भारतीय मानक

IS 4682 (Part 4) : 2024

Indian Standard

रासायनिक प्रक्रियाओं के लिए पात्रों और उपकरणों की परत — रीति संहिता

भाग 4 शीट थर्मोप्लास्टिक के साथ परत

(दूसरा पुनरीक्षण)

Lining of Vessels and Equipment for Chemical Processes — Code of Practice

Part 4 Lining with Sheet Thermoplastics

(Second Revision)

ICS 71.120.10

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July 2024 **Price Group 9**

Chemical Engineering Plants and Related Equipment Sectional Committee, MED 17

FOREWORD

This Indian Standard (Part 4) (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Chemical Engineering Plants and Related Equipment Sectional Committee had been approved by the Mechanical Engineering Divisional Council.

This standard was first published in 1969 and subsequently revised in 1998. This revision has been brought with a view incorporating the modification found necessary as a result of experience gained in the use of this standard. Also, in this revision, the standard has been brought into latest style and format of Indian Standards and references to Indian Standards wherever applicable have been updated.

Early consultation and exchange of information should take place between the lining contractor and all parties concerned in the design, manufacture, erection and use of vessels to be lined. This standard has been issued in several parts. The other parts issued in this series are:

Part 1	Rubber lining
Part 2	Glass enamel lining
Part 3	Lead lining
Part 5	Epoxide resin lining
Part 6	Phenolic resin lining
Part 7	Corrosion and heat resistant metals
Part 8	Precious metal
Part 9	Titanium
Part 10	Brick and tile

The composition of the Committee responsible for the formulation of this standard is given in Annex E.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES — CODE OF PRACTICE

PART 4 LINING WITH SHEET THERMOPLASTICS

(Second Revision)

SECTION 1 GENERAL

1 SCOPE

1.1 This standard (Part 4) specifies requirements for the lining of equipment for the process industries using sheet thermoplastics.

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

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

1.3 Requirements for the design and fabrication of the equipment and the state of preparation, necessary for the surfaces to be lined, are specified in section two.

1.4 Requirements for storage, handling, transportation and installation of the lined equipment are also specified in section eight.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards.

3 DEFINITIONS

For the purpose of this standard, the following definitions shall apply.

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

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

3.2 Resin — A solid, semisolid or pseudo-solid 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.

3.3 Thermoset — 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.

3.4 Purchaser [1)] — The organization or individual who buys the lined equipment for its own use or as an agent for the owner.

3.5 Fabricator[1)] — The organization or individual responsible for the fabrication of the equipment to be lined.

3.6 Applicator[1)] — The organization or individual responsible for the application of the lining.

3.7 Inspection Authority[1)] — The body or association appointed by the purchaser (or owner) to check that the design, fabrication and lining comply with this standard.

3.8 Lining — Thermoplastics applied as sheet linings which may or may not be bonded to the substrate.

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

3.9 Cure — The chemical reaction resulting in the final polymerized product.

3.10 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'.

3.11 Blister — A gas or liquid-filled cavity within the lining material or between the lining and substrate.

[1)] Where the word '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.

4 EXCHANGE OF INFORMATION

4.1 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 acclaim 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* **7**, **8** or **9**, and **10**);
b) Details of gasket materials (*see* **7.9** and **7.10**);
c) Details of the contents of the vessels or equipment, including trace materials [*see* **11.2(a)**];
d) The design temperature [*see* **11.2(b)**];
e) The design pressure [*see* **11.2(c)**];
f) The details of any solids to be handled [*see* **11.2(e)**];
g) The methods of heating and/or cooling [*see* **11.2(b)**];
h) Cleaning methods, for example, water washing, solvent washing, boiling out or steaming [*see* **11.2(a)**];
j) Where the lining work will be done;
k) Site conditions that may affect the work, for example, availability of services;
m) Any special requirements for materials used in blast cleaning (*see* **14.1.4** and **14.2.3**);
n) The type of material to be used for lining (*see* **11.1**);
p) The minimum thickness of the lining and where applicable the maximum thickness (*see* **12.2**);
q) The suitability of the adhesive if the lining is to be bonded to the substrate (*see* **12.3**);
r) When the lining is to be applied outside the applicator's works and the adhesive as applied contains solvents, the types of solvents shall be stated, together with their flash points, and threshold limit values;
s) The specified adhesive system (*see* **12.3** and **15**);
t) The provision of test plates (*see* **12.1.2** and **17.4.2**);
u) The minimum and maximum allowable temperature which is required for the correct application of a lining including the curing of the adhesive if used (*see* **15**);
w) Inspection techniques/procedures to be employed acceptance levels and stages of inspection (*see* **16** and **17**); and
y) Handling, transport, storage and installation procedure [*see* **11.2**(g) and **20.1** to **20.7**].

5 COMPLIANCE

5.1 Fabricator

The fabricator shall comply with the following:

a) Section 2 [*see* **4.1**(a)];
b) Requirements given in **16.1**(a) and **16.1**(b); and
c) Section 8 as agreed in **4.1**(w).

5.2 Applicator

The applicator shall comply with the following:

a) Section 3 (but *see* **12.1**);
b) Section 4;
c) Requirements given in **16.1**(c), **16.1**(d), **16.1**(e) and **16.1**(f);
d) Section 6;
e) Section 7; and
f) Section 8 as agreed in **4.1(w)**.

SECTION 2 DESIGN, FABRICATION AND SURFACE FINISH OF EQUIPMENT TO BE LINED

6 GENERAL

The basic design, fabrication and testing for mechanical reliability of the equipment to be lined shall be carried out to appropriate Indian standards and shall comply with **7**, **8** or **9** and **10**, as appropriate before the lining operation commences.

7 DESIGN OF METAL EQUIPMENT TO BE LINED

7.1 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.

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

7.3 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 IS 2825 or IS 803 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.

7.4 Riveted constructions shall not be used.

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

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

7.7 Discontinuities, crevices and sharp projections shall be avoided.

7.8 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.

7.9 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.

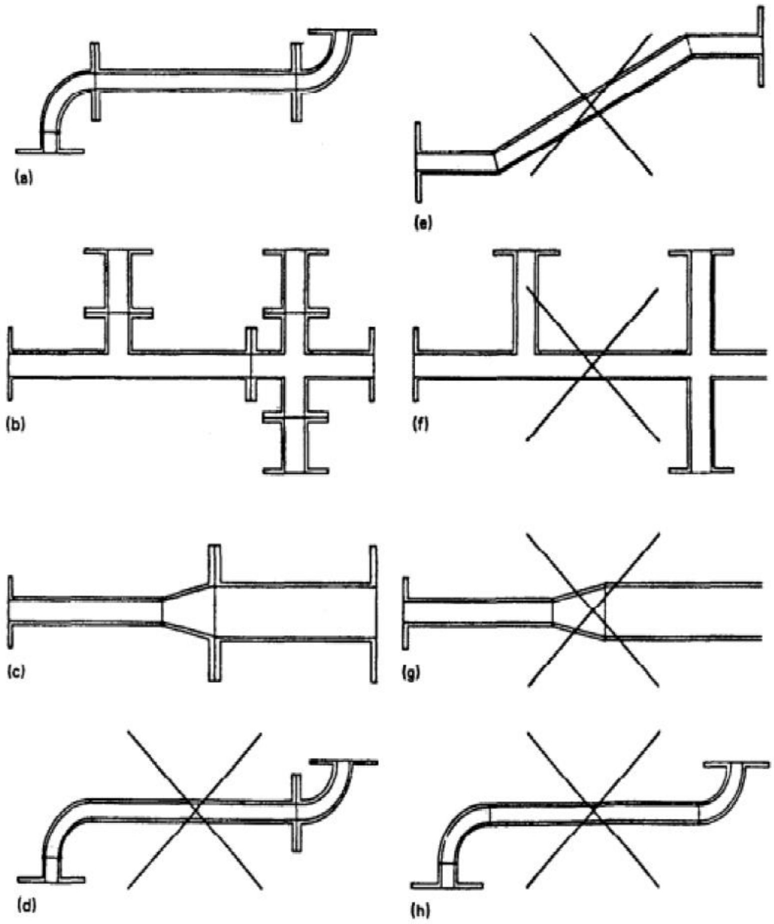
7.10 All nozzles and outlets shall be as short as possible, straight and flanged. Flange faces shall have a plain surface to allow the lining to continue over the face.

7.11 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.

7.12 The design of pipework shall be such as to allow ready access to welds and bends for weld and surface preparation and permit the fitting of extruded liners (*see* Fig. 1).

System shall be made up from straight lengths with separate bends and tees.



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

FIG. 1 PIPEWORK DETAILS

7.13 The design of equipment shall be such that there is easy hand access to areas where thermoplastic sheets need to be welded.

8 FABRICATION OF METAL EQUIPMENT TO BE LINED

8.1 All welds shall be continuous on surfaces to be lined. Only butt joints shall be permitted on surfaces to be lined. Stitch welding, spot welding and other non-continuous welding processes shall not be used.

8.2 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.

8.3 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.

8.3.1 All welds shall be free from the following surface defects:

a) Undercutting;
b) Cracks;
c) Porosity;
d) Any other type of surface cavity; and
e) Lack of fusion.

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

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

8.4 Weld profile details shall be generally in accordance with Fig. 2 to Fig. 6.

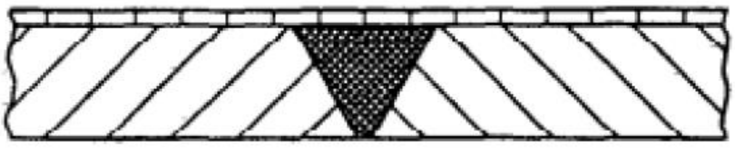
NOTE — Incorrect details are also illustrated.

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

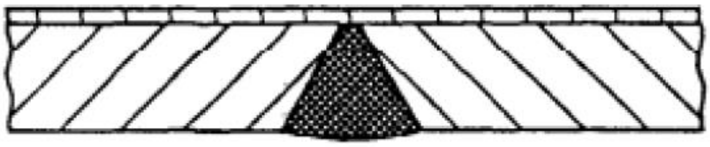
8.6 Before the equipment is passed for lining, all attachments to be made by welding, for example, lagging cleats and lifting lugs shall be complete.

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

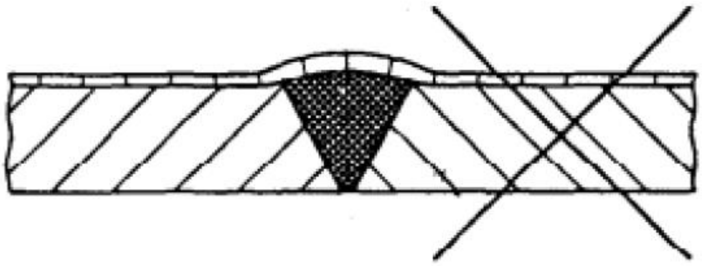
8.8 When the lining is to be thermo-formed at corners, those corners shall be finished to a radius of not less than 5 mm. When the lining is to be welded at corners, those corners shall be finished to a radius of a nominal 1.5 mm.



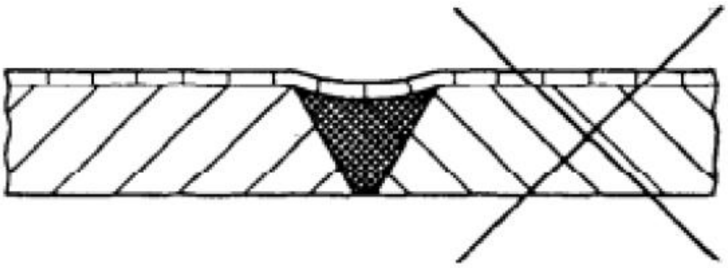
(a) WELD FLAT AND SMOOTH



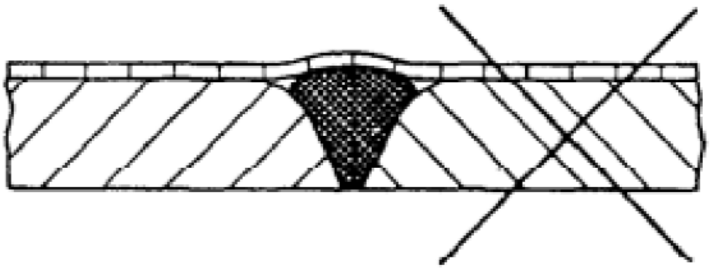
(b) WELD FLAT AND SMOOTH



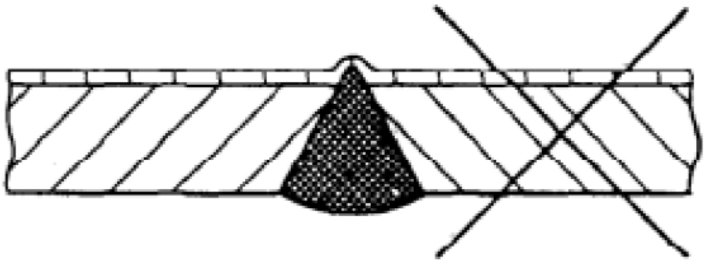
(c) WELD CONVEX AND SMOOTH



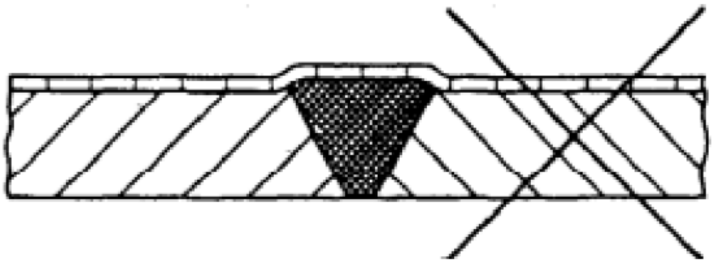
(d) WELD CONCAVE AND SMOOTH



(e) WELD UNDERCUT



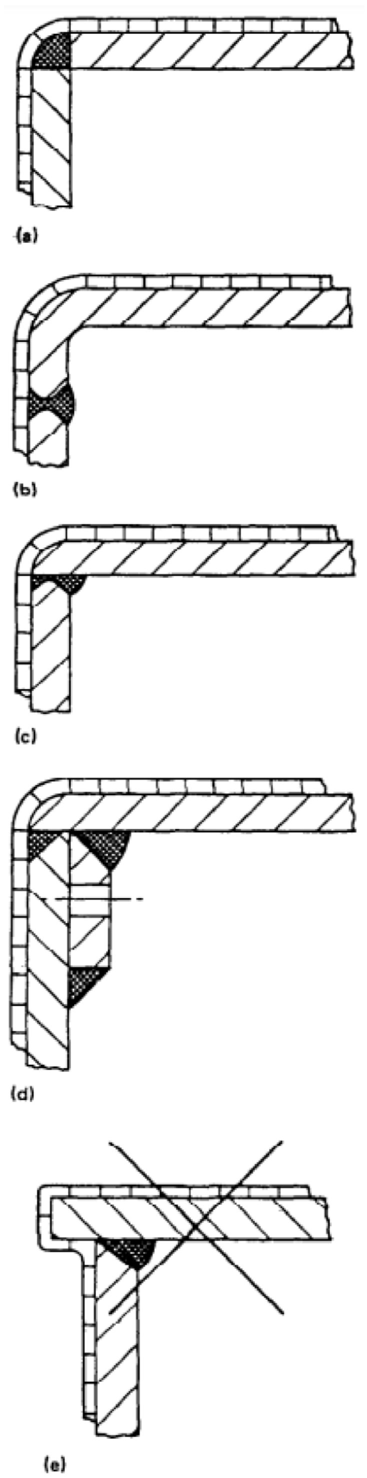
(f) EXCESSIVE WELD PENETRATION



(g) IMPROPER GRINDING

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

FIG. 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.

FIG. 3 WELD PROFILE DETAILS — EXTERNAL CORNERS AND EDGES

8.9 All slag, anti-spatter compounds or similar materials shall be removed. All weld spatter shall be removed by chipping and/or grinding.

8.10 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.

8.11 Rotating parts shall be balanced before and after lining.

9 DESIGN OF CONCRETE EQUIPMENT TO BE LINED

9.1 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 paid to avoiding cracking due to thermal stresses. In the case of loose liners, equipment shall be designed to IS 456. In the case of bonded liners, equipment shall be designed to IS 3370 (Parts 1 to 3 and Part 4/Sec 3).

9.2 If necessary extra reinforcements shall be used and construction joints treated to promote a bond between adjacent areas of concrete. Expansion joints create special problems in lining and shall not be used without consultation between the purchaser and the applicator of the lining.

9.3 Pipes and fittings shall be designed with puddle flanges and cast into the concrete. Where possible pipes and fittings shall either be of the same material as the liner so that a weld may be made between the liner and the fitting or designed so that the lining may be carried through the fitting. If this is not possible, the fitting shall be designed so that a mechanical joint can be made between the fitting and the lining. In the latter case the fitting shall be of a corrosion-resistant material.

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

9.5 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 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 the manhole should be 600 mm.

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

9.7 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.

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

10 CONSTRUCTION OF CONCRETE EQUIPMENT TO BE LINED

10.1 All concrete equipment shall be constructed in accordance with the requirements of IS 3370 or IS 456 as appropriate.

10.2 Proper curing of the concrete shall be ensured by the use of curing membranes wherever necessary. If shuttering is removed 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.

10.3 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 laitance.

10.4 All concrete not cast against shutters or slip formed shall be float finished.

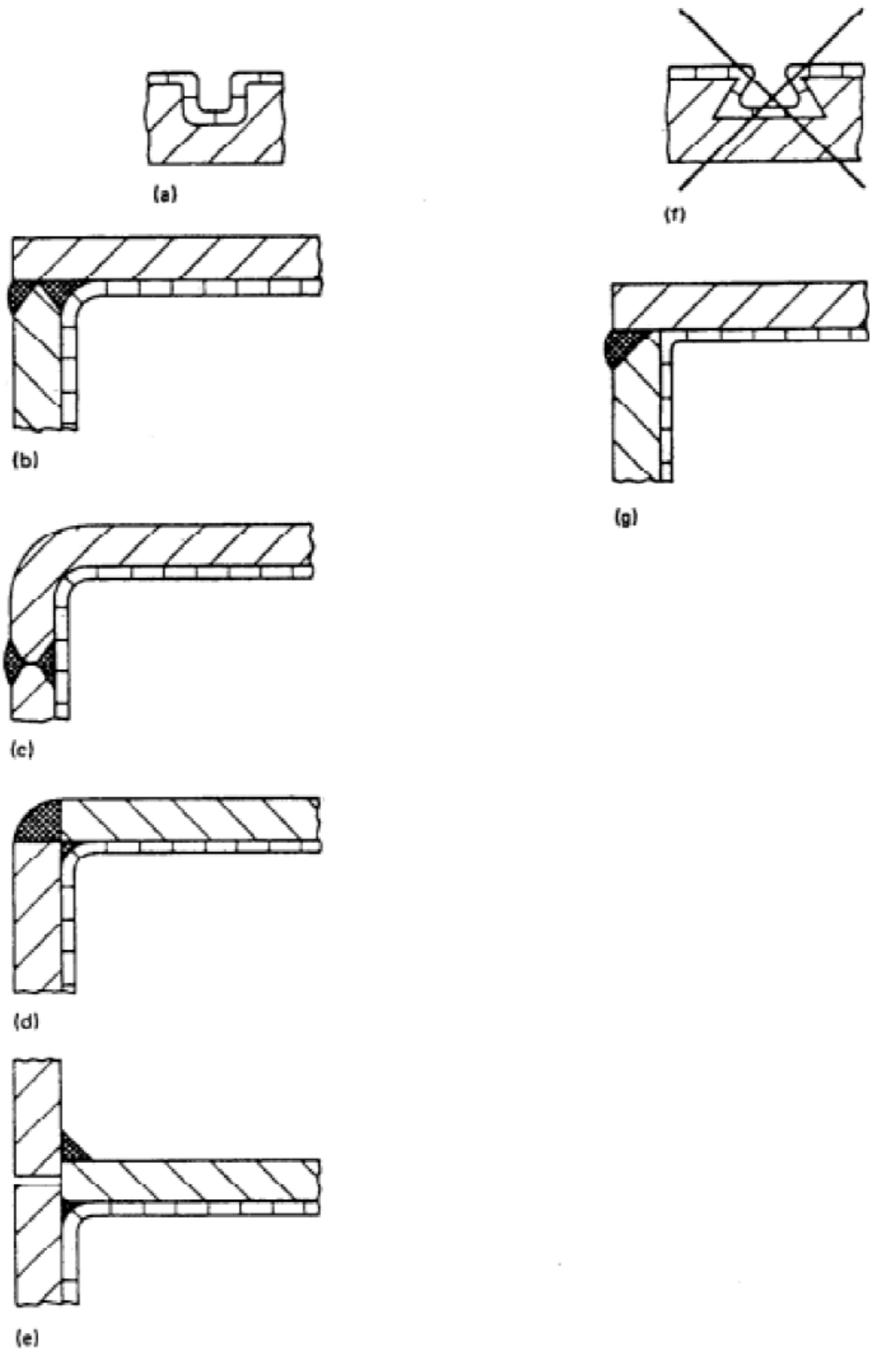
NOTES

1 In the case of equipment to be fitted with loose linings a steel float or a wooden float may be used; and

2 In the case of equipment where the lining is to be bonded a wooden float finish shall be used.

10.5 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.

10.6 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.

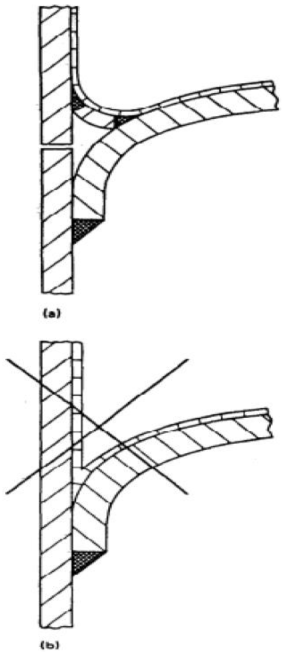


NOTES

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

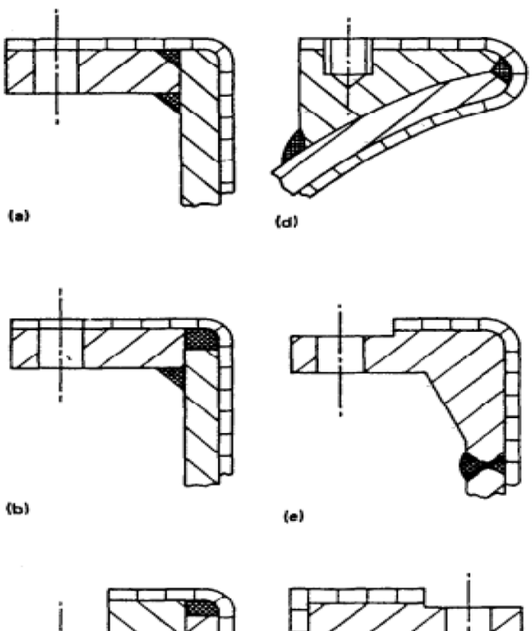
2 The details shown in (g) are not to be used only when the lining is bonded and is to be welded at the internal corner.

FIG. 4 WELD PROFILE DETAILS — INTERNAL CORNERS AND EDGES



NOTE — The details shown in (a) are permissible, those shown in (b) are permissible.

FIG. 5 WELD PROFILE DETAILS — CONCAVE HEADS



NOTE — The details shown in (f) are to be used only when the lining is bonded and is to be welded at the external corner.

FIG. 6 WELD PROFILE DETAILS — FLANGES

SECTION 3 SELECTION AND QUALITY OF LININGS

11 SELECTION OF LINING

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

NOTE — Descriptions of lining materials and their characteristics are given in Annex B.

11.2 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; and
3) Cycle of temperature variation.

c) Degree of vacuum or pressure

1) Normal operating pressure;
2) Maximum and minimum pressures; and
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 setting 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.

11.3 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.

11.3.1 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.

11.3.2 Substances including dissolved gases present in a process stream in trace quantities only shall be added to the test liquors.

11.4 In selecting a lining for a particular duty, the following factors shall be considered in addition to the chemical resistance of the lining:

a) The liability of the lining material to stress crack in the particular environment;
b) Whether or not the lining is to be bonded to the substrate and the temperature limit of the adhesive system when used;
c) The size of the equipment and whether or not the lining needs to be welded;
d) The complexity of the equipment;

NOTE — Some of the lining materials are backed with rubber, glass or other fibre to enable the lining to be bonded to the substrate. There may be limitations on shaping, such as double curvature.

e) The thermal expansion of the lining material;
f) The creep characteristics of the lining material; and
g) The effect of vacuum on-loose linings.

11.5 When selecting materials account shall be taken of Annex C.

12 QUALITY OF LINING

12.1 General

12.1.1 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 **11**. When the purchaser selects the grade of lining to be applied, the applicator shall be responsible only for correct application.

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

12.2 Thickness of Lining

The thickness of the finished lining will depend upon the material selected and the duties for which it is intended. The maximum thickness as well as a minimum thickness shall be specified [*see* **4.1**(p)].

If necessary, the material shall be capable of being thermo-formed and welded to give joints which are pinhole free.

12.3 Bonding of the Lining

12.3.1 When the lining is to be bonded to the substrate; the type of adhesive, the maximum service temperature and the conditions required for application and curing shall be given by the applicator.

12.3.2 The minimum bond strength between the lining and the substrate shall be 3.5 N/mm^2 in direct shear and 5 N/mm width in peel at a test temperature of 20 °C.

12.3.3 The adhesive shall be capable of maintaining a bond at the design temperature and after cycling between ambient and maximum surface temperatures. When requested, the applicator shall produce evidence of the suitability of the adhesive.

13 CONTINUITY OF FINISHED LININGS

When the process conditions are corrosive, there shall be no pinholes in the lining. Under non-corrosive conditions, the maximum number of holes per square metre of surface shall be specified [*see* **4.1**(q)].

SECTION 4 METHOD OF LINING

14 SURFACE PREPARATION

14.1 Metal

14.1.1 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.

14.1.2 Equipment to which loose liners are to be fitted shall be free from loose rust and dirt.

14.1.3 All surfaces to which a lining is to be bonded shall be maintained 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.

14.1.4 All surfaces to which liners are to be bonded shall be blast cleaned.

14.1.5 When thermosetting resin-based adhesives are to be used to bond linings to the equipment, a minimum temperature of 10 °C shall be maintained from the start of the lining process until the adhesive is fully cured.

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

14.2 Concrete

14.2.1 Any external corners not formed with a chamfer shall be rubbed down to a radius not less than 5 mm.

14.2.2 Equipment to which loose liners are to be fitted does not require further surface preparation provided that all surfaces are clean and smooth.

14.2.3 All surfaces to which a lining is to be bonded shall be treated to remove laitence and shutter release agents. The specified method for this operation is blast cleaning. The blast cleaning process 2023 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 — 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 laitence on a concrete surface varies considerably and it is very important that acid is allowed to dwell on the surface for a sufficient length of time to move all laitence. When acid etching is used the next operation should be water washing of the concrete, followed by a drying process.

14.2.4 Following the removal of laitence from concrete surfaces to which linings are to be bonded any small holes exposed shall be filled.

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

14.2.5 All surfaces to which a lining is to be bonded shall be maintained at least 3 °C above the dew point during the 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.

14.2.6 When thermosetting resin-based adhesives are to be used to bond linings to the equipment a minimum temperature of 10 °C shall be maintained from the start of the lining process until the adhesive is fully cured.

15 LINING PROCESS

15.1 Following the blast cleaning of metal surfaces to which a liner is to be bonded the clean surface shall be primed as soon as possible and, in any case, not more than 4 h later and before any visible rusting occurs.

15.2 In the case of concrete equipment to which linings are to be bonded lining shall not proceed until the free water content is down to a level compatible with the adhesive system used.

15.3 Whether the lining is to be bonded or not sheets shall be cut and where necessary hot formed so that there is a tight fit between the liner and substrate. Wherever possible corners in the plastic sheets shall be hot formed so that welding in corners is avoided.

NOTE — In the case of pipework special expansion techniques may be employed in the fitting of the liner.

15.4 When linings are being bonded to the substrate the material shall be fitted in such a way that air is not trapped behind the sheet. When adhesives are used for bonding, the batch shall be used within its pot life, or discarded.

15.5 The welding process used for joining the lining shall be appropriate to the material and circumstances.

15.6 The fabricator of the lining shall provide evidence that the operators engaged in lining the vessels are capable of making good welds.

15.7 When required, the applicator of the lining shall provide type welds for testing. These welds shall have at least 85 percent of the strength of the parent material. Welds made in a lining forming a mating surface shall be ground flat.

SECTION 5 INSPECTION AND TESTING

16 RESPONSIBILITY FOR INSPECTION AND TESTING

16.1 The fabricator of the equipment and the applicator of the lining when requested shall provide 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 in the case of metals; surfaces and edges in the case of concrete;
c) The equipment after blast cleaning;
d) The lining material;
e) After the lining is fitted;
f) After welding of the lining; and
g) Whenever remedial work is done.

In cases where the purchaser requires independent inspection of the work (that is, by the inspection authority) at various stages, those stages shall be defined [*see* **4.1**(w)].

17 INSPECTION

17.1 Surface cleanliness and profile of metal surfaces.

17.1.1 Blast-cleaned surfaces shall be inspected to ensure that they comply with **14.1**.

17.1.2 Reference photographs or plates shall be used to establish the level of surface cleanliness (*see* **14.1.4**).

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

17.1.4 If inspection of equipment after blast cleaning reveals defects in material or welds, the applicator shall inform the fabricator and/or the purchaser and any remedial action shall be determined after consultation between the parties concerned [*see* **4.1**(w)].

17.2 Concrete Surfaces

Concrete surfaces shall be inspected to see that they are free from laitence and that surface defects are properly filled (*see* **14.2**).

17.3 Visual Appearance of Lining

The lining shall be inspected visually for blisters and other flaws. In the case of bonded liners containing blisters action depends upon the size and number of blisters and the duty of the equipment; the level of acceptance shall be determined under the requirements of **4.1**(w).

NOTE — Although small blisters may be acceptable when blisters are large and there is the risk in service that trapped gas or liquid in the blister will lead to the lining becoming detached then part or the whole of the lining will have to be removed and replaced.

17.4 Adhesion of Lining

17.4.1 As far as possible adhesion testing of the applied lining shall be avoided because the test is destructive and the lining has to be repaired. All linings shall be inspected visually for evidence of lack of adhesion to the substrate.

17.4.2 If required [*see* **4.1**(t)], test plates shall be used to demonstrate that the process employed does provide a lining with the required level of adhesion. These test plates shall be of the same material as the substrate and the lining process shall be the same as that employed for the lining of the equipment and done under the same conditions and at the same time.

17.5 Continuity of Lining

The lining shall be tested for pinholes (*see* Section 6). For non-corrosive conditions, local repairs are permitted if the number of pinholes exceeds that specified (*see* **13**). If local repairs are not possible, the lining shall be removed and replaced.

SECTION 6 METHODS OF TEST

18 CONTINUITY TESTING

18.1 General

18.1.1 The appropriate method for the continuity testing of sheet thermoplastic linings is the spark test (*see* **D-3.1**) and the type of instrument to be used shall be clearly established in accordance with **4.1**(w) (*see* Annex D).

18.1.2 The testing of linings shall be done systematically. The surface of all but small equipment shall be divided up by a 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.

18.2 Spark Testing

18.2.1 The instrument shall be adjusted to the test voltage agreed under **4.1**(w). Before commencing testing the surface shall be made dry and free from dirt.

18.2.2 The 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.

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

SECTION 7 RECTIFICATION OF FAULTS

19 GENERAL

19.1 When it is necessary to replace part of the lining the sheet used for rectification shall be of the same grade as that used for the original lining.

19.2 In the case of linings bonded to the substrate the adhesive used for replacing part(s) of the lining shall be that specified for the original lining.

19.3 The process used for replacing part(s) of the lining shall be as specified in **15**.

19.4 If more than one fault is found in a weld and those faults are less than 50 mm apart then for the purpose of rectification the faults shall be considered as one large defect.

19.5 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

20 GENERAL

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

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

20.2.1 In the case of some linings which are flared over flanges wooden blanks shall be fitted as soon as flaring is complete. These blanks shall be left in place until just before the mating flange is bolted in position.

20.2.2 If for any reason flange joints in such equipment are broken the wooden blanks shall be fitted until the joint is remade.

NOTE — It is recommended that such joints are broken only at ambient temperature.

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

20.4 High local loads on lined surfaces shall be avoided.

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

20.6 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* **4.1**(y)].

20.7 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.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 456 : 2000	Plain and reinforced concrete — Code of practice (*fourth revision*)
IS 803 : 1976	Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks (*first revision*)
IS 1876 : 2005/ IEC 60052 : 2002	Voltage measurement by means of standard air gaps (*first revision*)
IS 2825 : 1969	Code for unfired pressure vessels
IS 3370	Concrete structures for retaining aqueous liquids — Code of practice:
(Part 1) : 2021	General requirements (*second revision*)
(Part 2) : 2021	Plain and reinforced concrete (*second revision*)
(Part 3) : 2021	Prestressed concrete (*first revision*)
(Part 4)	Design tables,
(Sec 1) : 2021	Plates (*first revision*)
(Sec 2) : 2021	Rectangular tanks (*first revision*)
(Sec 3) : 2021	Circular tanks (*first revision*)
IS 10500 : 2012	Drinking water — Specification (*second revision*)

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ANNEX B

(*Clause* 11.1)

CHARACTERISTICS OF THERMOPLASTICS USED AS SHEET LININGS

B-1 GENERAL

B-1.1 In the foregoing clauses reference is made to the maximum service temperature of the various thermoplastics used as linings. In most cases the maximum service temperature for a particular material will depend on whether or not the material is bonded to the substrate. When a lining is bonded to the substrate it may be the choice of adhesive which is the limiting factor. A typical maximum service temperature for bonded lining is 100 °C.

B-1.2 Except when stated otherwise the maximum service temperature quoted is for linings which are not bonded to the substrate. The limits suggested are below what might be considered the upper temperature limit for the stability of the material but are quoted as safe working temperatures for the materials used as linings.

B-1.3 The limits may be varied depending upon the process environment and the design of the equipment.

B-2 UNPLASTICIZED POLYVINYL-CHLORIDE (UPVC)

B-2.1 UPVC is resistant to most acids, including oxidizing acids. It has good resistance to alkalis and salt solutions. The resistance of UPVC to organic chemicals varies. It is not resistant to aromatic hydrocarbons, chlorinated hydrocarbons, ketones or esters.

B-2.2 UPVC softens and looses strength as the temperature increases. When fully bonded to a substrate it may be used as a lining material up to 85 °C. The resistance of UPVC to erosion is good. At normal ambient temperature UPVC should be treated as a brittle material. UPVC can be shaped easily and can be welded.

B-3 PLASTICIZED PVC

B-3.1 Plasticized PVC is resistant to dilute acids and alkalis at ambient temperatures. Its resistance to salt solutions is good.

B-3.2 The resistance of plasticized PVC to organic solvents is very limited. Many solvents can extract the plasticizer, ultimately causing cracking of the material.

B-3.3 Plasticized PVC is usually bonded to the substrate and the maximum service temperature is 60 °C.

B-3.4 Plasticized PVC can be shaped and welded.

B-4 POLYETHYLENE (PE)

B-4.1 There are two types of sheet available, low density polyethylene (LDPE) and high density polyethylene (HDPE). These materials have good resistance to strong mineral acids but limited resistance in the case of oxidizing acids. Their resistance to alkalis and salt solutions is good.

B-4.2 Polyethylenes are susceptible to environmental stress cracking in polar organic chemicals and swell in both aromatic and chlorinated hydrocarbons.

B-4.3 Polyethylene has very good resistance to erosion.

B-4.4 Polyethylene is not normally used as a bonded liner and the maximum service temperature is 65 °C.

B-4.5 Polyethylenes are easy to weld but complicated shapes are not easily formed.

B-5 POLYPROPYLENE (PP)

B-5.1 Polypropylene has good resistance to strong mineral acids but limited resistance to oxidizing acids. It has good resistance to alkalis and salt solutions. It is resistant to a wide range of organic chemicals but swells in aromatic and chlorinated hydrocarbons.

B-5.2 The maximum service temperature is 90 °C.

B-5.3 Polypropylene is available with a glass or synthetic fiber or rubber backing and therefore can be bonded to substrates. The backing material can impose limitations on the thermal forming process.

B-5.4 Glass fibre backed polypropylene is not readily formed into complex shapes, but can be welded easily.

B-6 POLYVINYLIDENE FLUORIDE (PVDF)

B-6.1 PVDF has excellent chemical resistance to most corrosive chemicals including acids, alkalis, strong oxidizing agents and halogens.

B-6.2 It is attacked by oleum and swells in some organic solvents particularly at elevated temperatures.

B-6.3 It has a maximum service temperature of about 110 °C.

B-6.4 PVDF is available with a glass or synthetic fibre or rubber backing and therefore can be bonded to substrates. The backing material can impose limitations on the thermal forming process. It is readily welded.

B-7 FLUORINATED ETHYLENE- PROPYLENE COPOLYMER (FEP)

B-7.1 FEP has excellent chemical resistance. The service temperature limit depends upon the environments and the type of application but may be as high as 120 °C.

B-7.2 The material is available with a glass fibre backing to provide a bondable surface. When FEP is bonded to a substrate the maximum service temperature will be determined by the adhesive used.

B-7.3 FEP can be thermo-formed, but in the case of glass backed material the complexity of the formed shape may be limited.

B-7.4 FEP can be welded.

B-8 PERFLUOROALKOXY (PFA)

B-8.1 PFA has excellent chemical resistance. With one or two exceptions it is inert to all chemicals.

B-8.2 The service temperature limit depends upon the configuration and duty of the equipment, but it may be as high as 160 °C.

B-8.3 PFA can be thermo-formed and welded. It may be used as a loose or a bonded liner.

B-9 POLYTETRAFLUQROETHYLENE (PTFE)

B-9.1 PTFE has excellent chemical resistance. With one or two exceptions it is inert to all chemicals.

B-9.2 The service temperature limit depends upon the configuration and duty of the equipment. It may be as high as 160 °C.

B-9.3 PTFE cannot be thermo-formed but when heated it can be swaged over flanges.

B-9.4 PTFE up to 4 mm thick may be welded. The process is very difficult and requires special techniques and equipment.

B-9.5 It is usually used as a loose liner, although it is possible to etch the surface to make bonding to a substrate possible. It is also available with a glass fibre backing.

B-10 ETHYLENE-CHLOROTRIFLUORO-ETHYLENE COPOLYMER (E-CTFE)

B-10.1 E-CTFE has excellent chemical resistance upto a service temperature of 120 °C. Some chlorinated solvents may cause swelling.

B-10.2 E-CTFE is available with a glass fibre backing and therefore can be bonded to a substrate; the backing material may impose limitations on the thermoforming process.

B-10.3 E-CTFE can be welded.

ANNEX C

(*Clause* 11.5)

EFFECT OF MATERIALS ON WATER QUALITY

C-1 When used under the conditions for which they are designed, materials in contact with or likely to come into contact with potable water shall not constitute a toxic hazard, shall not support microbial growth and shall not give rise to unpleasant taste or odour, cloudiness or discolouration of the water.

C-2 Concentrations of substances, chemicals and biological agents leached from materials in contact with potable water, and measurements of the relevant organoleptic/physical parameters shall not exceed the values specified in IS 10500.

ANNEX D

(*Clause* 18.1.1)

CONTINUITY TESTING

D-1 INTRODUCTION

D-1.1 It is essential that linings provide adequate protection to equipment under the conditions for which they are designed. Therefore, when there is a requirement that a lining be continuous, that is, free from pinholes and cracks, it is vital that test methods be used to prove the lining.

D-1.2 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; and
b) Spark testing in which a discharge from a high-frequency source or a direct current spark is used to find the fault.

D-2 WET SPONGE TESTING

D-2.1 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 which is soaked in a 3 percent solution of electrolyte to which a small amount of a 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.

D-2.2 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 percent 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.

D-2.3 It is a simple matter to calculate the minimum diameter of the hole that can be detected in a given thickness of lining for a specific sensitivity of instrument. If an instrument has a sensitivity of 1 000 000 Ω current will be detected in the primary circuit if the resistance is less than 1 000 000. Taking the resistivity of the electrolyte as 100 Ω cm, then it will be possible to find a hole approximately 15 microns in diameter in a coating 200 micron thick.

D-2.4 If the instrument is of the right sensitivity, a hole of 1 micron 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 conditions 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 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.

D-2.5 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 responds on a ‘go’ or ‘no go’ basis.

D-2.6 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.

D-2.7 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.

D-2.8 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.

D-3 SPARK TESTING

D-3.1 General

D-3.1.1 There are two types of spark testing equipment in general use:

a) High frequency with an a.c. source; and

b) Direct current (high voltage).

D-3.1.2 The mode of operation of the two types of quite different.

D-3.2 High-Frequency Test Equipment

D-3.2.1 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 IS 1876, 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.

D-3.2.2 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.

D-3.2.3 Tests have shown that the risk of damage by high-frequency spark testing is remote if the time the probe is allowed to dwell in any one place is short. The 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.

D-3.3 Direct Current Spark Testers

D-3.3.1 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 do 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.

D-3.3.2 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.

D-4 TESTING

D-4.1 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.

D-4.2 It is essential that inspectors have an understanding of how the instruments work and the need to survey the linings in a controlled fashion.

D-4.3 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.

ANNEX E

(*Foreword*)

COMMITTEE COMPOSITION

Chemical Engineering Plants and Related Equipment Sectional Committee, MED 17

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