BRITISH STANDARD

BS 6374-4:
1984

Lining of equipment with polymeric materials for the process industries —

Part 4: Specification for lining with cold curing thermosetting resins

UDC 621.772.4:66.023.3:678.6.073

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Pressure Vessel Standards Committee (PVE/-) to Technical Committee PVE/1 upon which the following bodies were represented:

Amalgamated Society of Boilermakers, Shipwrights, Blacksmiths and Structural Workers
Associated Offices Technical Committee
Association of Consulting Engineers
British Chemical Engineering Contractors' Association
British Compressed Gases Association
British Gas Corporation
British Steel Industry
Electricity Supply Industry in England and Wales
Energy Industries Council
Engineering Equipment and Materials Users' Association
Health and Safety Executive
Institution of Chemical Engineers
Institution of Gas Engineers
Institution of Mechanical Engineers
Liquefied Petroleum Gas Industry Technical Association (UK)
Process Plant Association
Water-tube Boilermakers' Association
Welding Institute
Coopted member

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Rubber Manufacturers Association
Institution of Corrosion Science and Technology
Plastics and Rubber Institute
Rubber and Plastics Research Association of Great Britain

This British Standard, having been prepared under the direction of the Pressure Vessels Standards Committee, was published under the authority of the Board of BSI and comes into effect on 31 December 1984

The following BSI references relate to the work on this standard:
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Contents

Foreword

This Part of BS 6374 has been prepared under the direction of the Pressure Vessels Standards Committee. It is one of five Parts that will supersede Parts 1, 4, 5 and 6 of CP 3003; the change in format arising from the fresh approach adopted to conform with developments in the associated lining technology.

The Technical Committee would like to acknowledge the contributions made by the Rubber and Plastics Research Association of Great Britain which supplied the initial draft document, and the users and the manufacturers on whose submissions the document was based.

The plastics linings referred to in this standard are used for a number of different duties, including protection against corrosive environments, prevention of contamination of products and surface finishes which do not foul easily or which can be cleaned easily. Specific linings are used for protection against abrasion or erosion.

The thickness of linings based on these materials varies considerably. When the thickness of the lining is less than 400 μm it is difficult to obtain linings which are pinhole free. Furthermore, even if thin linings as applied are free from imperfections, consideration has to be given to the possibility of damage in operation.

Before selecting a lining and the thickness at which it will be applied, some knowledge is required of the likely corrosion rate of the substrate and the mechanism of that corrosion. If the corrosion rate is low then the thickness of the lining is not a critical factor. If the corrosion rate is high and is due to simple solution of the metal, then it is not advisable to use thin linings because of the risk of severe corrosion through a pinhole. On the other hand, if a high corrosion rate is caused by an effect such as erosion/corrosion, then thin linings can be an effective barrier.

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

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

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 22, an inside back cover and a back cover.

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

Section 1. General

1.1 Scope

This Part of BS 6374 specifies requirements for the lining of equipment for the process industries using cold curing thermosetting resins.

It includes requirements for the choice of lining and its application and also requirements for subsequent inspection of the lining and the rectification of faults. It applies to equipment fabricated in metal or concrete.

The lining materials considered include epoxies, polyesters and furanes. Although not thermosetting resins, liquid elastomeric linings (such as polyurethanes) and solvated elastomeric linings (such as polychloroprene), are included since the same application techniques are used.

NOTE 1 The resins may contain fillers and/or reinforcing agents.

NOTE 2 The linings may be applied at the applicator's works or on site.

Requirements for design and fabrication of the equipment and the state of preparation necessary for the surfaces to be lined are specified in Section 2. Requirements for storage, handling, transportation and installation of the lined equipment are specified in Section 8.

This Part of BS 6374 does not apply to paint coatings as dealt with in BS 5493.

NOTE 3 The titles of the publications referred to in this standard are listed on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 6374, the following definitions apply.

1.2.1
plastic[1] (noun)

a material that contains as an essential ingredient a high polymer and which at some stage in its processing into finished products can be shaped by flow

NOTE 1 Elastomeric materials, which are also shaped by flow, are not considered as plastics.

NOTE 2 In some countries, particularly in the United Kingdom, the official position now is that it is a permitted option to use the term "plastics" as the singular form as well as the plural form.

1.2.2
resin [1]

a solid, semisolid, or pseudosolid organic material that has an indefinite and often high relative molecular mass, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range and, usually fractures conchoidally. In a broad sense, the term is used to designate any polymer that is a basic material for plastics

1.2.3
thermoset[1] (noun)

a plastic which, when cured by heat or by other means, changes into a substantially infusible and insoluble product

NOTE This term includes both thermosetting plastics and thermoset plastics.

1.2.4
purchaser[2]

the organization or individual who buys the lined equipment for its own use or as an agent for the owner

1.2.5
fabricator[2]

the organization or individual responsible for the fabrication of the equipment to be lined

1.2.6
applicator[2]

the organization or individual responsible for the application of the lining

1.2.7
inspection authority[2]

the body or association appointed by the purchaser (or owner) to check that the design, fabrication, and lining comply with this standard

1.2.8
lining

a cold curing thermosetting resin coating based on resins which cure by chemical reaction at normal ambient temperatures

NOTE 1 Although in common usage the terms "lining" and "coating" are interchangeable, in this document "lining" will be used.

NOTE 2 Examples are: epoxies, modified epoxies, epoxy novolaks, furanes, polyesters, bisphenol polyesters, vinyl polyesters, and polyurethanes.
Formulations based on these resins may or may not contain solvents which evaporate before the curing process is complete.

1.2.9
cure

the chemical reaction resulting in the final polymerized product

1.2.10
pinhole

a small defect in the lining that would permit corrosion of the substrate under the conditions for which the lining is designed

NOTE The word "pinhole" is synonymous with "holiday" and "pore".

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[1] These terms have been extracted from BS 1755-1.
[2] Where the words "purchaser", "fabricator", "applicator" and "inspection authority" occur in the text, they are intended also to include representatives of the purchaser, fabricator, applicator and inspection authority.

1.2.11
blister

a gas or liquid filled cavity within the lining material or between the lining and substrate

1.3 Exchange of information

Early consultation shall be arranged between all parties concerned with the application of this standard, to establish the following information which shall be fully documented. Both the definitive requirements specified in this standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

a) Design and fabrication details of the equipment to be lined and provision of drawings (see **2.2**, **2.3**, **2.4** and **2.5**).

b) Details of gasket materials (see **2.2.9** and **2.2.10**).

c) Details of the contents of the vessels or equipment, including trace materials [see **3.1.1** a)].

d) The design temperature [see **3.1.1** b)].

e) The design pressure [see **3.1.1** c)].

f) The details of any solids to be handled [see **3.1.1** e)].

g) The methods of heating and/or cooling [see **3.1.1** b)].

h) Cleaning methods, for example, water washing, solvent washing, boiling out or steaming [see **3.1.1** a)].

i) Where the lining work will be done.

j) Site conditions that may affect the work, for example availability of services.

k) Any special requirements for materials used in blast cleaning (see **4.1.1.3** and **4.1.2.2**).

l) The type of material to be used for lining (see **3.1.1**).

m) The minimum thickness of the lining and where applicable the maximum thickness (see **3.2.2**).

n) The provision of test pieces (see **3.2.1** and **5.2.4**).

o) The maximum number of pinholes per square metre of surface if they are permitted (see **3.3**).

p) When the lining is to be applied outside the applicator's works and the resin as applied contains solvents, the types of solvents shall be stated, together with their flash points and threshold limit values.

q) The minimum and maximum allowable temperature that is required for the correct application of the lining (see **4.2**).

r) The minimum temperature required during the curing of the lining and where applicable the curing schedule (see **4.2**).

s) Inspection techniques/procedures to be employed, acceptance levels and stages of inspection (see **5.1** and **5.2**).

t) Use of different materials for repair (see **7.1.5**).

u) Handling, transport, storage and installation procedure (see **3.1.1** g) and **8.1.1** to **8.1.7**).

1.4 Compliance

1.4.1 Fabricator

The fabricator shall comply with the following:

a) section 2 [see **1.3** a)];

b) **5.1** a) and b);

c) Section 8 as agreed in **1.3** u).

1.4.2 Applicator

The applicator shall comply with the following:

a) Section 3 (but see **3.2.1**);

b) Section 4;

c) **5.1** c), d), e) and f);

d) Section 6;

e) Section 7;

f) Section 8 as agreed in **1.3** u).

Section 2. Design, fabrication and surface finish of equipment to be lined

2.1 General

The basic design, fabrication and testing for mechanical reliability of the equipment to be lined shall be carried out to appropriate British Standards and shall comply with **2.2** and **2.3** or **2.4** and **2.5**, as appropriate, before the lining operation commences.

2.2 Design of metal equipment to be lined

2.2.1 Equipment to be lined shall be sufficiently rigid that there is no possibility of deformation which would result in damage to the lining during transportation, installation and operation. When stiffeners are required, they shall normally be applied to the unlined side of the equipment.

2.2.2 The arrangements for the lifting of equipment shall be determined at the design stage.

2.2.3 The design of all equipment shall allow for access during the preparation of the surface and application of the lining and for venting of fumes evolved during the operation.

In completely enclosed vessels there shall be at least one manhole that after lining complies with BS 470 and one additional branch of not less than 75 mm bore to permit adequate circulation of air.

NOTE It is recommended that, where practicable, the minimum diameter of a manhole should be 600 mm.

2.2.4 Riveted constructions shall not be used.

2.2.5 Bolted joints shall be permitted only if they can be dismantled for lining.

2.2.6 Surfaces to be lined shall be of a smooth contour.

2.2.7 Discontinuities, crevices and sharp projections shall be avoided.

2.2.8 Fittings that have to be installed after the completion of the lining process shall be designed to be lined or fabricated from materials that will not be affected by the process conditions.

2.2.9 Normally all connections to lined parts of equipment shall be flanged. If for any reason screwed connections are required, then these parts shall be fabricated in corrosion-resistant materials.

2.2.10 All nozzles and outlets shall be as short as possible, straight and flanged. Flange faces shall have a plain surface to allow the lining to continue over the face.

2.2.11 Heating coils, immersion heaters and sparger pipes shall be installed after the completion of the lining process and shall be located so that no part is closer than 100 mm from a lined surface. In the case of nozzles through which heating coils, etc. enter equipment, a smaller clearance is permitted provided that the temperature of the pipe through the nozzle does not exceed 80 °C. In no case shall this clearance be less than 25 mm. Fluid introduced through sparger pipes or dip pipes shall not impinge directly on to the lining. External heating of equipment shall not be permitted without full consultation with the applicator of the lining.

2.2.12 The design of pipework shall be such as to allow ready access to welds and bends for inspection and surface preparation.

NOTE Systems made up from straight lengths with separate bends and tees meet this requirement (see Figure 1).

Where pipes incorporating branches and bends are to be used, the diameter of the pipe and length of the fitting shall allow access for surface preparation and application of the lining. There shall be not more than one bend in any one pipe length [see Figure 1 d)]. The dimensions of such pipes shall form part of the requirements of **1.3** a).

2.3 Fabrication of metal equipment to be lined

2.3.1 All welds shall be continuous on surfaces to be lined.

NOTE Butt welds are preferred to fillet welds.

Stitch welding, spot welding and non-continuous welding processes shall not be used.

2.3.2 Weld surfaces shall be smooth. Some welding procedures provide surfaces of adequate smoothness but, in other cases surfaces shall be ground wholly or partly to remove weld ripples. The grinding process shall be done so that the remaining weld does not have sharp edges.

2.3.3 Welding procedures shall be chosen to avoid porosity on the side of the weld to be lined.

NOTE It is preferable that capping runs are applied to the lining side in order to minimize this effect.

All welds shall be free from the following surface defects:

a) undercutting;

b) cracks;

c) porosity;

d) any other type of surface cavity;

e) lack of fusion.

Weld defects that are exposed either on initial inspection or after blast cleaning shall be repaired.

Repairs shall be by grinding or by welding (with or without subsequent grinding) provided that the requirements for equipment design and fabrication are met.

2.3.4 Weld profile details shall be generally in accordance with Figure 2 to Figure 6.

NOTE Incorrect details are also illustrated.

2.3.5 Filler materials, such as resin, putties, fillers and low melting point solders and brazes, shall not be used.

2.3.6 Before the equipment is passed for lining, all attachments to be made by welding, for example lagging cleats and lifting lugs, shall be complete.

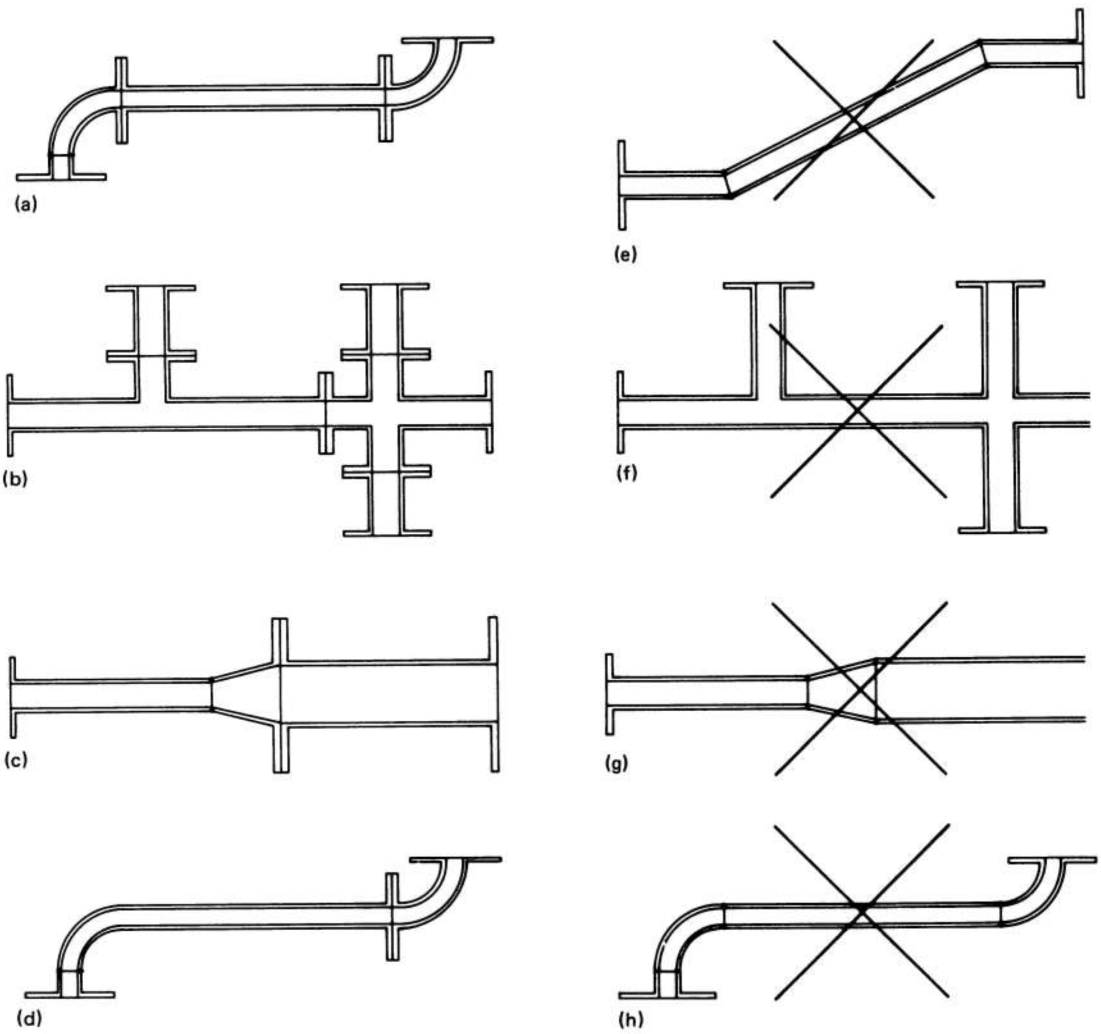
2.3.7 All drilling shall be completed before the equipment is passed for lining.

2.3.8 All changes in contour shall be finished to a radius of not less than 3 mm.

2.3.9 All slag, anti-spatter compounds or similar materials shall be removed.

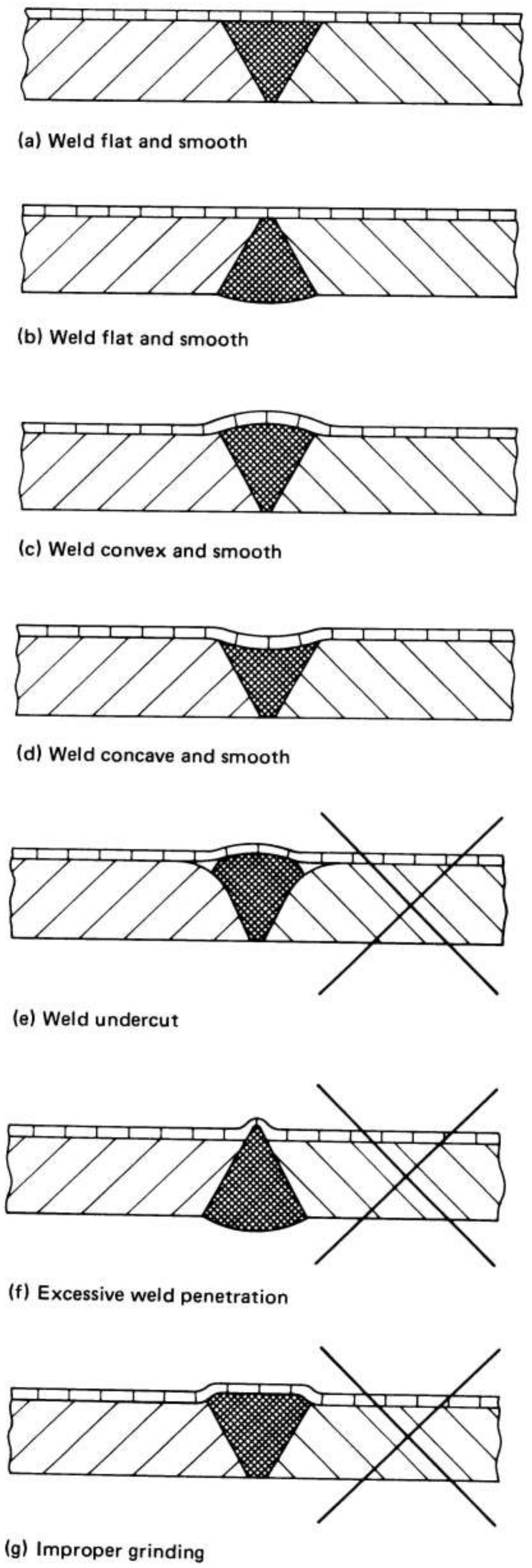
All weld spatter shall be removed by chipping and/or grinding.

2.3.10 Surface defects such as scores, pitting and rolling defects, shall be removed by grinding, or where necessary repaired by welding provided that the requirements of design and construction are met.



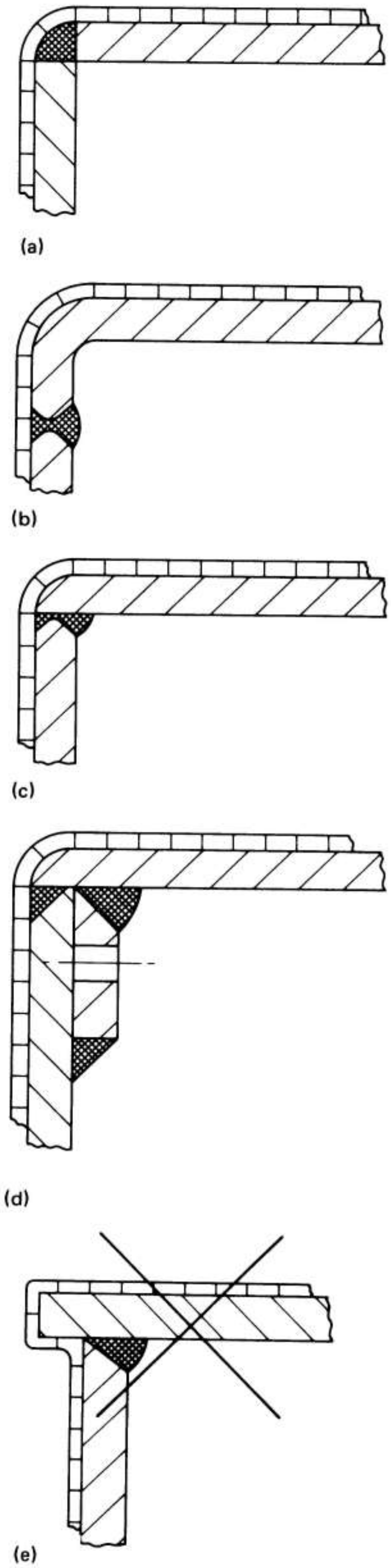
NOTE The details shown in (a), (b), (c) and (d) are permissible; those shown in (e), (f), (g) and (h) are not permissible.

Figure 1 — Pipework details



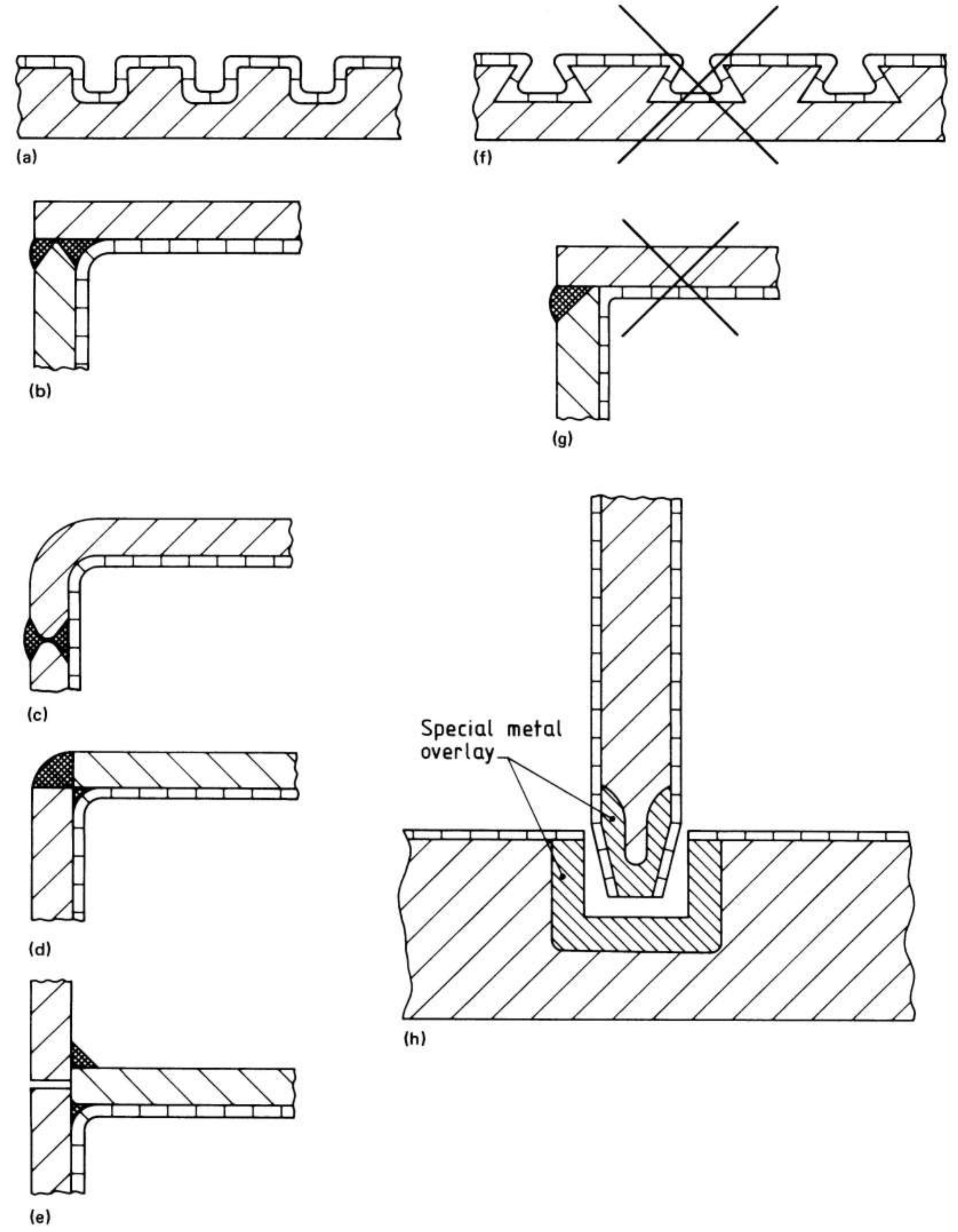
NOTE The details shown in (a), (b), (c) and (d) are permissible; those shown in (e), (f) and (g) are not permissible.

Figure 2 — Weld profile details: butt welds



NOTE The details shown in (a), (b), (c) and (d) are permissible; those shown in (e) are not permissible.

Figure 3 — Weld profile details: external corners and edges



NOTE The details shown in (a), (b), (c), (d), (e) and (h) are permissible; those shown in (f) and (g) are not permissible.

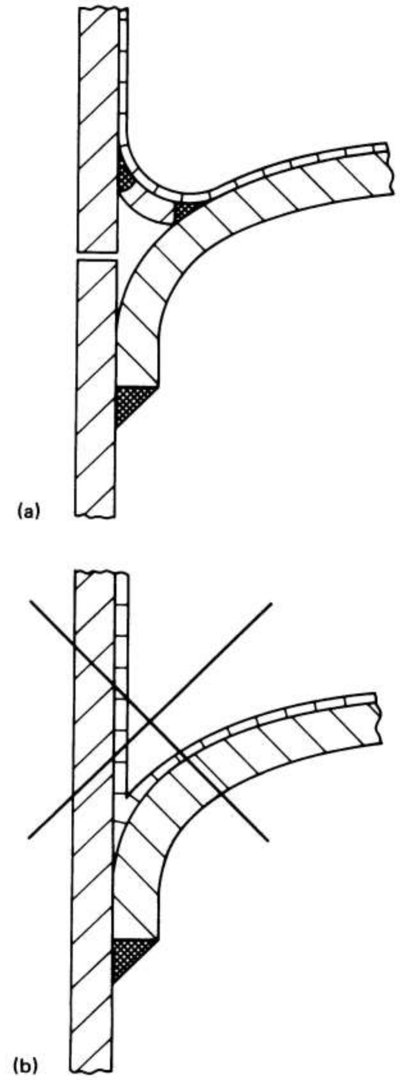
Figure 4 — Weld profile details: internal corners and edges

2.4 Design of concrete equipment to be lined

2.4.1 Concrete equipment shall be designed to BS 5337. Whilst it is not possible to eliminate shrinkage cracks in concrete, the design shall be such that structural cracking is eliminated.

Particular attention shall be given to the need to avoid cracking due to thermal stresses.

NOTE Ability of the lining material to accommodate cracking of the concrete will determine the detail of design. Equipment fabricated to Class A of BS 5337 is liable to develop shrinkage cracks up to 0.1 mm wide. Equipment fabricated to Class B of BS 5337 is liable to develop shrinkage cracks up to 0.2 mm wide.



NOTE The details shown in (a) are permissible; those shown in (b) are not permissible.

Figure 5 — Weld profile details: concave heads

2.4.2 If necessary, extra reinforcements shall be used and construction joints treated so as to promote a bond between adjacent areas of concrete. Expansion joints create problems in lining and shall not be used without consultation between the purchaser and the applicator of the lining [see **1.3** a)].

2.4.3 Pipes and fittings shall be designed with puddle flanges and cast into the concrete. Where necessary such fittings shall be designed in a corrosion-resistant material.

2.4.4 The arrangements for the lifting of equipment shall be determined at the design stage.

2.4.5 The design of all equipment shall allow for access during the preparation of the surface and application of the lining and for venting of fumes evolved during the operation.

In completely enclosed vessels there shall be at least one manhole that after lining complies with BS 470 and one additional branch of not less than 75 mm bore to permit adequate circulation of air.

NOTE It is recommended that, where practicable, the minimum diameter of a manhole should be 600 mm.

2.4.6 All corners shall be designed to be formed with a 45° fillet with a minimum leg length of 20 mm.

2.4.7 All equipment to be placed below ground level or subject to external water pressure shall be provided with a waterproof barrier on the outside of the equipment.

2.4.8 All equipment shall be designed with a minimum of 20 mm of concrete over reinforcement.

2.5 Construction of concrete equipment to be lined

2.5.1 All concrete equipment shall be constructed in accordance with the requirements of BS 5337.

2.5.2 Proper curing of the concrete shall be ensured by the use of curing membranes wherever necessary. If shuttering is removed in under 7 days a curing membrane shall be applied.

Concrete equipment shall be allowed to cure for 28 days before the work of lining proceeds.

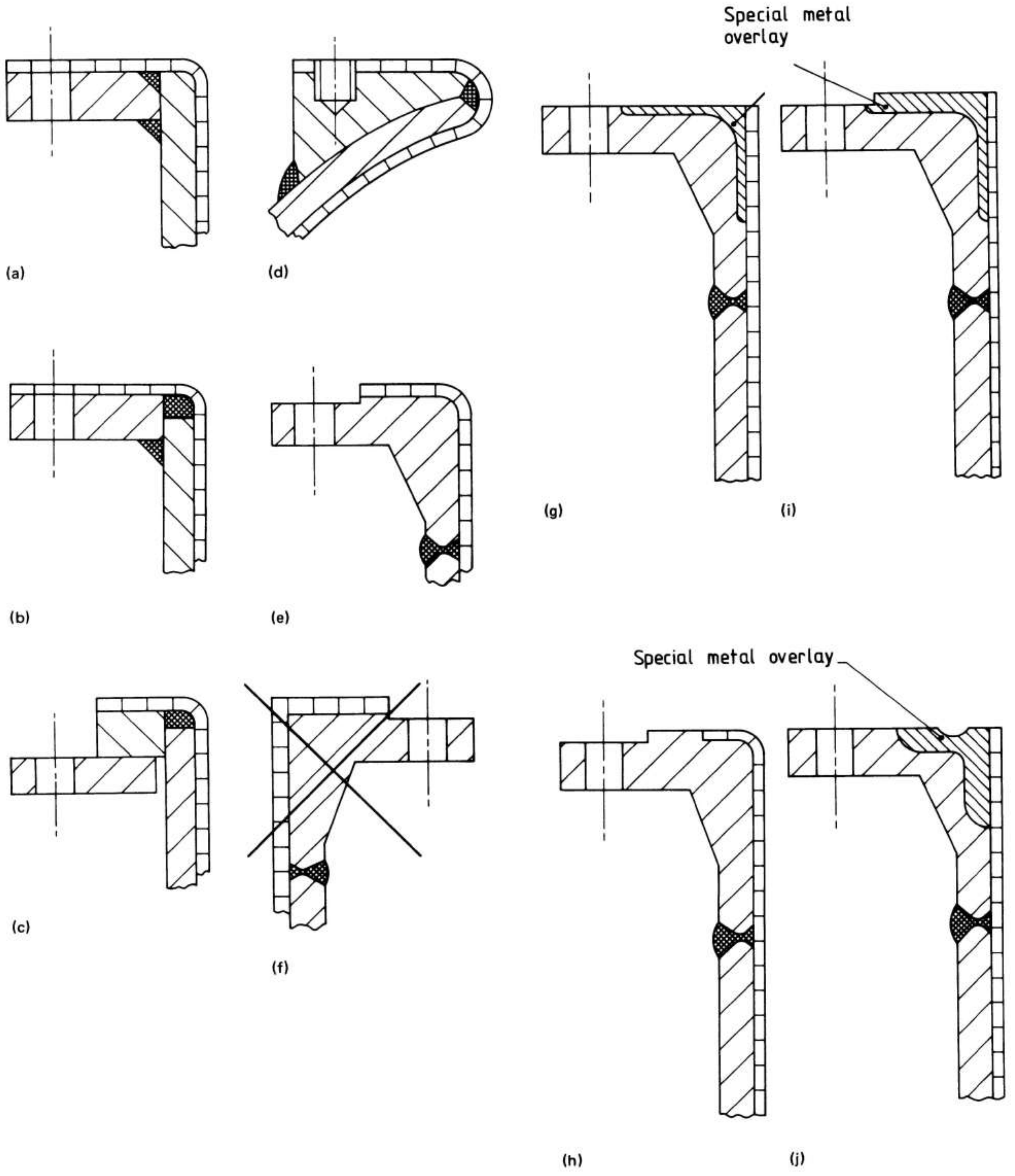
2.5.3 Equipment which is slip formed shall be bagged as the concrete leaves the formwork before the curing membrane is applied.

NOTE This process will reduce the amount of laitence.

2.5.4 All surfaces not cast against shutters shall be finished with a wooden float. Curing membranes shall be applied and not disturbed for 7 days.

2.5.5 Any steps in the concrete due to misalignment of shutters or surplus material formed because of gaps at joints in shutters shall be dressed off and ground smooth.

2.5.6 All holes left after removal of ties to secure and align formers shall be filled. Any surface defects such that the aggregate is exposed shall be filled. The material used for filling shall be a sand/cement grout with a high cement content or a sand/cement water miscible epoxy resin grout or an epoxy resin mortar.



NOTE 1 The details shown in (a), (b), (c), (d), (e), (g), (h), (i) and (j) are permissible, those shown in (f) are not permissible.
NOTE 2 The details shown in (a), (b), (c), (d) and (e) relate to flanges with lined faces.
NOTE 3 The details shown in (g), (h), (i) and (j) relate to flanges with metal-to-metal faces.

Figure 6 — Weld profile details: flanges

Section 3. Selection and quality of linings

3.1 Selection of lining

3.1.1 Selection of the grade of lining to be used shall be based on the duty for which it is intended.

In selecting a lining for a particular duty, the rate of corrosion of the substrate, the mechanism of that corrosion and the thickness of the type of lining to be used shall be considered, in addition to the chemical resistance of the lining.

NOTE Descriptions of lining materials and their characteristics are given in Appendix A.

The selection of the grade of lining shall be based on the following information. When an applicator is to select and apply the lining, full details of the duties of the equipment shall be supplied.

a) *General:* full analysis of the contents of the equipment including constituents present in small and trace quantities, and details of cleaning operations.

b) *Temperature of materials to be handled:*

1) normal operating temperatures;

2) maximum and minimum temperatures;

3) cycle of temperature variation.

c) *Degree of vacuum or pressure:*

1) normal operating pressure;

2) maximum and minimum pressures;

3) cycle of pressure variation.

d) *Cycle of operations:* whether batch or continuous process.

e) *Abrasion and erosion:* details of amount, particle size and physical characteristics of the suspended matter together with rates of flow.

f) *Mechanical damage:* any difficulties expected in the handling and final siting of the equipment or any vibration of equipment and the possibility of mechanical damage.

g) *Special conditions:* for example extremes of weather likely to be encountered during the handling, transport and storage of the equipment.

3.1.2 Unless previous experience demonstrates that a lining will be suitable for a particular duty, appropriate testing shall be carried out.

NOTE Attention is drawn to the dangers of short term testing and the need to reproduce service conditions accurately.

Where it is not possible to place samples in process streams, service conditions shall be simulated. Where it is known that a lining has to withstand an environment where heat transfer is made through the lining, the heat transfer condition shall be maintained during the test.
Substances including dissolved gases present in a process stream in trace quantities only shall be added to the test liquors.

3.2 Quality of lining

3.2.1 General

When the applicator is responsible for selecting the grade of lining to be applied, he shall verify that such a lining will withstand the chemical and physical conditions specified in **3.1**. When the purchaser selects the grade of lining to be applied, the applicator shall be responsible only for correct application.

The applicator shall supply test pieces such as panels to which the lining has been applied and which will serve as reference samples.

3.2.2 Thickness of lining

The dry film thickness of the finished lining will depend upon the grade of material selected and the duties for which it is intended. The maximum thickness as well as a minimum thickness shall be specified [see **1.3** m)].

3.3 Continuity of finished linings

In the case of thin linings (less than 400 µm) it is not always possible to eliminate pinholes. This question shall be considered when information is exchanged [see **1.3** o)]. When the process conditions are corrosive, there shall be no pinholes in the finished lining. Under some process conditions, for example when linings are used to preserve product purity, a small number of pinholes are permissible. The maximum number per square metre of surface shall be specified [see **1.3** o)] when the tender documents are prepared but shall not exceed 5 pinholes/m^2.

Section 4. Method of lining

4.1 Surface preparation

4.1.1 Metal

4.1.1.1 All grease, oil, temporary protectives and chalk shall be removed from the surface to be lined. Degreasing shall be carried out using vapour degreasing equipment or as recommended in **14.2** of BS 5493:1977.

4.1.1.2 All surfaces to be lined shall be maintained at a temperature at least 3 °C above the dew-point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

4.1.1.3 All surfaces to be lined shall be blast cleaned. In the case of carbon steel and cast iron the standard of blasting shall be as defined in Swedish Standard SIS 05 5900[3] according to Table 1.

Only non-metallic grit shall be used for blast cleaning aluminium and its alloys. The average surface profile of the prepared substrate measured peak-to-trough shall be 38 µm.

NOTE Special treatment may be required for other metals.

4.1.1.4 All dust, residues and debris left on the surface after blast cleaning shall be removed by brushing and vacuum cleaning.

4.1.2 Concrete

4.1.2.1 Any external corners not formed with a chamfer shall be rubbed down to a radius of not less than 3 mm.

4.1.2.2 All surfaces to be lined shall be treated to remove laitence and shutter release agents. The specified method for this operation is blast cleaning. The blast cleaning process shall be controlled so that all laitence is removed without exposing the profile of the aggregate. After blast cleaning all dust and debris shall be removed.

NOTE 1 An alternative method of removing laitence which is sometimes used is that of acid etching. This process is only really applicable to horizontal surfaces. Furthermore, the presence of shutter oils will reduce the effectiveness of acid etching. The thickness of the laitence of a concrete surface varies considerably and it is very important that acid is allowed to dwell on the surface a sufficient length of time to remove all the laitence. When acid etching is used the next operation should be water washing of the concrete, followed by a drying process

Acid etching is not suitable when the equipment is to be lined with polyurethane.

NOTE 2 Removal of laitence on concrete invariably leaves a surface which contains a large number of small holes which vary in diameter and depth.

4.1.2.3 Unless the lining material will fill or effectively bridge the holes remaining after the removal of laitence, then these holes shall be filled before the work of lining commences.

NOTE One material recommended for this purpose is a smooth paste made from a water-miscible epoxy resin, cement and a fine filler.

4.1.2.4 After removal of laitence all surfaces to be lined shall be maintained at a temperature at least 3 °C above the dew-point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

4.2 Lining process

4.2.1 Start of lining process: metal

In the case of metal equipment the lining process shall start as soon as possible after blast cleaning is complete and before any visible rusting occurs. Unless maintained in a dehumidified atmosphere application of the lining shall commence within 4 h. If signs of rusting occur then the surface shall be prepared again to the required standard (see **4.1.1.3**).

4.2.2 Start of lining process: concrete

In the case of concrete equipment lining shall not proceed until at least 28 days after the concrete was cast and when the free water content is down to the level specified [see **1.3** a)].

4.2.3 Primed surfaces

Where necessary surfaces shall be primed in order to promote a bond with the lining material. Once a primer has been applied the equipment shall be kept clean and the lining process shall start as soon as possible.

NOTE 1 The primer should be pigmented to facilitate uniform application and to assist in establishing full coverage of the surface to be lined.

NOTE 2 In the case of steel equipment with large surface areas, holding primers may be used to hold the blast cleaned surface, provided that the holding primer is compatible with the lining material and does not interfere with the adhesion of the lining.

4.2.4 General

The lining process shall be appropriate to the grade of material selected for the lining (see **4.2.5** to **4.2.9**).

4.2.5 Polyesters

4.2.5.1 With all systems applied to metal substrates a resin-based primer shall be sprayed or brushed on to the substrate immediately after preparation. The resins shall be catalysed immediately before application and thorough mixing with a mechanical mixer is essential.

[3] Available from BSI, Linford Wood, Milton Keynes MK14 6LE.

Table 1 — Standard of blasting

Types of lining	Grade (see Appendix A)		Cleanliness	Average surface profile (measured peak-to-trough)
				µm
Polyester	A	A.2.3	Sa 2½	75
Polyester	B, C and D		Sa 2½	150
Epoxies	A and E	A.3.2	Sa 2½	38
Epoxies	C and D		Sa 2½	75
Epoxies	C and D hot spray applied		Sa 2½	150
Epoxies	E		Sa 2	75
Furane	all	A.4	Sa 2½	75
Polyurethane	spray	A.5	Sa 2½	75
Polyurethane	trowel		Sa 2½	75
Polyurethane	all	A.6	Sa 2½	75

4.2.5.2 Systems which incorporate a layer or layers of glass fibre reinforcement shall be rolled to ensure proper consolidation. Care shall be taken during the rolling operation to fully wet out the glass and expel all air. Adjacent pieces of reinforcement shall be overlapped by not less than 50 mm. The edges shall be worked out by brushing with a stippling action. If more than one layer of glass reinforcement is used then all joints shall be staggered through the thickness of the laminate.

When the outer layer is reinforced with chopped strand material then an additional layer of resin and surface tissue shall be applied.

4.2.5.3 The final coat shall consist of a flow coat of resin.

NOTE This resin should normally contain 0.4 % to 0.6 % paraffin wax (with a melting point of 55 °C to 60 °C) to prevent loss of styrene and minimize air inhibition of the cure.

4.2.5.4 The work shall be scheduled so that good adhesion is obtained between successive layers in adjacent areas. To attain this, any coat shall be applied before the previous coat has reached a state of cure which would prevent good inter-coat adhesion.

4.2.5.5 If work is interrupted so that one layer is fully cured before work is complete then the surface of the resin of the previous coat shall be removed by grinding. If the previous coat contains glass fibres then these shall be exposed in the grinding process.

4.2.6 Epoxies and coal tar epoxies

NOTE Some of the resin systems are moisture sensitive and in the case of site work it may be necessary to install and operate dehumidifying equipment during the lining process.

4.2.6.1 When the resin system contains solvents the interval between coats shall be sufficient to allow the solvent to evaporate.

4.2.6.2 The work of applying successive coats of material shall be scheduled so that one coat is applied before the preceding coat has reached a state of cure which would prevent good inter-coat adhesion.

4.2.6.3 If work is interrupted so that one coat is cured before the next coat is applied then the surface of the previous coat shall be ground to remove the gloss in order to promote inter-coat adhesion.

4.2.7 Furanes

4.2.7.1 All surfaces to which furane linings are to be applied shall be primed before the application of any furane resin.

4.2.7.2 The primer shall be fully cured before the application of the furane.

4.2.7.3 The components of the resin system shall be mixed thoroughly and applied within the time limit specified by the manufacturer of the lining.

4.2.7.4 Application by brush, roller, trowel or special spray equipment is permissible. When glass fibre reinforcement is used the coats shall be well rolled to ensure a void-free laminate.

4.2.7.5 It is usual for more than one coat of resin to be applied, and the work shall be scheduled so that good adhesion is obtained between successive layers in adjacent areas. To attain this any coat shall be applied before the previous coat has reached a state of cure which would prevent good inter-coat adhesion.

4.2.7.6 When a final top coat of un-reinforced resin is applied the thickness shall not exceed 0.5 mm.

4.2.7.7 Cure of furane resin linings shall be in accordance with the resin manufacturer's recommendations. When the conditions of cure involve heating, hot air shall be used.

No part of the lining shall be heated above 50 °C during the early stages of the cure.

4.2.8 Polyurethanes

4.2.8.1 All the polyurethane systems used for lining process equipment shall be multi-component. The components shall be mixed thoroughly before application.

4.2.8.2 When polyurethane systems used for lining contain solvents the interval between coats shall be sufficient to allow the solvents to evaporate.

4.2.8.3 The work of applying successive coats shall be scheduled so that the next coat is applied before the preceding coat is fully cured, otherwise poor inter-coat adhesion will result.

NOTE All the polyurethane systems used for lining are sensitive to moisture. A small amount of moisture will accelerate the cure of the lining. Excessive moisture has an adverse effect and it may be necessary to control the moisture content of the atmosphere during the application of the lining.

Where concrete equipment is to be lined the free water content of the concrete is of particular importance.

4.2.9 Polychloroprene

4.2.9.1 Special primers shall be used to promote a bond between substrates and liquid polychloroprene.

4.2.9.2 The liquid rubber contains solvents and the lining process requires the application of a number of coats. The lining process shall be scheduled to allow the evaporation of the solvents from one coat before the next coat is applied.

4.2.9.3 The work of applying successive coats shall be scheduled so that the next coat is applied before the preceding coat has fully cured, otherwise poor inter-coat adhesion will result.

NOTE Cure of the lining is dependent upon the type of curing agent and the temperature. At 15 °C the cure time is approximately 7 days. The process may be accelerated by the application of heat.

Section 5. Inspection and testing

5.1 Responsibility for inspection and testing

The fabricator of the equipment and the applicator of the lining when requested shall provide a certificate of inspection and testing. The stages of inspection shall be as follows:

a) the equipment as fabricated;

b) the equipment after preparation of welds and edges;

c) the equipment after blast cleaning;

d) if appropriate, after application of the primer;

e) after application of the lining;

f) whenever remedial work is carried out.

In cases where the purchaser requires independent inspection of the work (i.e. by the inspection authority) at various stages, those stages shall be defined [see **1.3** s)].

5.2 Inspection

5.2.1 Surface cleanliness and profile of metal surfaces

Blast cleaned surfaces shall be inspected to ensure that they comply with **4.1.1**.

Reference photographs or plates shall be used to establish the level of surface cleanliness (see **4.1.1.3**).

Comparator plates shall be used to check the surface profile. In cases of dispute replicas shall be taken and the profile determined with the aid of a microscope.

5.2.2 Concrete surfaces

Concrete surfaces shall be inspected to see that they are free from laitence and that surface defects are properly filled (see **4.1.2**).

5.2.3 Visual appearance of linings

The lining shall be inspected visually for blisters, flaws, sagging and inclusions of foreign material. Defects shall be removed and the lining replaced. If the number of defects is large and covers a large surface area the lining shall be removed completely and the work of lining re-done.

5.2.4 Adhesion

The lining shall be inspected visually for evidence of lack of adhesion to the substrate and, where applicable, lack of inter-coat adhesion.

NOTE As far as possible adhesion testing of the applied lining is to be avoided because the test is destructive and the lining has to be repaired.

If required, test pieces [see **1.3** n)] shall be used to demonstrate that the process employed does provide a lining with the required level of adhesion. These test pieces shall be of the same material as the substrate and the lining process shall be the same as that employed for lining the equipment and done under the same conditions and at the same time.

5.2.5 Thickness of lining

A survey of the thickness of the lining shall be made. Of the instruments available those that operate on a single probe electromagnetic or eddy current principle shall normally be used [see **1.3** s)]. Selection shall be determined in other cases by the nature of the substrate. The instruments shall be calibrated against reference plates at least twice a day.

NOTE 1 Attention is drawn to the fact that thickness measurements of thin films in corners and on curved surfaces of small radii may not be accurate.

NOTE 2 If concrete is the substrate it may be appropriate to monitor thickness of the linings as applied by use of wet film thickness gauges.

5.2.6 Continuity of lining

The lining shall be tested for pinholes (see Section 6). Local repairs are permitted if the number of pinholes exceeds that specified [see **1.3** o)]. If local repairs are not possible the lining shall be removed and replaced.

NOTE 1 It is usual for wet sponge probes operating on low voltage to be used for linings up to 350 µm thick.

NOTE 2 When concrete is the substrate the only method of testing for pinholes is by spark testing using an a.c. type instrument.

5.2.7 Cure of lining

5.2.7.1 The lining shall be examined for the state of cure.

5.2.7.2 The hardness of the lining is a good indication of the cure and shall be the minimum specified [see **1.3** s)].

5.2.7.3 The lining shall be tested for solvent resistance using the specified solvent [see **1.3** s)].

This test shall be carried out by laying a cloth soaked in the specified solvent [see **1.3** s)] over selected areas of the lining for 3 min. After this time the lining shall show no sign of tackiness.

In the case of linings based on polyester resins any wax shall be removed from the surface before applying this test.

5.2.7.4 If the lining is found to be under-cured and the appropriate curing schedule has been followed then remedial action shall be investigated. If this treatment is not successful then the lining shall be removed and replaced.

Section 6. Methods of test

6.1 Continuity testing

6.1.1 General

There are two main types of instrument used for continuity testing (see Appendix B) and the type of instrument to be used shall be clearly established in accordance with **1.3** s).

The testing of linings shall be done in a systematic way. The surface of all but small equipment shall be divided up by chalk line or other suitable marks into smaller areas of about 1 m^2.

NOTE By these means it is possible to check that the whole of the lining has been examined.

6.1.2 Wet sponge testing

6.1.2.1 The sponge probe of the instrument shall be wetted with a 3 % solution of sodium chloride to which a small amount of wetting agent (detergent) has been added. If the substrate is austenitic steel then a 3 % solution of ammonium sulphate shall be used instead of the salt solution.

6.1.2.2 The sponge shall be moved across the surface in a systematic way so that the whole of the surface is examined.

The speed of travel shall be controlled so that time is allowed for imperfections in the lining to wet out.

When a pinhole is discovered, the position of the hole shall be clearly marked.

Before proceeding with further testing the surface of the lining adjacent to the pinhole shall be dried thoroughly in order to avoid tracking back to the pinhole(s) already discovered.

6.1.3 Spark testing

6.1.3.1 The instrument shall be adjusted to the test voltage agreed under **1.3** s).

Before commencing testing the surface shall be made dry and free from dirt.

6.1.3.2 A probe shall be moved continuously over the surface of the lining at a speed not exceeding 100 mm/s. Applying the spark to one spot for any appreciable length of time shall be avoided as prolonged exposure to the spark can cause damage to the lining.

When a defect in the lining is discovered, it shall be clearly marked.

Section 7. Rectification of faults in fully cured linings

7.1 General

7.1.1 When rectification of faults is to be made in linings which are fully cured special attention shall be paid to the problems of achieving adhesion between new resin and the cured lining.

7.1.2 In the case of linings based on polyester resins the first step shall be to remove the surface wax over a patch which extends 50 mm beyond the area to be repaired.

7.1.3 With all linings a patch which extends 25 mm beyond the area to be repaired shall be ground to remove the gloss.

7.1.4 When priming of the substrate is an essential part of the system the first step after preparation shall be to establish whether the primer is intact. If the primer is damaged then it shall be repaired before the rest of the work proceeds.

7.1.5 Rectification of faults shall be done either with the same material as originally used for the lining, or other materials that shall be used only with the purchaser's written consent [see **1.3** t)].

7.1.6 After all rectification work the lining shall be subject to inspection as appropriate and in particular to continuity testing.

Section 8. Storage, handling, transportation and installation

8.1 General

8.1.1 Lined equipment shall be stored under cover or in a protected compound. When necessary, linings shall be shielded from direct sunlight.

8.1.2 All branches, manholes and other openings shall be protected from mechanical damage by using wooden blanks or other suitable material.

8.1.3 Lifting shall be arranged so that chains and other lifting aids do not come into contact with lined surfaces.

8.1.4 High local loads on lined surfaces shall be avoided.

8.1.5 Loose fittings shall not be placed inside lined equipment whilst it is being transported.

8.1.6 Responsibility for arranging transport of, lined equipment will vary and whoever is responsible (purchaser, fabricator or applicator) shall instruct the carrier about the precautions in handling [see **1.3** u)].

8.1.7 It is essential that the purchaser issues instructions on the handling procedures to those responsible for installation and that special reference is made to the need to wear soft, clean footwear when entering lined equipment and the need to protect lined surfaces from ladders and scaffold poles.

Appendix A Characteristics of lining materials specified in 3.1

A.1 General characteristics of linings

A.1.1 ***Effect of temperature***

The effect of temperature varies with the type of lining and duty. The temperature limits will vary between 70 °C and 120 °C.

A.1.2 ***Effect on heat transfer***

All of the linings in **A.2** to **A.6** are poor thermal conductors and therefore reduce heat transfer.

A.1.3 ***Resistance to erosion***

Most of these linings offer good resistance to erosion by suspended particles.

A.1.4 ***Deposit build-up***

Most of these linings offer good resistance build-up of deposits and in some cases it is exceptionally good.

A.2 Polyesters

A.2.1 ***Description***

There are a number of resins which are grouped together under the name "polyesters". The resins are unsaturated polyesters. The different types are known as isophthalic, terephthalic, bisphenol, vinylester and HET acid. They are usually supplied dissolved in a reactive monomer which is styrene. With addition of appropriate catalysts all these resins will cross-link (cure) with styrene to form solids.

A.2.2 ***Preparation of lining materials***

The lining materials are prepared by mixing the selected resin with inert fillers and/or reinforcing agents such as mica, silica, glass flake, glass fibre and carbon black.

A.2.3 ***Grades***

All polyester resins may be applied in a variety of ways and it is usual to grade according to the thickness of the applied lining. Typical grades are as follows.

A. *Reinforced linings up to* 1 mm *thick*. These systems consist of a resin reinforced with mica, carbon or small diameter glass flakes. A resin primer is normally used. The systems are applied in two coats and are used for light corrosive duties and for situations where protection of the product from contamination is necessary.

B. *Reinforced linings from* 1 mm *to* 2 mm *thick*. These systems are made up from resins reinforced with glass flakes of up to 3 mm diameter. A resin primer is used. The systems are applied either in two coats or in two coats with a special top coat to provide a smoother surface. These systems provide a tough corrosion resistant lining.

C. *Laminate reinforced linings*. These systems are up to 5 mm thick and normally consist of:

1) a resin based primer;

2) glass fibre reinforcement (chopped strand mat or chopped fibre) thoroughly wetted out with resin;

3) a resin based top coat.

D. *Laminate reinforced linings with screed*. These systems are up to 5 mm thick and normally consist of:

1) a resin based primer;

2) a screed of resin and inert filler up to 2 mm thick;

3) glass fibre reinforcement laid on top of the screed and thoroughly wetted out with the resin;

4) a resin based top coat.

They are applied by trowel and roller.

A.2.4 ***Chemical resistance***

A.2.4.1 Polyesters have good resistance to acids, depending upon concentration and temperature.

A.2.4.2 All polyesters have some resistance to alkaline conditions. Vinylester, bisphenol and HET acid resin systems are particularly good against alkalis.

A.2.4.3 Vinylester, bisphenol and HET acid resin systems have good resistance to wet chlorine and hypochlorites.

A.3 Epoxy resins

A.3.1 ***Description***

There are a number of systems available under the general term "epoxy". Most systems consist of two or more components which are mixed immediately before application and the cure proceeds at normal ambient temperature. The base resin may be a solid or liquid resin. If a solid it will be dissolved in solvents. Resins are supplied pigmented or filled as required. Epoxy resins may be extended in a number of ways, the most common being by addition of coal tar or coal tar pitch.

A.3.2 ***Grades***

Typical grades are as follows.

A. *Amine cured solvent containing systems.* These systems can be based on liquid epoxy resins but more often a solid resin is used, the latter tending to give a better performance. The hardener is usually in the form of an amine adduct. Sensitivity to temperature and humidity depends upon the type of hardener that is used.

The lining is applied as a multi-coat system which may well include a primer.

B. *Polyamide cured solvent containing systems.* In these systems a polyamide resin is used as the hardener in place of an amine. They are not often used as lining materials as their general properties are substantially reduced compared with amine cured systems. They are generally sensitive to conditions of high humidity.

C.*High solids epoxy systems*[4]. These systems are similar to (A) and (B) except that the solvent content is very low. They are nearly all based on liquid epoxy resins. Hardeners will be either an amine, aromatic or aliphatic polyamine or a polyamide. Sensitivity to temperature and humidity depends on the type of hardener that is used.

The lining is usually applied in two coats.

D. *Solvent-free epoxy systems.* These systems are similar to (C) except that they are based on liquid epoxy resin with no solvent present. When the hardener is an aromatic polyamine a 3-pack system consisting of base, hardener and accelerator is used.

These systems are suitable for use with food and drink products provided a suitable non-toxic and taint-free resin is used.

These resins also may be reinforced with glass flake or glass fibre to provide additional strength.

E. *Coal tar epoxy systems.* These are 2-pack systems containing either coal tar or coal tar pitch. The epoxy may be liquid or solid resin. Amounts of solvent are small or the systems may be solvent-free.

Corrosion resistant properties vary markedly depending on the coal tar/epoxy resin ratio and it is important that this is specified. For instance, where good resistance to sulphuric acid is required, a proportion of at least 40 % epoxy resin is required.

Hardeners such as amines, amine adducts and polyamides are commonly used depending on temperature and humidity. Systems are usually two or three coats.

A.3.3 ***Chemical resistance***

A.3.3.1 The resistance to acids, particularly oxidizing and organic acids is limited to about 10 % concentration.

A.3.3.2 All epoxies have good resistance to water and alkalis.

A.3.3.3 Epoxy resins have good resistance to a wide range of organic chemicals. Notable exceptions are phenols and methanol. Epoxy resins are unsuitable for solvents such as ketones and esters.

A.4 Furanes

A.4.1 ***Description***

The furane resins available for lining are those based on furfuryl alcohol. The cure is effected with acid catalysts. If the resins are applied directly to metals and concrete the acid catalyst reacts with the substrate and the cure of the resin is inhibited and the bond between resin and the substrate is affected. For these reasons this class of resin is always used in conjunction with special primers.

Primers are required to have the following properties:

a) provide a good bond to the substrate;

b) resist penetration and attack by the powerful solvent action of the furane resin;

c) be capable of forming a strong bond with the furane resin;

d) have no residual chemical activity when cured which may interfere with the cure of the furane resin.

This class of resin is always used with reinforcing fillers, for example silica flour or as a laminate with glass fibre.

Reinforced furane resin linings can develop adequate physical properties without post-cure but for maximum corrosion resistance they should, where possible, be postcured using hot air.

The rate of cure of furane resin linings depends upon a number of factors including the resin/catalyst system, nature of the reinforcement and temperature. Temperature has a very marked effect.

A typical furane lining will take approximately 20 days to cure at 15 °C but only 5 days to 7 days at 40 °C.

[4] These are sometimes referred to as solventless epoxy systems.

It should be noted that the chemical resistance of a furane lining will be dependent upon the final post-cure temperature. Special care should be taken to ensure that any samples used for test purposes have been cured according to the procedure to be adopted for the lining.

A.4.2 ***Chemical resistance***

A.4.2.1 Furane resins have resistance to most organic acids. Their resistance to oxidizing acids is very limited.

A.4.2.2 Furane resins have good resistance to alkalis with the exception of ammonium hydroxide.

A.4.2.3 Furane resins have good resistance to a very wide range of organic solvents.

A.5 Polyurethanes

A.5.1 ***Description***

Polyurethane resins are available in single or multicomponent formulations. Single component systems react with atmospheric moisture to cure and are usually used for paint formulations.

Multi-component systems cure in the absence of atmospheric moisture but, its presence may improve the state of cure.

Polyurethane resins can be formulated to give products varying between hard glossy linings and flexible tough elastomeric linings.

A.5.2 ***Chemical resistance***

A.5.2.1 The chemical resistance of polyurethane linings is dependent upon the type used and on the temperature of the environment.

A.5.2.2 Some polyurethanes are suitable for acids but many have limited resistance.

A.5.2.3 Some polyurethane linings have good resistance to alkalis.

A.5.3 ***Abrasion/erosion***

Some polyurethane linings are particularly suitable for conditions of abrasion/erosion.

A.6 Liquid elastomeric linings

A.6.1 ***Polychloroprene***

Linings based on liquid polychloroprene coatings are available as single or multi-component systems. The single component system is usually only used for external protection having inferior chemical resistance to the multi-component systems.

A.6.2 ***Chemical resistance***

A.6.2.1 The acid resistance of polychloroprene linings is limited to some non-oxidizing acids and some organic acids. They are not resistant to hydrochloric acid.

A.6.2.2 Polychloroprene linings have very good resistance to alkalis with the exception of amines.

A.6.2.3 Polychloroprene linings have good resistance to water up to 100 °C.

A.6.2.4 Polychloroprene linings have limited resistance to aliphatic hydrocarbons and alcohols and are unsuitable for aromatic hydrocarbons, chlorinated hydrocarbons, ketones, esters and nitro compounds.

A.6.3 ***Abrasion***

Linings based on liquid polychloroprene are very tough and have good resistance to abrasion.

Appendix B Continuity testing

B.1 Introduction

It is essential that linings provide adequate protection to equipment under the conditions for which they were designed. Therefore, when there is a requirement that a lining be continuous, i.e. free from pinholes and cracks, it is vital that test methods be used to prove the lining.

The approach to continuity testing is to consider the lining as an electrical insulator and search for holes by trying to make electrical contact to the substrate through the lining. There are two main methods of searching:

a) wet sponge testing which consists of a wet sponge soaked in an electrolyte as one probe of a low-voltage circuit, the other being the earth return;

b) spark testing in which a discharge from a highfrequency source or a direct current spark is used to find the fault.

B.2 Wet sponge testing

The instruments used for this type of testing are quite simple. Normally there are two circuits powered by low-voltage batteries. The primary circuit carries two probes, one of which is connected to the metal substrate. The second is connected to a sponge that is soaked in a 3 % solution of electrolyte to which a small amount of wetting agent has been added. The sponge is passed over the lining. If the lining contains a pinhole or some other form of discontinuity, the electrolyte penetrates the defect to the metal substrate, current flows in the primary circuit which triggers the secondary circuit and the alarm operates.

The sensitivity of this type of instrument depends upon the resistance below which current can be detected in the primary circuit. The voltage at which the instrument operates is not an important factor. The resistivity of 3 % sodium chloride solution (a commonly used electrolyte) is less than 100 Ω cm. The resistivity of tap water is about 1 000 Ω cm. Therefore it is important that sponges are soaked in an electrolyte.

It is a simple matter to calculate the minimum diameter of hole that can be detected in a given thickness of lining for a specific sensitivity of instrument. If an instrument has a sensitivity of 10^6 Ω, current will be detected in the primary circuit if the resistance is less than 10^6 Ω. Taking the resistivity of the electrolyte as 100 Ω cm, then it will be possible to find a hole approximately 15 µm in diameter in a coating 200 µm thick.

If the instrument is of the right sensitivity, a hole of 1 µm in diameter will be found providing that the hole fills with electrolyte. It is not possible with this type of instrument to find a hole that is so small as to be of no significance, because if the electrolyte can penetrate then so can a corrodant. In fact, with conditions of varying temperature and pressure in service, the working condition can be more searching than the test. However, it is possible to produce an instrument that is too sensitive. For example, if the primary circuit of an instrument will operate up to a resistance of 500 MΩ, then it is possible to demonstrate in humid conditions that if the operator using a probe touches the metal substrate, he will trigger the alarm. Furthermore, if a defect is found, unless all traces of moisture are removed from the surrounding lining, then sufficient current will track and the instrument will indicate holes that are not present. In practice instruments with a sensitivity up to 1 MΩ have been found to be satisfactory.

Some instruments are available that give a varying signal according to resistance. This means that the signal has to be interpreted. It is preferable that the instrument respond on a "go" or "no go" basis.

It is a requirement of this standard that the sensitivity of the test instrument be declared when the lining is specified. There has been evidence in the past that similar models of instrument vary considerably in sensitivity. Therefore, a certificate of performance should be available for individual instruments.

Instruments of the wet sponge type can be used for testing a wide range of linings but they are not considered suitable for use with some partially cured resin linings.

It should be remembered that before attempting to repair defects found by wet sponge testing it is necessary to remove traces of electrolyte and dry the lining.

B.3 Spark testing

B.3.1 ***General***

There are two types of spark testing equipment in general use:

a) high frequency with an a.c. source;

b) direct current (high voltage).

The mode of operation of the two types is quite different.

B.3.2 ***High-frequency test equipment***

In these instruments a Tesla coil is used to generate a high-frequency discharge. Models are available that operate on supply voltages of 240 V, 110 V or 50 V. The voltages at which they discharge can be varied between 5 000 V and 50 000 V. Normally output is controlled but the actual output cannot be recorded on a meter. However, it is possible to measure the voltage for any set position of the control by the method laid down in BS 358, namely measuring the gap the spark will jump between 20 mm diameter spheres. The voltage of the discharge does vary but the peak voltage for any setting of the instrument will not be exceeded.

The instruments have a single electrode. When the electrode is held on or close to the lined surface, there is a corona discharge. When a fault is present, the discharge concentrates at that point and the fault is readily identified. It is possible to survey a large area very quickly with quite a small probe. When linings are being examined it is possible, for ease of operating, to use an extended probe so that a band, for example 150 mm wide, can be examined in one sweep.

Tests have shown that the risk of damage by high-frequency spark testing is remote if the time the probe is allowed to dwell on any one place is short. Breakdown of a lining by spark testing is by erosion until a critical thickness is reached. During the time that the surface of a lining is exposed to a spark in test conditions the material lost by spark erosion is negligible. The only time the critical thickness of a lining is likely to be reached is when there is a bubble in the lining and that bubble has a thin skin. Such imperfections are undesirable.

B.3.3 ***Direct current spark testers***

This type of instrument may be powered by mains or a rechargeable battery. The output voltage varies with the make but a common range is 1 000 V to 20 000 V. Most instruments to have a voltage control and a built-in voltmeter and this is the model recommended for use. In the case of models operating from a battery the operator should check frequently that full output voltage is available. Batteries need recharging at frequent intervals.

With d.c. instruments it is necessary to have an earth return. Unlike the high frequency instrument there is only a discharge when the electrode is close enough to a defect for the d.c. spark to bridge the gap to earth. When contact is made, the spark can be seen but most instruments of this type incorporate an audio signal. The energy of the spark from a d.c. instrument is greater than that from a high-frequency instrument and it is possible for defects to be enlarged by the action of the spark.

B.4 Testing

Whichever type of instrument is selected for continuity testing, it is absolutely essential that the whole of the lining be surveyed. The spark from a high-frequency tester ionizes the air and the spark from such a source will jump a much larger gap than is the case with d.c. sparks. It is particularly important that electrodes used with d.c. instruments conform to the surface contour otherwise defects may be missed. It may be difficult to meet this requirement when using very wide probes.

It is essential that inspectors have an understanding of how the instruments work and the need to survey the linings in a controlled fashion.

Because of the need to ensure that continuity testing is carried out to the required standard, it is preferable that the test work be done by a person other than the operator(s) who has applied the lining.

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BS 358, *Method for the measurement of voltage with sphere-gaps (one sphere earthed).*
BS 470, *Access and inspection openings for pressure vessels.*
BS 1755, *Glossary of terms used in the plastics industry.*
BS 1755-1, *Polymer and plastics technology.*
BS 5337, *Code of practice for the structural use of concrete for retaining aqueous liquids.*
BS 5493, *Code of practice for protective coating of iron and steel structures against corrosion.*
Swedish Standard SIS 05 5900 Pictorial surface preparation standards for painting steel surfaces.

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