WSA Engineering and Operations Committee: Materials and Standards

No. 4-52-02
January 1993: Issue 1
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ISSN 0267-0305

Information and Guidance Note

Water Industry Specifications and IGNs are also issued by: UK Water Fittings Byelaws Scheme ISSN 0267-0313 and Process Systems Committee ISSN 0956-5132

THE USE OF POLYMERIC ANTI-CORROSION (BARRIER) COATINGS

FOREWORD

This Information and Guidance Note has been prepared by WRc plc under the direction of the Sewers and Water Mains Committee (now superseded by the Engineering and Operations Committee). Representatives of the UK Water Industry, coatings material suppliers and coating applicators were regularly consulted during the development of the document through the Materials and Standards Working Group's Coatings Liaison Group.

This guidance has been issued in conjunction with the Water Industry Specification No. 4-52-01 to satisfy the immediate needs of both users and suppliers.

This guidance note calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

It has been assumed in the drafting of this guidance note that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Information contained in this note is given in good faith but neither the Foundation for Water Research, Water Services Association nor WRc plc can accept any responsibility for actions taken as a result.

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1. INTRODUCTION

1.1 Objective

This note is intended to provide the Water Industry with general guidelines on the use of polymeric anti-corrosion coatings. It covers the selection of appropriate coatings and the design, packaging and handling of coated products. It provides information which complements the Water Industry Specification No. 4-52-01 for Polymeric Anti-Corrosion (Barrier) Coatings[25].

1.2 Background

1.2.1 The problem of corrosion

Metallic corrosion is an electrochemical process in which a metal is converted into oxides or other stable compounds analogous to the ore from which the metal was originally won. The effects of corrosion on the properties of a metallic article are almost always undesirable and frequently these effects determine the useful lifespan of the article.

From the Water Industry viewpoint, many valuable assets such as water mains, sewerage, and above-ground structures incorporate metallic components which are susceptible to corrosion. In order both to minimise the total cost of owning these assets and to improve operational reliability, the Water Industry has in recent years sought to prevent or inhibit corrosion more effectively, and thereby both reduce the frequency of maintenance required and extend the lifespan of the protected assets.

A wide range of corrosion protection systems is available to the Water Industry, so first of all it is necessary:

- to identify which systems are covered by this guidance note and
- to put these systems into perspective with the other alternatives available.

1.2.2 Polymeric coatings in perspective

Corrosion protection systems can be divided into two broad categories:

- Passive physical barriers which are intended to isolate the metal surface from the corrosive environment; and
- Active protection systems which are either based on cathodic protection or chemical passivation of the bare metal surface. Cathodic protection systems are either of the sacrificial type, whereby anodic sacrificial metal electrically connected to the protected article corrodes preferentially, or the externally applied impressed current type. Both of these cathodic protection systems stifle corrosive anodic reactions at the surface of the protected article by changing the electrical potential locally. Chemical passivation involves making the metal surface unreactive e.g. cement mortar lining of ductile iron pipes. The cementitious coating, which is alkaline, raises the pH at the metal surface, passivating it and thereby inhibiting corrosion attack.

Polymeric coatings fall into the category of passive physical barriers. For the purposes of the Water Industry Specification for such coatings, WIS No. 4-52-01, the term "polymeric coating" is intended to encompass both thermoplastic and thermosetting coating materials. It is not intended to cover lower molecular weight hydrocarbon-based materials such as bituminous paints and enamels.

It should be pointed out that the specification itself does not preclude any polymeric coatings by name and is purposely based on technical performance requirements. These requirements are intended to reflect the need for effective long term corrosion protection in typical Water Industry service applications and it is most unlikely that cosmetic or decorative finishes will meet the required levels of performance.

1.3 Structure of this note

The guidance in this note is presented in the following three self-contained sections:

Section 2 Design

Polymeric coatings are capable of affording substantial long term protection to metallic products and structures. The design of these items does however have a significant influence on the ability of any particular polymeric coating system to fulfil its anti-corrosion function over prolonged service exposure periods. Indeed, there have been many case histories reported(1) in which inappropriate product design has led directly to premature coating failure. It is therefore important to emphasise that consideration must be given to provision for coatings at the product design stage, rather than after the product design has been finalised. This section provides both generalised and specific design guidance.

Section 3 Selection

WIS No. 4-52-01 contains minimum performance requirements for high performance polymeric anti-corrosion coatings and should therefore be used wherever appropriate as the primary basis for coating selection. However, it should be noted that each coating material is likely to have its own advantages and limitations, and these should be considered at the selection stage. There is seldom a unique solution for every particular service application, and similarly, it is unlikely that any one coating will be suitable for all Water Industry applications. This section provides generalised guidance which is intended to help users select suitable corrosion protection systems for their intended service applications.

Section 4 Packaging and handling

Once care has been taken over the design of workpieces and selection of coatings, it is important to take equal care over the subsequent packaging and handling of coated workpieces.

If the protective coating deteriorates or is damaged during handling, storage or delivery on site, the coated product will face a greatly increased risk of corrosion and, consequently, premature failure. Although repairs to such coating damage can be, and indeed should be carried out prior to installation, it is preferable to reduce the number of such repairs to a minimum since each repair may potentially be a weakness in the coating barrier. The guidance in this section concentrates on the prevention of coating damage and deterioration.

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1.4 Definitions

Cathodic disbondment - cathodic protection generates alkalinity (hydroxyl ions) at the surface of the protected metal, and this can cause the coating to lose adhesion. This adhesion loss is known as cathodic disbondment.

Crevice corrosion - corrosion which occurs in a very narrow gap between two surfaces, due to acid build-up and lack of oxygen in the crevice.

Holiday - a small through-thickness or near through-thickness discontinuity in a coating.

Plastisol - a liquid mix of polymer and plasticiser, which is applied to a hot metal surface. Gelation and solidification occur subsequently.

Polymer - an organic material formed from long-chain, high-weight, carbon-based molecules.

2. DESIGN

2.1 Introduction

This section presents general guidance on the ideal approaches which should be adopted when designing products which are subsequently to be protected using polymeric anti-corrosion coatings. However, it is recognised that numerous products currently used by the Water Industry have been developed over many years. It will not always be technically or commercially feasible to implement the suggested design approach needed to enable the full potential of polymeric coatings to be realised. In these cases it may be appropriate to consider suitable alternative or complementary protection systems, particularly for service applications which are known or suspected to be highly arduous. However, for future product developments and capital projects in which polymeric coatings have been chosen as the primary means of corrosion protection, it is recommended that the design guidelines contained in this section are adopted.

2.2 General points

Any structure or component which is to be coated should ideally provide a base upon which the chosen coating can be easily applied to form an adherent, continuous film of reasonably uniform thickness.

Most commonly used polymeric coatings tend to "pull away" from sharp edges as a result of surface tension effects prior to solidification. It is therefore critical that such features are eliminated from surfaces which are to be coated. In this respect it is generally more cost-effective to eliminate such features at the product design stage where possible, rather than having to resort to removing sharp edges prior to preparation for coating (see Figure 2.1).

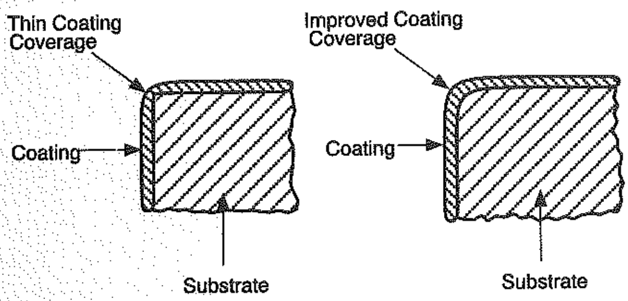

**Figure 2.1 - Coating coverage over edges
Left: Thin coating coverage over a sharp edge
Right: Improved coating coverage over a rounded edge**

Prior to preparation, any surface which is to be coated should ideally be as smooth as is practically possible, bearing in mind other design conditions. Deep recesses and blind holes should be avoided at all times since they can cause difficulties in several stages of the coating process.

Every effort should be made to avoid the formation of surface defects (raised protrusions or holes and indentations) during the manufacture of products and structures which are to be coated. Where such defects are inevitable, they should be located by inspection and suitably ground flat and smooth or filled in as appropriate with materials which are compatible with the subsequent preparation and coating procedures.

All handling attachments, raised lettering, and any other features which may interrupt the smooth profile of a coated product should be located on surfaces where any premature corrosion attack which might occur would not impair the performance of the product over its design life.

Components and fasteners which do not lend themselves to being coated successfully with relatively thick polymeric coatings (i.e. due to the presence of screw threads, etc.) should ideally be protected by alternative means (to achieve an equivalent degree of protection). Active systems such as hot-dip galvanising or zinc end caps can provide useful sacrificial protection, but the protection will only last as long as the lifespan of the sacrificial metal, which will start to be consumed immediately the article is exposed to a corrosive environment. Experimental evidence suggests that the lifespan of this type of protection can be usefully extended if the active system is complemented by a passive barrier or shield such as a thin polymeric coating over the zinc plating or galvanising, or by an insulating sheath or sleeve used to cover the exposed shank or head of a bolt and so restrict the access of the corrosion reactants.

It is important that dissimilar metals should be insulated from one another, since bimetallic corrosion can occur when they are in contact, e.g. steel bolts should be insulated from iron surroundings.

Narrow gaps and crevices (e.g. between bolts and plates) should be sealed to prevent crevice corrosion (see Figures 2.6 and 2.7).

Care should be taken to ensure that when sacrificial zinc caps are used, a good electrical connection is made between the cap and the article it is intended to protect. Therefore, where complementary passive insulating coatings are to be used in conjunction with such caps, they should not cover the area which is to be in contact with the sacrificial cap.

Where hot-dip galvanised or electroplated protective finishes are to be used, the recommendations contained in BS 4479: 1990[3] should be considered during the design of the article.

2.3 Castings

2.3.1 Introduction

Castings in the form of pipeline fittings and other associated equipment are often used in corrosive service applications. In recent years, polymeric coatings have been used in increasing quantities to protect these products against corrosion attack.

Where possible, the following design guidelines should be adopted in order to ensure that cast products benefit from the full protection potential of the polymeric coating.

2.3.2 Design guidelines for castings which are to be coated

2.3.2.1 Sharp edges and corners

The general profile of castings should be as smoothly contoured as other design considerations will allow. Wherever practicable, edges and corners should not be sharper than a radius of 3mm (see Figure 2.2).

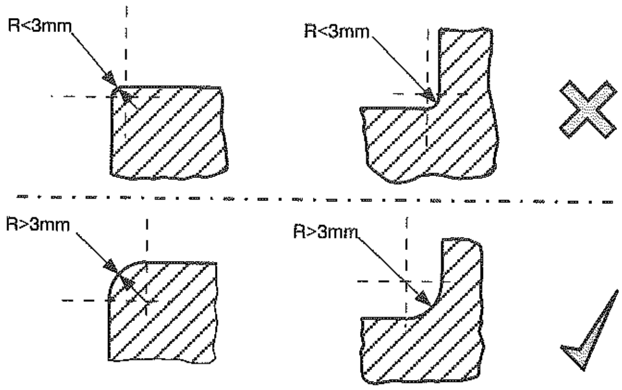

Figure 2.2 - Preferred and non-preferred edges and corners

2.3.2.2 Surface texture and other features

Care should be taken to produce a uniform cast surface texture. Any surface breaking blowholes or porosity should be filled with a compatible material prior to coating and any sharp protrusions should be ground flat prior to further preparation operations.

2.3.2.3 Raised identification features

Raised lettering, figures or trade marks, etc. should ideally be avoided on surfaces which are to be coated since they are likely to lead to coating weaknesses. Alternatives, such as adhesive labels, permanent metal tags, etc. should be used where possible. In cases where permanent identification of the casting is mandatory, the raised lettering should either be located on non-critical exterior surfaces, or rounded as much as possible whilst remaining legible (Figure 2.3).

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2.3.2.4 *Recesses*

It is good practice where possible, to eliminate deep recesses from castings which are to be coated since these features will inevitably present difficulties during surface preparation and coating application.

2.3.2.5 *Handling facilities*

Castings which are required to be stood up on their base should have suitable flats on the underside. Heavier castings should also incorporate features which facilitate the attachment of appropriate handling equipment.

2.3.2.6 *Assembly methods*

Methods used to assemble cast components should minimise the use of bolts where possible. Where bolts are to be used they should either be made from corrosion resistant material or suitably protected against corrosion, including bimetallic corrosion (see 2.2).

2.3.2.7 *Internal surfaces of pipeline fittings*

Internal surfaces of cast fittings which are to be coated should permit adequate access for all stages of the preparation and coating processes.

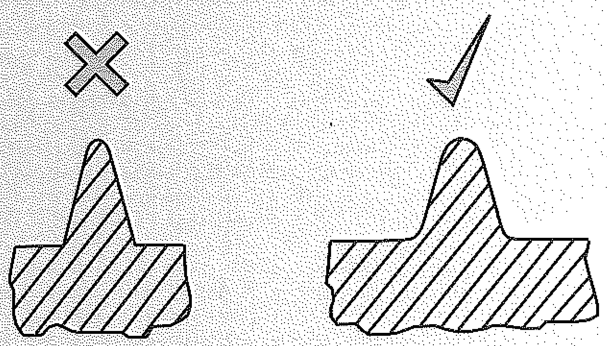


**Figure 2.3 - Lettering on surfaces to be coated
Left: Sharply raised lettering to be avoided
Right: Rounded lettering preferred**

2.4 Structures

2.4.1 Introduction

The useful lifespan of an unprotected metal structure will, in many service applications, be limited by the rate at which it corrodes in its service environment. This lifespan can be significantly increased if effective anti-corrosion protection systems are employed. In relatively low corrosivity service applications, e.g. external surfaces of above ground structures, regular maintenance is often feasible. The paints or coatings used may then be touched up or re-applied frequently. Polymeric anti-corrosion coatings can offer longer term protection which is not so dependent on frequent maintenance, but the full potential of these systems can only be realised when they are applied correctly to suitably designed and constructed structures.

A significant proportion of costly service failures due to corrosion could be avoided by giving appropriate consideration to corrosion prevention and coating practice at the design stage.

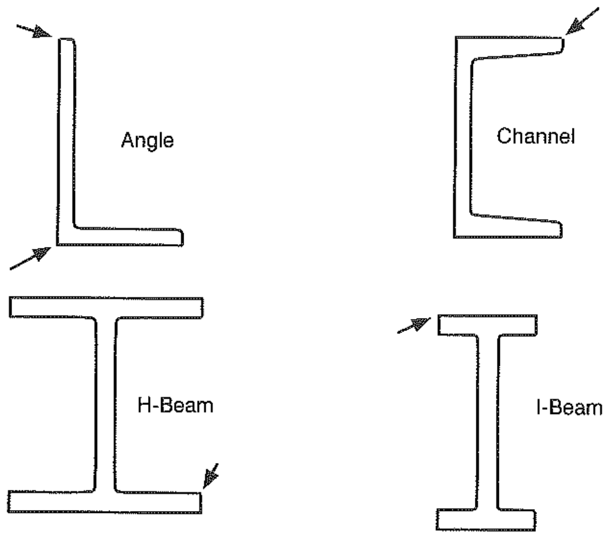
2.4.2 General points

The structure which is to be coated should be designed in such a way that the coating can be readily applied to all areas of the surface to form a continuous film of reasonably uniform thickness. In order to facilitate the application of such a coating, all of the surfaces to be coated should be easily accessible by the preparation and coating processes. Such accessibility should also make any subsequent maintenance easier to carry out.

The following section contains detailed design guidance which is intended to reduce the risk of corrosion on coated structures in general.

Traditional structural steel sections such as angles, I and H beams and channels, etc. do not always lend themselves to good design from a corrosion resistance viewpoint (see Figure 2.4). As evident from offshore engineering experience, it is often more appropriate to construct simple structures using cylinders and pipes joined by continuous welds (see Figure 2.5). However, it is recognised that suitability for coating/corrosion resistance is only one factor to be considered by the structural designer, and in some cases traditional structural sections will be preferred for other reasons. When such sections are used, it is important to ensure that the structure does not incorporate features which will collect standing water. For example, where possible, channel sections should be positioned with the opening facing downwards.

In general the surfaces to be coated should ideally be smoothly contoured and where possible free from overlaps, riveted or bolted joints, sharp edges and corners. Figures 2.6 and 2.7 show common focal points of corrosion attack on riveted and bolted assemblies respectively.



Arrows Point to Potential Sites of Corrosion Attack

Figure 2.4 - Sites of potential coating weakness on common structural sections

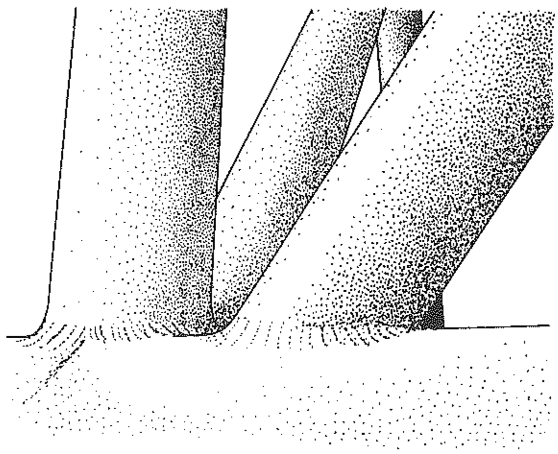


Figure 2.5 - Example of a structure comprising welded cylinders

2.4.3 Design guidelines for structures which are to be coated

2.4.3.1 Sharp edges and corners

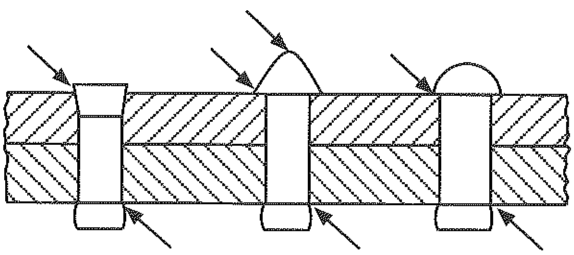
Such features should be avoided in design or ground smooth (to at least a 3mm radius) prior to surface preparation.

2.4.3.2 Fasteners (bolts, studs, nuts, rivets, etc.)

Such components should either be made from a corrosion resistant material which does not promote bimetallic corrosion of neighbouring metal surfaces, or protected from corrosion by a proven system (such as hot-dip galvanising or zinc plating followed by coating). Crevices beneath pre-protected fasteners should be caulked with a suitable material during assembly to eliminate the conditions which are commonly found to promote crevice corrosion (see Figures 2.6 and 2.7).

2.4.3.3 Welds

Welds which are rough, or which contain slag, spatter or sharp protrusions should be ground clean and smooth. Figure 2.8 shows examples of butt welds which are likely to lead to coating problems, and an example of a correctly-prepared weld.



Arrows point to sites of potential corrosion attack

Figure 2.6 - Common focal points of corrosion attack on three types of riveted joint

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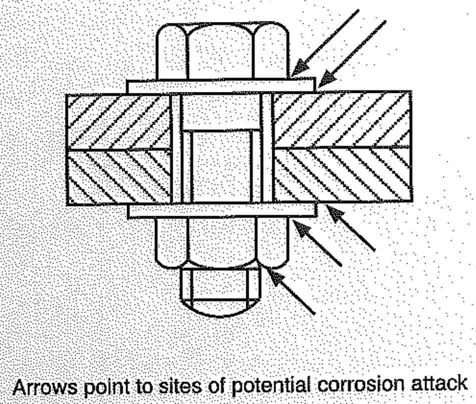

Figure 2.7 - Common focal points of corrosion attack on bolted assemblies

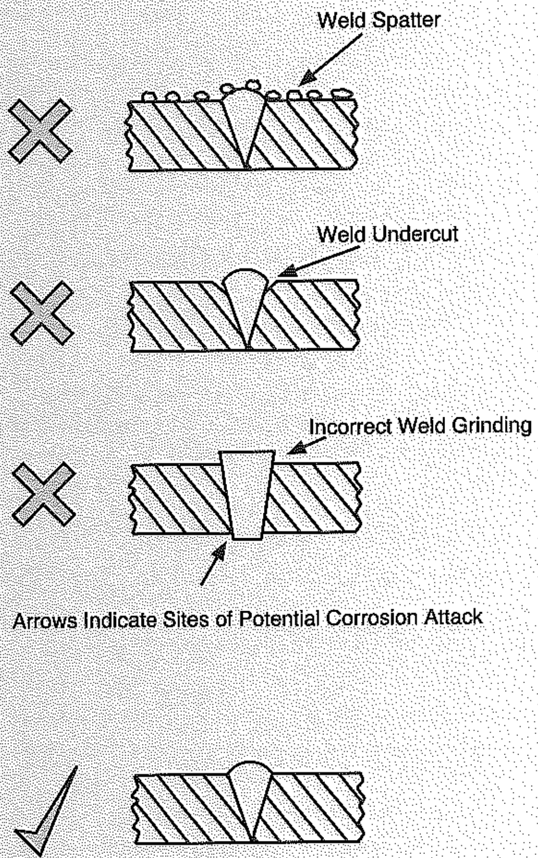

Figure 2.8 - Common focal points of coating weakness and corrosion attack on poorly prepared butt welds, and an example of a correctly-prepared butt weld

2.4.3.4 *Crevices and gaps*

Any crevices or small gaps arising from flat plates or sections which are joined back to back should be seal welded, in order to prevent crevice corrosion.

2.4.3.5 *Pipe or cylindrical construction*

All openings on structural members should be closed with seal welded end covers.

2.4.3.6 *Recesses*

Sites where standing water could potentially gather should be eliminated, either by drilling 25mm diameter drain holes or by filling recesses with a material which is compatible with the subsequent preparation and coating processes. All such drilled holes should have edges with a radius of >3mm.

2.4.3.7 *Tanks*

Outflow pipes from tanks should be designed so that all liquid drains out when the tank is emptied. (See Figure 2.9).

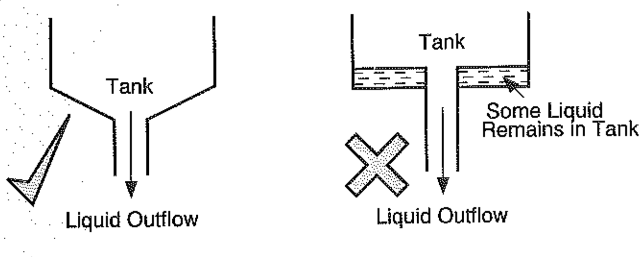

Figure 2.9 - Examples of complete and incomplete tank drainage

2.4.3.8 *Compatibility of coatings*

Where pre-coated or primed parts are to be used in combination with a final site-applied coating on all or the remainder of the structure, the coatings must be compatible.

2.4.3.9 Pre-coating of structural parts

It is sometimes preferable to assemble factory pre-coated parts on site. In this way some of the risks of, and difficulties encountered with on-site coating application can be avoided. In cases where the pre-coated parts are to be welded together on site, sufficient coating cut-back should be made from the site of the weld and proper weld joint coating should subsequently be carried out. Coating material suppliers should be consulted for advice on minimum cut back requirements.

2.4.3.10 Closed vessels

Where appropriate, closed vessels should be designed with manholes (to BS 470)[4] of at least 600mm for access purposes. At least one other opening should be incorporated and located in such a way as to facilitate adequate venting of lining fumes, etc. Smaller vessels should have appropriate means of access for coating and inspection.

2.5 Pipework sections

2.5.1 Introduction

The design of pipeline sections which are to be factory lined and coated with polymeric materials may differ according to whether they are to be coated by conventional spray or dip application techniques, or by specialised internal application machinery.

For small diameter pipework which cannot be successfully coated by conventional spray or dip techniques, it may be useful to refer to BS 6374: 1984[5], which is primarily aimed at the process industries but is also relevant to the Water Industry. The applicator of the lining should be consulted to determine the limiting length for individual sections of pipework.

For large diameter pipework, it is usually preferable to make use of welded joints rather than flanges, since this minimises and simplifies the surface, and avoids the need for bolted joints which have been shown to be susceptible to corrosion attack (see Section 2.5.3).

2.5.2 General guidelines for the design and construction of pipework which is to be lined and/or coated

(a) Riveted or bolted joints should be avoided where possible. Where bolted joints have to be used for other reasons, the assembly should be capable of being dismantled for coating/lining

(b) All welds on surfaces which are to be lined or coated should be continuous, and should be ground free of sharp edges and protrusions. They should also be free from pitting, undercutting, cracks, porosity, and all spatter should be removed prior to surface preparation.

(c) The design of pipework should allow ready access to all welds, corners and bends for inspection and surface preparation.

(d) All surfaces to be lined or coated should have smooth contours and be free of sharp edges or corners and protrusions. Wherever possible, the radii of edges and corners should be no less than 3mm (as in Figure 2.2).

(e) Coating thickness on flange faces should be controlled sufficiently so that a good seal can be achieved on assembly.

(f) Handling/lifting should be facilitated either by appropriate features incorporated into the design, or by suitably designed equipment.

3. COATING SELECTION

3.1 Introduction

This section provides guidance on the selection of various forms of corrosion protection. It covers not only high performance polymeric coatings but also introduces some of the alternatives which could be considered. It also gives detailed advice on the selection and specification of polymeric coatings. In doing so, it assumes that users will rely primarily on WIS No. 4-52-01 as the basis for their choice of coating.

3.2 Other relevant information and standards

There are many existing sources of generalised guidance dealing with the selection of corrosion protection systems for a broad range of service applications, some of which include information which is relevant to the Water Industry. In

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addition, guidance on corrosion protection is given in several specialised WRc publications. Some of these references are listed below together with summaries of the information they contain relating to the selection of corrosion protection.

- **BS 5493 Code of Practice for protective coating of iron and steel structures against corrosion**[6]

  This standard comprehensively classifies recommended methods of protection for iron and steel exposed to commonly encountered environments (ranging from very low to high corrosivity). It describes the characteristics of metallic coatings and paint systems in detail and identifies other protective systems such as powder coatings, grease paints, wrapping tapes and sleeves, cementitious linings and cathodic protection, but in these cases does not include detailed recommendations. The standard also includes useful guidance on the recommended approach to the selection and specification of protection systems, the need for maintenance and relevant procedural considerations, and health and safety issues.

  The Code of Practice is particularly useful for service applications where maintenance is feasible, and where lifespans to first maintenance of up to around 20 years are envisaged or required. In these cases, high performance corrosion protection systems such as polymeric coatings will compete for selection against a broad range of alternative protection systems such as those described in detail in this Code of Practice. It should be noted however that this Code of Practice does not lay down technical performance requirements for the protection systems it describes and as such, cannot be used in itself for specification purposes.

- **WRc ER 293E Review of the use and performance of sea outfall pipeline materials 1988**[7]

  This report provides a comprehensive overview of the methods which are likely to be considered for the protection of ferrous sea outfall pipelines against corrosion. The specific performance requirements for such applications are referred to in the descriptions of the properties of each of the corrosion protection systems. The information contained in this report may also have relevance to other onshore, offshore and splash/tidal zone applications.

- **WRc Pipe Materials Selection Manual: Water Mains 1988**[8]

  The Manual includes sections dealing with the need or otherwise for corrosion protection of the various pipeline materials and fittings available for use in the construction of water mains. The recommended approaches for copper, steel and ductile iron pipes are presented together with those for pipes made from asbestos cement and prestressed concrete. The corrosion protection requirements for metallic pipeline fittings are also discussed.

- **BGC/PS/CW5 Code of Practice for the selection and application of field-applied external pipework coatings (other than resin coatings)**[9]

  This Code of Practice includes guidance on the use of hot enamels, hot applied tapes, self adhesive cold applied tapes, cold applied laminate tapes, grease-based tapes, heat shrinkable plastics, mastics, fillers and putties, brush/spray applied coatings (compounds), and loose PE sleeving.

  It should be stressed that the information included in this document is based on the Gas Industry's experience and requirements and, whilst in some areas it will be relevant to the Water Industry, it may not in all cases be directly applicable.

3.3 Characteristics and application methods of commonly used polymeric coatings

3.3.1 General characteristics

For the purpose of the Water Industry specification for polymeric anti-corrosion (barrier) coatings, the term polymeric has been taken to cover both thermoplastic and thermosetting polymers.

Thermoplastics are characterised by their ability to soften and ultimately melt each time they are heated to elevated temperatures. Conversely, thermosets undergo a molecular cross linking or "curing" reaction during which they are transformed from relatively low molar mass materials into a solid which cannot be significantly softened or melted, without thermal degradation, by the subsequent application of heat.

The particular characteristics of individual coating materials determine the range of methods by which they can be applied.

Thermosetting coating materials are supplied either in powder form, or in one or two-pack liquid form. The powders contain partially reacted materials which are heated to form the polymer. Two-pack systems must be mixed during or a short time before application, and are generally formulated to react at ambient temperatures. One-pack systems contain two components which react only in the presence of moisture, heat, or some other catalyst.

Thermoplastic coatings do not undergo a chemical curing or cross linking reaction during conventional coating application methods. Instead, the solidification of the coating occurs as a result of cooling the coated item from an elevated temperature to one below the coating's melting range.

They are most commonly applied in the form of powders but are also used in the form of liquid melts or plastisols.

3.3.2 Application methods

3.3.2.1 Powder methods

All powder application methods rely on making coating powder particles adhere to the surface of the metal workpiece, and fusing them together through the action of heat to form a continous coating. This process is sometimes referred to as "fusion bonding".

(a) Fluidised bed - Air under pressure is forced through powder contained in a chamber or "bed". This makes the powder behave as a liquid, and items to be coated are pre-heated and lowered into the fluidised bed. The heat from the metal melts the powder onto the surface. Post-heating may be necessary to fuse the powder completely. (See Figure 3.1).

(b) Electrostatic spraying - The powder particles are sprayed from a gun, which charges them as they leave the nozzle. The object to be coated is earthed or charged oppositely, so the particles adhere to it by electrostatic attraction. The object is then heated to fuse the powder particles. (See Figure 3.2).

(c) Flock spraying - Powder is sprayed onto a hot object, which may then require post-heating. The object is not electrically charged during this process.

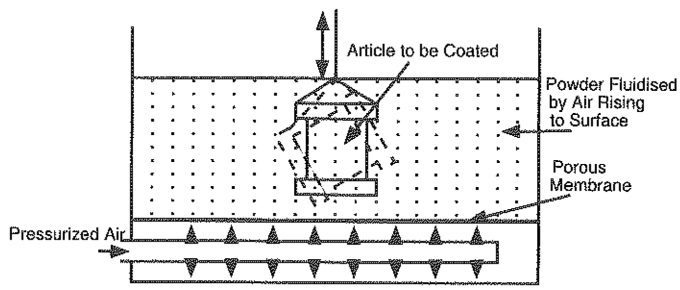

Figure 3.1 - Schematic diagram of fluidised bed principle

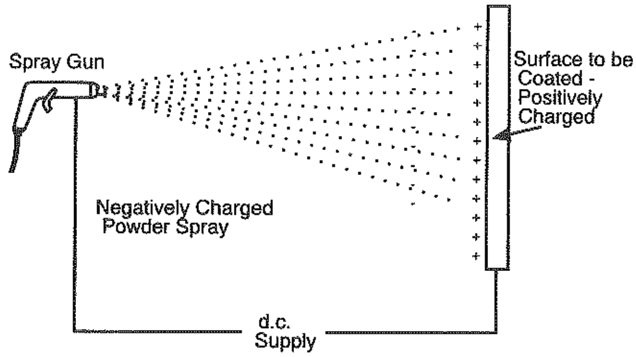

Figure 3.2 - Schematic diagram of electrostatic spray principle (in some cases the polarity may be reversed)

3.3.2.2 Liquid methods

Coatings applied in liquid form may solidify by evaporation of a solvent, by chemical reaction between two components, by cooling to below melting point, or by gelation and subsequent hardening.

(a) Hand-applied coatings - These may be applied by brush, roller or trowel, and are commonly solvent-evaporation or multiple-component systems.

(b) Spray - There are many variations on this technique, including air spraying, airless spraying, hot spraying, and multiple-component mixer gun spraying. All types of liquid may be sprayed, provided their viscosity is (or can be made) low enough.

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(c) Plastisol dipping - The article to be coated is lowered into a tank of hot liquid plastisol, which gels on removal and subsequently solidifies. Post-heating may be necessary to complete this process.

3.3.3 Surface preparation and primers

Appropriate surface preparation is essential to coating performance. Coatings vary in their sensitivity to surface preparation, but surfaces should always be prepared in accordance with the coating supplier's instructions. These instructions frequently cover such treatments as effective degreasing, grit blasting to a specified standard, and various chemical treatments.

Many coatings (generally, thermoplastics) require primers to be applied to the metal to improve adhesion to the surface. Care should be taken when heating primed articles for coating application, since overheating may impair the primer's performance.

3.3.4 Characteristics of various coating types

The information in this subsection is provided to help users discriminate between the various types of high performance coating available, on the basis of their respective characteristics.

Table 3.1 lists many of the coating types available for use in the Water Industry. This information should be used with caution, since it is not intended to be totally comprehensive and is generalised. There can be large variations in the properties of each type of material listed, according to the grade.

3.4 Selection guidelines

3.4.1 Preliminary considerations

Before a water utility user sets out to select a corrosion protection system for any particular service application, it is recommended that careful consideration is given to the following points.

(a) The corrosivity of the intended service environment.

(b) The likely consequences of a corrosion-related failure of the asset.

(c) The strategic and financial value of the asset.

(d) The planned asset lifespan.

(e) The feasibility of regular inspection and maintenance.

(f) The scale and typical production volumes of the component parts which go to make up the installed asset.

(g) Any specific coating performance requirements.

(h) Whether or not a corrosion resistant material has been considered as an alternative to materials which need to be protected against corrosion.

From this consideration of the service application it should be possible to identify the general level of corrosion protection required of the system together with any other outstanding performance requirements specific to the application. At this stage, it should be decided whether a high-performance polymeric coating is needed, or whether a lower-performance form of protection will be adequate for the application.

3.4.2 Selection of the corrosion protection system

Having identified what is required from the corrosion protection system there are various approaches to the final selection which can then be followed.

These approaches include:

- Consideration of previous experiences of similar service applications;
- The use of relevant performance specifications (e.g. WIS No. 4-52-01);
- Expert consultation.

In most cases, a combination of two or more of these approaches will be followed. Each of these approaches is discussed in detail in the following paragraphs.

3.4.2.1 Previous experience

Since polymeric anti-corrosion coatings have only been used in the UK Water Industry in relatively recent times, the range of in-service performance data available for these systems cannot be viewed

Table 3.1 - Characteristics of some commercially available anti-corrosion coatings

GENERIC GROUP	TRADE NAME	DESCRIPTION	APPLICATION METHODS	TYPICAL THICKNESS RANGE (µm)	COLOUR
Polyolefins	Plasinter LD Polyethylene	Low density polyethylene	Fluidised bed or flock spray	300 - 900	Extensive
	HDPE	High density polyethylene	Fluidised bed or flock spray	300 - 900	Limited
	PP	Polypropylene	Fluidised bed or flock spray	300 - 900	Limited
Adhesive-modified polyolefines	Kelvar Sintercoat	Polar-modified polyolefins	Fluidised bed or electrostatic spray	350 - 1000	Extensive
EVA	Levasint Eval	Ethylene vinyl alcohol copolymer	Fluidised bed or flock spray	350 - 1000	Extensive
Polyolefin-based alloy	Plascoat PPA range of coatings	Polyolefin-based alloy	Fluidised bed or flock spray	200 - 900	Various
Polyamide	Rilsan nylon coating	Polyamide type 11	Fluidised bed or electrostatic spray	75 - 500	Various
Vinyl polymers	Vyflex PC80GS PVC coating	PVC powder	Fluidised bed	150 - 750	Extensive
	Vylastic RS60 PCV coating	PVC plastisol	Plastisol	1.5mm - 6mm	Black
Fluoropolymers	Fluoroplas PVDF	Polyvinyledene fluoride	Fluidised bed or electrostatic spray	400 - 1000	Red/brown
	PTFCE	Polytrifluoromonochloroethylene	Pressure spray	200 - 250	Black
	Halar ECTFE	Ethylenechlorotrifluoroethylene	Fluidised bed or electrostatic spray	375 - 1000	Grey
Thermoplastic polyester	Macrotect	Polyester	Electrostatic spray, fluidised bed or flame spray	100 - 500	Extensive
Epoxies	Scotchkote 206N	Fusion-bonded epoxy	Fluidised bed or electrostatic spray	150 - 1000	Blue-green
	Duraguard epoxy	Fusion-bonded epoxy	Electrostatic spray	50 - 75	Extensive
	Epicol L1193	Two-pack, solventless epoxy	Brush, roller or airless spray	200 - 600	Off-white/red
Polyurethane	Irathane	Two-component polyurethane	Brush or airless spray	500 - 3000	Various

NOTE: The thicknesses quoted do not necessarily give a holiday-free coating. Only coatings which comply with WIS No. 4-52-01 are considered suitable for corrosion-free protection. Inclusion of a coating in this table does not imply any form of approval.

as an assurance of further longer term fitness for purpose in every application. This is particularly true for the Water Industry, where maintenance-free service lifespans of well over 50 years are commonly required. However, the performance of coatings which have been in use for a few years may give some guide to long-term suitability. Some systems may have failed prematurely, so for similar applications in the future the limitations of such systems should be considered carefully. When judging the performance of a coating in a service environment, the standard of the original application process should be taken into account.

It is important not to rely on hearsay or suppliers' claims which cannot always be substantiated. Where possible, independently reported or validated data should be sought on performance histories.

3.4.2.2 Relevant performance specifications

In service applications where WIS No. 4-52-01 is applicable, it is recommended that only those coatings complying with the WIS are used. This specification calls for a minimum level of coating performance which is aimed specifically at Water Industry applications. It is recommended that any additional performance requirements not covered in this WIS should be specified by the purchaser as supplementary requirements as appropriate. Where particular applications require specific coating performance features to be enhanced (e.g. abrasion resistance), this should be reflected by suitable amendments to the base specification.

As a preliminary measure, the WIS allows two standards of coating to be recognised. The first, referred to as category A, is required to be completely holiday-free. The second, referred to as Category B, is allowed to include a small number of holidays.

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Whilst Category A coatings will in all likelihood offer the greater security from corrosion attack, it should be noted that Category B represents a worthwhile standard of protection for products where completely holiday-free coatings cannot be applied cost effectively.

For service applications in which other types of corrosion protection are thought to be more appropriate, relevant standard performance specifications e.g. British Standards, CEN, ISO, or other WIS, should be used by the purchaser where they exist.

3.4.2.3 Expert consultation

There are many circumstances when expert advice will be helpful to individuals faced with the selection of a corrosion protection system. The advice sought could range from that which could be conveyed in a short telephone conversation to that which is derived from a carefully planned, long term testing programme.

In service applications where the asset has a great strategic or financial value it is advisable to consider obtaining expert advice on the selection of the corrosion protection system. Together with WRc, there are a number of other bodies which could be consulted for such advice and some of these are listed in the DTI's Committee on Corrosion's booklet entitled Controlling Corrosion, No. 2 Advisory Services[10].

3.5 Particular service application considerations

The following points are likely to have major influence in the selection of a polymeric coating for a particular service requirement:

3.5.1 Size of the article to be coated

The size of an article to be coated may range from a small component weighing less than 100g to a large fabricated structure or section of pipework weighing several tonnes. Whilst small articles may be readily heated to the temperatures required for certain application processes, they may not have sufficient thermal mass to enable the coating to be fully cured or fused. In this case, a post-application heating stage might be necessary to ensure the coating is fully fused and/or cured.

At the other extreme, it may not be feasible to pre-heat large structures and sections of pipework. Consequently, coatings which can only be applied to a hot surface will be eliminated from the range of options available.

3.5.2 Above-ground service applications

In applications where a coated structure is likely to be exposed to direct sunlight and weathering, the coating selected will obviously need to withstand these conditions. Coatings designed for below-ground use do not always contain the necessary ultra-violet-absorbing additives which are required to provide effective long term resistance to sunlight. WIS No. 4-52-01 includes a test for resistance to weathering. It is recommended that purchasers make reference to this test as appropriate. The duration of the weathering test exposure should be specified to reflect the intended service application.

Coated structures installed above ground are usually readily accessible. This factor makes periodic inspection and maintenance a realistic option not usually available when selecting coatings for below-ground applications. It is recommended that for low corrosivity applications, consideration is given to the use of low cost protection systems such as paints, which can be maintained periodically. However, in applications where exposure to marine or industrial environments results in high levels of corrosivity, it is advisable to make use of the high performance polymeric coatings.

It should be borne in mind that although a coated item may be designed for underground use, it may spend many months in open storage exposed to the weather.

3.5.3 Wear resistance

WIS No. 4-52-01 provides a basic abrasion resistance requirement based on a combination of two generalised performance tests. These tests include the stone impact test and the tumbling slurry abrasion test. Where abrasion is a particular problem, consideration should be given to uprating the specification requirements.

In service applications where a specific mode of coating wear can be foreseen which is not adequately covered by the tests mentioned above, consideration should be given to the specific wear properties required of the coating. The following applications are presented as examples:

(a) pump impeller coatings which are required to withstand the effects of cavitation of the conveyed water;

(b) internal valve coatings which are required to withstand periodic movements of gates which may be forced against the coated surface by the pressure of the conveyed water.

3.5.4 Resistance to chemicals

In service applications where the concentration of aggressive chemicals is likely to be significant, assurances should be sought from coatings suppliers as to the likely effect of these chemicals on the performance of their coatings. Such assurances, where given, should be substantiated either by successful case histories or valid accelerated laboratory testing.

Contaminated ground may occur in a wide range of situations e.g. reclaimed waste tips, industrial sites, spillage etc. Guidance on investigation of contaminated sites is contained in WRc plc report entitled "The Effect of Soil Contaminants on Materials used for Distribution of Water" (PRD 1452-M/1)[25]. In all cases, the contaminants present should be identified so that a suitable product can be chosen. Further guidance on this can be obtained from WRc plc.

3.5.5 Soil conditions

Soil types vary in terms of their moisture content, pH, abrasiveness, microbial activity etc. Conditions likely to affect the choice of coating should be investigated. It may be useful to have a soil survey carried out.

3.5.6 The use of cathodic protection and the phenomenon of cathodic disbondment

Since polymeric coatings rely on their physical barrier properties for the protection they afford to metal surfaces, it is often considered necessary to provide some supplementary form of protection particularly where coating damage or flaws may arise, as these, are likely to be potential starting points for corrosion.

In service applications where such impairment of the coating performance cannot be tolerated, cathodic protection may be employed to suppress the corrosive anodic reactions which would otherwise take place at these coating discontinuities.

In these circumstances, and in areas where stray electrical currents are likely to be encountered, polymeric coatings should be selected which have adequate resistance to the phenomenon of cathodic disbondment. WIS No. 4-52-01 includes a test which assesses the resistance of polymeric coatings to this effect.

3.5.7 Flexibility

Whilst some degree of flexibility is required in all polymeric coatings in order to provide adequate resistance to general flexure and impact, some coated products are required to withstand particularly high strains in the course of their installation or use. Such products include pipe repair clamps, flexible pipe couplers and pipework which is highly strained during factory or field handling or during installation.

In extreme cases the general specification requirement for flexibility contained in WIS No. 4-52-01 (i.e. no damage to the coating after three point bending to 1% strain at 0°C) may not be sufficiently demanding and consideration should be given to uprating the test strain appropriately in the purchaser's specification.

3.5.8 Temperature

All coatings have a recommended temperature range outside which they should not be used. Some of these are so wide that they are not a limitation for most Water Industry uses, but some coatings are not suitable for hot-water applications, whereas others (more unusually) may have impaired properties at very low temperatures (e.g. below 0°C).

3.5.9 Making good welded joints on site

Where precoated articles are to be welded on site it will be necessary to make good the uncoated weld and cut-back areas with a coating which is compatible with existing pre-applied coatings. For

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such applications it will be necessary to ensure that compatible and effective combinations of factory and site applied coatings are selected at the design stage.

When selecting a coating which is to be applied on site, it is also necessary to consider the tolerance of the candidate materials to the likely prevailing conditions on the site (e.g. particular generic types of material may well be more tolerant of damp surfaces than others).

The same advice applies for maintenance repairs. In these cases the condition and possible preparation of the substrate must be considered.

3.5.10 Coatings containing solvents

The evolution of solvent during the "drying out" of solvent-based coatings, whether it be during factory or site application, can constitute a hazard, especially when the coating has been applied in a confined space. Care should be taken at the design stage to ensure that closed vessels which are to be coated with such systems contain adequate vents through which the solvent can be extracted. In cases where adequate ventilation and extraction of the solvent cannot be carried out reliably, solvent-based coatings should be avoided.

3.5.11 Multi-component coatings for use in contact with potable water

Multicomponent, resin-based coatings often contain constituents which, if not fully reacted during cure, may be leached out during subsequent immersion of the coating in water. When such coatings are likely to come into contact with potable water, it is essential that, where they contain compounds which could conceivably affect the quality of potable water, the mix ratio and curing process are closely controlled, so as to minimise the quantity of unreacted substance available. WIS No. 4-52-01 requires that all coatings which are likely to come into contact with potable water during their service life comply with the requirements of Regulation 25 of the Water Supply (Water Quality) Regulations 1989[27].

In practice, new materials must be proven to satisfy the requirements of BS 6920 and be approved under the Water Byelaws Scheme. If the surface area in contact with the water is small, the above requirements are likely to be sufficient for the product to be used under Regulation 25(1) (b). If the surface area is relatively large, then Secretary of State approval under Regulation 25(1) (a) is required. This involves consideration of the product by the 'Department of the Environment Committee on Chemicals and Materials of Construction for Use in Public Water Supply and Swimming Pools'. If the coating is to be applied in situ (e.g. on-site repair materials), the approval of the Secretary of State must be sought.

A list of approved substances and products is published annually and is available from the Technical Secretary of the Committee at the Drinking Water Inspectorate, Room B153, 43 Marsham Street, London SW1 3PY.

This requirement may influence the prospects for the selection of certain types of coating which cannot be mixed within sufficiently close tolerances by typical industrial application procedures.

3.6 Continuing performance assessment

It has been suggested in Section 3.4 that previous experience of coating performance in particular service applications can provide some indication as to whether or not that coating should be selected for future applications of a similar nature.

In order to build up such experience, it is recommended that Water Industry users of polymeric anti-corrosion coatings maintain an ongoing assessment of the performance of such protection systems.

It is recommended that such assessments should be carefully reported from the outset to ensure that the full value of the exercise is realised. A typical assessment report might include for example:

- A description of the protected product;
- A full description of the coating used to protect the product;
- A full account of the quality history of the coating itself (e.g. inspection and test results from both the coating material production and the factory application stages);
- A full description of the service application environment including such parameters as soil resistivities, concentration of chloride present, presence and nature of ground water etc.

Where water utilities opt to pursue this approach of collecting service performance data it is suggested that they collaborate with other utilities with a view to co-ordinating their assessment programmes. In this way, it should be possible to collect a wide range of performance data in an efficient manner, to which all participating water utilities will have access.

4. PACKAGING AND TRANSPORTATION

4.1 Introduction

The information contained in this section is intended to augment and complement both the generalised requirements included in Section 4.14 of BS 5750: Part 2: 1987[11] and other guidance provided in existing product specifications.

The overall aim of these requirements is to ensure that damage to, or deterioration of, the product is prevented during handling, storage and transport by the use of adequate product packaging and appropriate operational procedures.

One obvious way of overcoming this potential problem is to apply a complementary safeguard in the form of cathodic protection. Although cathodic protection has not been widely used in the UK Water Industry to date, it has been employed successfully in the protection of steel mains. The cathodic protection of individual fittings is, however, highly problematical and is rarely carried out.

Whilst cathodic protection can be used to inhibit corrosion at sites of coating damage which have escaped detection and repair, it is important to minimise the incidence of such coating damage for two reasons. The first is that as the area of metal exposed by coating damage increases, the current demanded by the cathodic protection system may ultimately reach an unacceptable level. The second is that sites of coating damage may initiate further localised disbondment of the coating as a direct effect of the concentration of cathodic protection current and the associated localised increase in pH, due to the production of hydroxyl ions at the cathodic surfaces.

The following guidelines are intended to cover each stage of handling, storage and transportation, from the point of initial coating application to the final installation of the coated product by the Water Industry user or its contractor.

4.2 General points

4.2.1 Personnel and training

In addition to the training requirements included in Clause 4.17 of BS 5750: Part 2: 1987[11], all persons employed for the handling of coated products, whether manually or by mechanical equipment, should be instructed and trained in the correct and safe procedures.

4.2.2 Safety and relevant legislation

The following Acts and Regulations should be consulted where relevant, and their provisions observed:

- The Control of Substances Hazardous to Health Regulations 1988;[12]
- Health and Safety at Work, etc. Act 1974;[13]
- Factories Act 1961;[14]
- The Construction (General Provisions) Regulations 1961;[15]
- The Construction (Lifting Operations) Regulations 1961;[16]
- The Construction (Working Places) Regulations 1966;[17]
- The Construction (Health and Welfare) Regulations 1966;[18]
- The Offices, Shops and Railway Premises Act 1963;[19]
- Motor Vehicles (Rear Marking) (Amendments) Regulations 1970;[20]
- Motor Vehicles (Construction and Use) Regulations 1986.[21]

Note: Any Water Industry certifications gained in recognition of compliance with the recommended practices contained in this guidance do not absolve the certificated party from any legal obligations which may be incumbent upon them.

4.2.3 Product design

Careful consideration should be given during the design of a coated product to the way in which it is to be packaged and subsequently handled and transported prior to its final installation. The design of the packaging itself should also be considered at this stage.

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4.3 Packaging for transportation

There are numerous options available for the protection of coated products during transportation and handling and the Purchaser should specify at the time of tendering or ordering the degree of protection to be provided.

Suitable types of packaging include:

- Shrink wrapping;
- Polythene bubble sheet wrapping;
- Corrugated cardboard;
- Loose polystyrene packing;
- Individual cardboard boxes;
- Plastic mesh protection;
- Heavy duty polythene bags.

Flanges, pipe ends and other openings can be protected with push-on plastic caps or wooden blanks.

Where several items are to be transported in one container, suitable soft packing materials should be used to separate and protect individual items against contact with their neighbours and the surrounding container.

Palletisation is advisable for boxes or individual items.

Screws, nuts, washers and other coated components of a similar size are frequently handled loose together in large containers prior to assembly. In cases where such handling is found to result in coating damage the following alternative handling methods should be considered:

- Corrugated cardboard or plastic trays;
- Expanding plastic mesh cylinders;
- Peg boards for nuts and washers, etc.

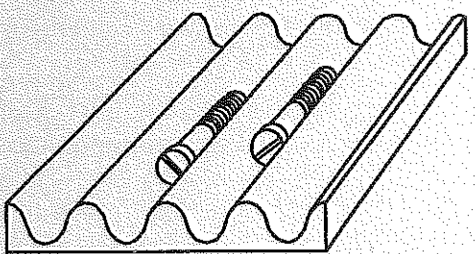

Figure 4.1 - Corrugated cardboard or plastic trays

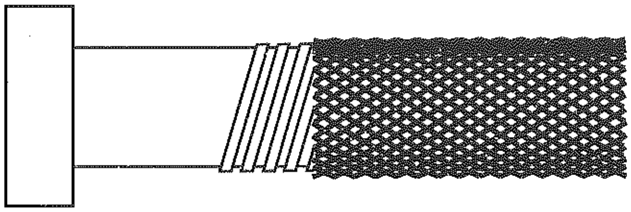

Figure 4.2 - Expanding plastic mesh cylinders

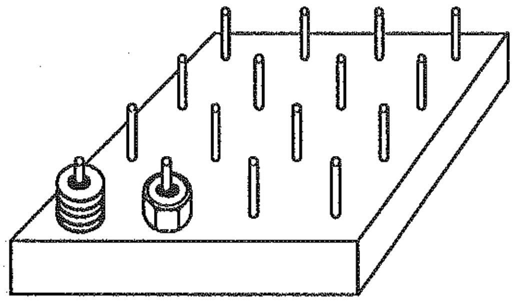

Figure 4.3 - Peg boards for nuts and washers, etc.

When specifying a packaging or protection method, the Purchaser should take into account:

- The purpose for which the coated item is being purchased;
- The required asset life of the item;
- The degree of risk of damage prior to installation and use;
- The cost and availability of damage repair facilities prior to the installation and use of the item;
- The storage facilities available and the length of time the item is likely to be stored prior to installation and use.

It should be borne in mind when deciding on the extent of additional protection to be provided by way of packaging that most manufacturers and suppliers have their own standard methods of packaging. These are frequently suitable for normal transport conditions where short distances, minimum delays in transit and minimum handling are involved but are rarely sufficient for more severe conditions. It would always be wise therefore for the Purchaser to consult potential suppliers at an early stage regarding their standard methods and to decide if they meet his requirements. When they do, details of the methods should be agreed and written into the purchase specification before tenders are invited or orders placed. If they do not, they should be rejected and an adequate method of protection agreed with the supplier.

The Department of Trade and Industry's guide to practice in corrosion control (Number 3) contains further detailed notes on packaging for handling and transport of coated goods in the Construction Industry(22).

Any product identification provided with a consignment of goods should be firmly fixed to the exterior of the packaging. Where the products are individually identified, these identifications should also be included in the external notice. This practice is intended to eliminate the need to open protective packaging until absolutely necessary for inspection purposes or prior to installation.

The cost of packaging, particularly of large pieces, should always be compared with the likelihood, extent and effect of any damage, and the cost of repairs. On large items it may well be more cost-effective to use less packaging, and carry out repairs on site in accordance with the coating supplier's recommended procedure.

4.4 Transportation

It is not possible to define a standard method for the transportation of coated items owing to the diversity of shapes and sizes of coated product used in the UK Water Industry and the variety of quantities which are transported. The principles to be observed are that all coated items are to be stored, packed, loaded and protected safely for conveyance so as to prevent damage and deterioration.

All loads should be adequately secured against any kind of movement during transportation and adequate padding should be used to protect the coated items against damage caused by securing straps. Care should be taken to ensure that wire ropes, chains, etc. do not come into direct contact with the coated items. Additional padding should be placed between all possible points of contact to prevent damage.

If a specified method of packaging for transportation such as palletisation is required, then this should be specified by the Purchaser at the time of tendering or ordering.

When coated fittings are to be transported, liaison should be established to ensure that the method of packaging for transportation to be used is compatible with the means of off loading at the delivery point.

Spreader beams and nylon belt slings complying to BS 3481: Part 2(21) are favoured for the lifting of coated pipes and they should be used whenever appropriate and practicable. Alternatively, profiled hooks or rod inserts can be used in conjunction with a spreader beam, where necessary. The effective length of the spreader beam should always be less than that of the span between the connections to the profiled hooks or rod inserts. It is not advisable to use wire ropes or chains for lifting coated pipes.

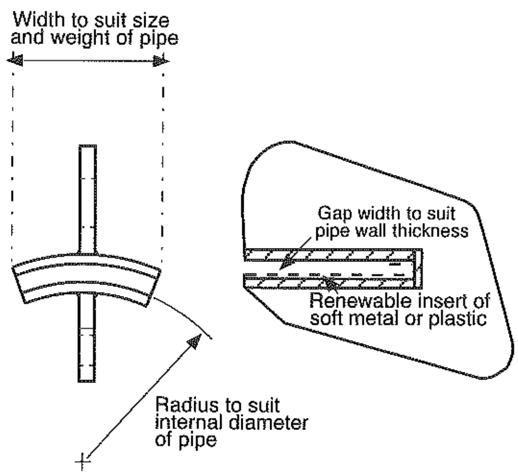

Figure 4.4 - Example of profiled hook

The responsibility for arranging the transportation of coated items may vary and whoever is responsible (supplier/purchaser/fabricator or contractor) should instruct the carrier as to the specific precautions to be observed.

Further details on the handling, storage, and transportation of coated and wrapped steel pipes are contained in the Department of Trade and Industry's Guide to Practice in Corrosion Control (Number 5)(23).

4.5 Storage

Whilst coatings which have been developed for outdoor exposure applications may be stored outside for long periods without problems, anti-corrosion coatings, which are formulated for

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below ground use, may be susceptible to degradation if exposed to direct sunlight for prolonged periods.

The type of storage arrangements required therefore depends upon the type of coating in question, the local climate and the likely duration of the storage.

Whenever possible or practical, coated items should be stored under cover if serious damage or deterioration to the coating is likely to result from external storage.

Stocks should be rotated to ensure that they are used in such an order as to prevent unnecessarily long periods of storage.

For external storage, the following general guidelines should be applied:

- the storage site should be secure and should have good access from the public highway;
- the storage area should be level, well drained and suitable for the provision of firm foundations;
- the site should be remote from chemical and industrial environments that could be detrimental to the protective coating;
- suitable and adequate standings should be provided to avoid damage to the items being stored;
- the method used for the stacking of coated items should be safe, should prevent damage and should aid subsequent handling and transportation.
- all stocks and stacks should be so arranged as to provide adequate vehicular and pedestrian access and the necessary space for manoeuvring transport vehicles and lifting appliances.

5. REFERENCES

This note makes reference to or should be read in conjunction with the latest edition of the following documents, including all addenda and revisions.

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