-STAN 03-18
Proprietary Powder Coating
As recommended by the supplier

This system in combination with conversion coatings to DEF-STAN 03-18 used as surface pretreatments represents the ultimate in terms of corrosion protection and chemical resistance and has excellent mechanical properties including scratch, impact and abrasion resistance. The decorative properties are excellent. It should be noted that this system is factory applied. It has limited application on thin gauge fabricated containers as distortion may occur. The expense of this system coupled with the factory application indicates that it should only be applied where ambient conditions are particularly hostile and a long service life is required. Maintenance will be difficult as the system can only be repaired using coatings other than powder coatings.

12.3 Inorganic Systems

Inorganic finishes are not considered to be necessary due to the superior corrosion resistance of low-alloy steels.

13 FINISHING SYSTEMS FOR PLASTICS

13.1 General

The painting of, or indeed the need to paint or coat plastics is a vexed one, not least because of the very large number of commercially available plastics, each having specialised properties, which are available and in use. In many cases the user may be unaware of the chemical constitution and properties of the material and may not have access to the information allowing these important factors to be established.

A general reference to a material as being a plastic is usually understood by the user to mean a glass fibre reinforced polyester or epoxy or a thin film and this may have been true in the past. This is no longer the case and a very wide range of different materials collectively known as being 'plastics' is in use. These range from the previously mentioned glass fibre reinforced structural materials based on cross-linked polyester and epoxy resins collectively referred to as fibre glass, a range of fibre filled phenolic materials usually referred to under the trade name of Tufnol®, to unsupported thin films such as polyethylene and polypropylene and including polyurethane foams.

Two distinct classes of plastic exist, thermosets which are cross-linked and do not melt on heating and thermoplastics which are not cross-linked and have a definite melting point or range. Both may be used in fibre reinforced systems and appear in many forms:

<p>Thermosets include :</p>	<p>alkyds epoxies melamine formaldehyde resins phenol formaldehyde resins polyurethanes polyesters (but not all) polyimides silicones</p>
<p>Thermoplastics include :</p>	<p>acrylonitrile butadiene styrene (ABS) celluloses polyamides (nylons 6,11,12 etc.) polyethylene polypropylene polystyrene polyester terephthalates polyvinyl chloride polyvinyl acetate/butyrate polycarbonates</p>

and many others used singly or in combination. Many of the thermoplastic materials are used in the blown or cast form in mouldings or thin films.

It is important that if there is any intention to paint or otherwise coat a particular plastic material that the user knows at the very least the broad class to which it belongs. This is because the thermoplastics as a group present a low energy surface to which coating materials do not bond or adhere and are prone to stress cracking in contact with many of the solvents present in paint, or may even dissolve. Examples of the latter are polycarbonates and polystyrene. Adhesion to many thermoplastics can be improved by drastic thermal treatment or radio-frequency plasma etching but these are generally only applicable to small objects. As a general rule thin films and sections below 5mm in thickness should not be painted as a combination of poor adhesion and the flexibility of the substrate will lead to premature failure by cracking and flaking. The Specific cases may mean that the need to coat is paramount and a user may have to proceed at risk.

Thermosets are considerably easier to paint, and glass fibre or other fibre reinforced composites can be readily and successfully coated providing the surface is free from oils, greases or other mould release agents. Removal of release agents, particularly silicone based materials is imperative.

In spite of the difficulties inherent in coating thermoplastic materials already enumerated, this type of surface can be coated successfully provided that either the type of thermoplastic is known, the appropriate coating system is chosen, if necessary by practical application tests, and the coating manufacturers' advice is sought. Where the composition of the plastic is unknown a practical application test in which the candidate(s) coating system is applied by the method of application to be used in practice should be carried out and the coated substrate carefully examined for signs of cracking, crazing or loss of adhesion. If any of these defects are present, the coating system should be rejected. It should be noted that even if these defects are not visible the coating may still have enhanced the tendency of some plastic material to show stress cracking in service.

The safest procedure is to avoid coating thermoplastic materials and choose the correct starting material for the envisaged use and expected environmental conditions. Should it prove necessary to coat an unknown or a solvent susceptible plastic then it is possible to use a suitable primer which has the necessary adhesion to the substrate and is itself resistant to solvents, thus providing a solvent resistant barrier between the plastic and subsequent coatings. Suitable primers include water and alcohol based preparations. An alternative approach, albeit expensive, is to plate the plastic with copper or nickel or vapour deposit aluminium on the plastic surface to act as a solvent barrier and provide enhanced adhesion. If in any doubt consult the coating manufacturer.

Although many coated thermoplastics are in use in the coated condition it should be appreciated that these have been factory coated where aggressive surface pretreatments such as oxidation of the surface by gas torch under carefully controlled conditions are possible.

13.2 Organic Systems

There is a wide choice of organic coatings suitable for application to thermoset plastics the selection of which is dependent chiefly on the environmental conditions of service and the substrate composition but as a rule of thumb coat like with like i.e. epoxy paints on epoxies.

13.2.1 For Maximum Exterior Exposure Resistance, Ease of Decontamination and Mechanical Properties on Thermosets

Surface Preparation - Section 2 Methods 1,2.9			
Finishing System O-20			dft
Primer/Undercoat	Two Pack Polyamide Cured Epoxy Primer/Undercoat		25-35 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-45 microns
Total dft			60-80 microns

This system will provide maximum exposure resistance to most exterior environments including immersion in fresh and salt water; its ultra-violet resistance is excellent and it will retain its decorative properties for very long periods. The chemical resistance of this system is high to all but strong oxidising acids and alkalis and it is resistant to most organic solvents. The mechanical properties of this system, particularly abrasion resistance are excellent. The ease of decontamination is excellent if a coating having the necessary BS 4247-1 Method A certificate is selected. As with all polyurethane coatings the COSHH requirements are likely to be onerous. The system will be expensive to apply.

13.2.2 For Maximum Chemical Resistance on Thermosets

Surface Preparation - Section 2 Methods 1,2,9			
Finishing System O-21			dft
Primer/Undercoat	Two Pack Polyamide Cured Epoxy		25-35 microns
Finish	Primer/Undercoat		50-75 microns
	Two Pack Amine Adduct Cured Modified Epoxy Topcoat		
Total dft			75-110 microns

This system will provide maximum chemical resistance to a wide range of organic and inorganic acids, alkalis and organic solvents and will be resistant to most decontaminants except high concentrations of oxidising acids e.g. nitric acid. The decorative properties of this system will be moderate as it will show pronounced chalking and loss of gloss on prolonged exterior exposure and discolouration on interior exposure, particularly in the absence of light or in artificial light. In this respect it is inferior to System O-20. The system will have good mechanical properties including scratch and abrasion resistance but is unlikely to have more than a Good rating in the BS 4247-1 Method A test. Maintenance will be moderate to easy as the finishing coat contains strong solvents. It will be moderately expensive to apply.

13.2.3 For General Purpose Use on Thermosets

Surface Preparation - Section 2 Methods 1,2,9			
Finishing System O-22			dft
Primer	Zinc Phosphate Alkyd Primer		25-35 microns
Undercoat	Alkyd Undercoat		25-35 microns
Finish	Alkyd Topcoat		25-35 microns
Total dft			75-105 microns

This system will provide good decorative properties on both exterior and interior exposure but has only moderate chemical resistance particularly to inorganic acids, alkalis and most solvents. In this respect it is very much inferior in performance to Systems O-20 and O-21. The mechanical properties of this system are only moderate, abrasion resistance particularly. It is unlikely to have a high ease of decontamination and its resistance to all but mild decontaminants is likely to be poor. It does however have the merit of ease of application and low cost and should be chosen where there are no specific harsh exposure conditions. It is one of several possible systems which are suitable for general purpose use the choice of which may be dependent on cost.

13.2.4 For Use on Thermoplastics

There are no specific recommendations under this heading and specialist advice must be taken if premature failure or damage to the substrate is not to result.

13.3 Inorganic Systems

Most plastics can be coated with metals either by electroplating methods or vacuum deposition. Before electroplating it is necessary to deposit a conducting layer on the plastic by an electroless process in which a salt of copper, nickel or chromium in aqueous solution is deposited on the plastic surface and reduced to the metallic state in situ by a suitable reducing agent which is itself simultaneously oxidised. These deposits may be used as protective/decorative finishes in their own right or as a solvent resistant barrier for subsequent organic finishing systems.

13.3.1 For Use as a Solvent Barrier Prior to Painting

Surface Preparation - Section 2 Methods 1,2,9
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Finishing System I-11 Vacuum deposited aluminium - Factory applied.
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This system can be applied to acetals, acrylonitrile butadiene styrene, acrylics, phenolics, polyamides, polycarbonates, polyethylene, terephthalate, polystyrene and polysulphones. In most cases a vacuum bake-out and application of a base coat will be necessary. The deposited aluminium film will provide an excellent barrier to solvent attack by subsequent paint coats and be relatively decorative in its own right although not mechanically strong or chemical resistant unless subsequently lacquered or painted.

14 FINISHING SYSTEMS FOR STAINLESS STEEL

14.1 General

There are a multiplicity of stainless steels available commercially, many of them used in small quantities for specific purposes and a full discussion of the types available is beyond the scope of this document. Although the term stainless steel has not been precisely defined a working definition is those alloys which consist mainly of iron and not less than 10% chromium. Other constituents may consist of carbon, manganese, nickel, molybdenum, silicon and selenium. They are available in ferritic, martensitic and austenitic forms, the form and composition together dictate the properties and behaviour of a particular grade and thus its end use.

The resistance to atmospheric corrosion varies considerably with the grade, but all grades are considerably more corrosion resistant than carbon steel or indeed than aluminium, copper and zinc. In general the austenitic grades containing high quantities of nickel show the best corrosion resistance but in this respect may be only marginally superior to the ferritic grades.

The improved corrosion resistance of stainless steel over other metals is due to the fact that it exhibits passivity in a very wide range of environments. It is assumed that this passivity is due to the presence of a firmly adherent and continuous oxide film. All grades show some corrosion breakdown on exterior exposure usually associated with pollutants particularly chloride and sulphureous gases, all attack is in the form of pitting. Mineral acid resistance to all but hydrochloric acid is very good, as is resistance to organic acids, alkalis and most salts.

In particularly aggressive environments, notably the presence of chlorides, and where the stainless steel is under stress, martensitic and austenitic forms of stainless steel may suffer rapid intergranular cracking rather than the general intercrystalline penetration occurring in the absence of stress. This stress-accelerated intercrystalline corrosion can lead under certain conditions to catastrophic stress corrosion cracking. The ferritic grades appear to be largely immune.

The ease of decontamination of stainless steel depends largely on the surface topography and polished surfaces are preferable, however surface roughening will reduce the ease of decontamination to a marked extent and under these conditions surface coating may be necessary.

In general the corrosion resistance of the correctly selected stainless steel is more than adequate for most purposes and protection by organic surface coatings is seldom necessary except in the presence of chlorides, especially where the possibility of stress corrosion cracking exists, i.e. chlorides, stress and temperature. It follows that any coating to be used on stainless steel must be chloride free, thus precluding the use of chlorine containing polymers, which may be used either as paint binders or as plasticisers used in conjunction with non-chlorinated resins. In this respect all identification labels, tapes or marking inks should also be chloride free.

Stainless steel is regarded as a difficult material to paint and adhesion and retention of adhesion is a serious problem. Surface preparation may be difficult particularly if the surface is already corroded and pitted. In this case the removal of contaminants contained within the pits is the major problem. The best method of surface preparation is to blast – clean using non-metallic abrasive, but it must be borne in mind that this will remove the passive surface oxide layer.

14.2 Organic Systems

Most of the organic paint systems which provide protection to carbon steels will be suitable for use on stainless steel where they are likely to provide enhanced protection over that on carbon steel provided that good adhesion can be obtained. This being the case it is possible

to reduce the overall dft from that used on carbon steel. The manufacturer must be consulted about the suitability of any paint for use on stainless steel.

14.2.1 For Maximum Corrosion Resistance and Ease of Decontamination

Surface Preparation - Section 2 Methods 1, 2, 3, 9, 15			
Finishing System O-23			dft
Pretreatment	Etch (Wash) Primer Two Pack Zinc Phosphate Epoxy Primer Two Pack Solvent Free Epoxy Topcoat		10 microns
Primer			25-35 microns
Finish			75-100 microns
		Total dft	110-145 microns

This system will provide maximum corrosion resistance against most environmental conditions including chloride containing atmospheres and under immersion conditions. Excellent ease of decontamination can be achieved by the selection of an appropriate paint manufacturer having a product showing a DF of 1000+. The system has good mechanical properties including scratch and abrasion resistance. This protection will be achieved at the expense of decorative properties as the finish will show chalking and loss of gloss on exterior exposure. In this respect it is inferior to a two pack aliphatic isocyanate cured polyurethane top coat recommended in System O-25. Maintenance will be moderate to difficult and will depend on the degree of surface preparation carried out to remove all corrosion and to improve intercoat adhesion. This system is expensive but note that high film build will be achieved with low volume/weights of finish as the coating is 100% solids.

14.2.2 For Maximum Chemical Resistance

Surface Preparation – Section 2 Methods 1, 2, 3, 9, 15			
Finishing System O-24			dft
Pretreatment	Etch (Wash) Primer Two Pack Amine Adduct Cured Modified Phenolic Epoxy Primer		10 microns
Primer			35-50 microns
Finish	Two Pack Adduct Cured Modified Epoxy Topcoat		125-150 microns
		Total dft	170-210 microns

This system will provide maximum resistance to a wide range of chemicals, acids, alkalis and chlorinated solvents and most decontaminants except high concentrations of strong oxidising acids, e.g. nitric acid.

14.2.3 For Maximum Decorative Properties and Ease of Decontamination

Surface Preparation – Section 2 Methods 1, 2, 3, 9, 15			
Finishing System O-25			dft
Pretreatment	Etch (Wash) Primer Two Pack Polyamide Cured Epoxy Primer		10 microns
Primer			35-40 microns
Finish	Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		70-80 microns
		Total dft	115-130 microns

This system will provide maximum decorative properties and ease of decontamination together with excellent corrosion resistance. The decorative properties and exterior exposure resistance of this system are outstanding and it will retain its initial gloss without chalking for long periods of time. The mechanical properties particularly abrasion resistance

are excellent. Maintenance will be moderate to difficult and care must be taken to achieve good intercoat adhesion. The system is expensive and COSHH regulations will be onerous as isocyanates are known respiratory sensitisers.

14.2.4 General Purpose

No specific recommendation is made under this heading as for normal non-aggressive situations it is not necessary to coat stainless steel.

14.3 Inorganic Systems

No inorganic systems are recommended.

15 FINISHING SYSTEMS FOR WOOD

15.1 General

Wood is a very common structural engineering material with unique properties and an extremely long service life under some conditions of use, but suffers from several major disadvantages. It is water permeable, dimensionally unstable, readily attacked by micro-organisms and readily degraded by ultra-violet radiation, this is particularly the case with the 'soft' woods, but also true to a lesser extent of the 'hard' woods. It also gives off a variety of organic acid vapours which attack many metals, notably zinc, cadmium and lead, and requires protection of some sort in almost every situation of use if anything more than a short life or a temporary use is indicated in all but the most benign environments. A notable exception to this is the use of elm under water immersion conditions.

Wood is a composite material consisting of lignins and cellulose derivatives, ultra-violet radiation attacks the lignin resulting in de-methoxylation leading to the formation of water soluble products at some stage degradation of the cellulose commences allowing oxidation and free radical formation. In this condition the wood is susceptible to mould growth, fungal penetration and insect attack.

The resistance of woods to attack from any hostile agency will depend on the type of wood used, in general hard woods, (oak, beech and tropical hardwoods etc) will be considerably more resistant than any of the commercial softwoods. However few woods will have any real degree of chemical resistance, and water penetration and ultra-violet degradation will present a problem whichever type of wood is used. Penetration of water into wood can cause dimensional changes of up to 12% in the end grain resulting in cracking of the applied paint film and flaking of the system particularly as the age of the coating system increases. All construction joints are vulnerable to water ingress particularly in situations where water can be trapped and special care is required in protecting joints and sharp edges. Joints in kiln dried softwoods are most at risk.

Past practice has been to paint wood using alkyd based pigmented coatings for exterior and interior use and varnishes for interior use only as the life of unpigmented coatings e.g. varnishes on exterior exposure has been short. Recent modern practice has been to use permeable paint systems such that water, once in the wood, can permeate out without disrupting the paint film, or to use lightly pigmented or transparent coatings containing ultra-violet absorbers.

15.2 Organic Systems

There are a very large number of organic coatings which can be used on wood to give an adequate service life under both exterior and interior exposure conditions in all but the most severe environments. Under exterior exposure conditions regular maintenance and repainting is required, especially if good decorative properties are required, as all paint systems will eventually show chalking and colour change and unless specially protected, mould growth. Varnishes and stains are likely to require more regular maintenance. A useful guide to the types of coating systems available and their properties is provided by BS EN 927 - 1.

Surface preparation, although important, is not difficult and it is only necessary to remove surface contamination and rub down sharp edges and asperities. All knots and areas of resinous exudation must be sealed before painting.

15.2.1 For Maximum Decorative and Protective Life Exterior or Interior Exposure, Hard or Soft Woods

Surface Preparation – Section 2 Method 19			
Finishing System O-32			dft
Primer Finish	Two Pack Polyamide Cured Epoxy Primer Two Pack Aliphatic Isocyanate Cured Polyurethane Topcoat		35-40 microns 70-80 microns
		Total dft	105-120 microns

This system will provide long term decoration and protection to most types of wood under both exterior and interior exposure conditions. The decorative properties of the system are outstanding and little or no chalking or loss of gloss will occur during long term exterior exposure. It may or may not be easily decontaminable and if this property is essential then the purchaser must arrange for it to be tested to BS 4247. The supplier must be consulted if it is to be applied to oak, iroko or teak and in every case where the wood has been treated with a preservative.

15.2.2 For Maximum Decorative Life Interior on Hard or Soft Woods

Surface Preparation – Section 2 Method 19			
Finishing System O-26			dft
Primer	Solvent-borne Exterior Quality Primer to BS 7956		25-35 microns
Undercoat Finish	Alkyd Based Undercoat Hard Gloss Alkyd topcoat (applied in two coats)		35-50 microns 70-80 microns
		Total dft	130-165 microns

This system will provide long term decorative properties on all types of wood under interior exposure conditions and will also be suitable for most exterior conditions. Under interior exposure conditions it is unlikely to fail except by showing discolouration depending on the colour chosen or by mould growth under damp conditions. It is unlikely to be decontaminable. The supplier must be consulted if it is to be applied to oak, iroko or teak.

15.2.3 For Maximum Ease of Decontamination, Interior Exposure on Soft Woods

Surface Preparation – Section 2 Method 19			
Finishing System O-27			dft
Primer Undercoat Finish	Water-borne General Purpose Primer to BS 7956 Water-borne Acrylic Undercoat Water-borne Acrylic Topcoat		25-35 microns 35-50 microns 50-75 microns
		Total dft	110-160 microns

This system will provide an easily decontaminable surface resistant to many chemicals but with only moderate resistance to some solvents and no resistance to aromatics, ketones and esters. Its decorative properties will be considerably inferior to those of Systems 15.2.1 and 2. The supplier must be consulted before this system is specified and applied to any wood.

15.2.4 For Maximum Ease of Decontamination and Decoration, Interior Exposure, on Hard Woods

Surface Preparation - Section 2 Method 19		
Finishing System O-16		dft
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Two Pack Aliphatic Isocyanate Cured Polyurethane Varnish		35-50 microns
Note : It may be necessary to apply a further coat depending on the porosity of the substrate. Measurement of the dft will be difficult, if not impossible. The manufacturers recommendations should be followed.	Total dft	70-100 microns

This system will provide excellent abrasion resistance, ease of decontamination and decorative appearance. Application should preferably be by brush to avoid droplet inhalation and COSHH regulations may be onerous as isocyanates are respiratory sensitisers. An alternative and safer system to use is a urethane alkyd varnish system O-18.

15.3 Inorganic Systems

There are no inorganic systems for wood.

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