AMD 3072

Amendment Slip No.3
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to CP 3003 : Part 1 : 1967

Lining of vessels and equipment for chemical processes
Part 1 : Rubber

Revised text

Clause 3.1.2 Access to vessel and ventilation. Delete the existing text and substitute the following:

'The design of all vessels and equipment shall allow for adequate access and ventilation of fumes evolved during lining (e.g. for the preparation of the surface or the lining operation) or during subsequent maintenance in service.

In completely enclosed vessels manholes shall have a minimum diameter, *after lining,* that complies with the requirements of Section 30 of the Factories Act 1961, currently 460 mm, although a larger size is preferred (600 mm) to facilitate rescue operations.

The method of ventilation shall be the subject of agreement, at the tendering stage, between the lining contractor and the user, and it shall ensure that, in no case, can pockets of stagnant air occur. This would normally require at least one additional branch not less than 75 mm in diameter.'

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BRITISH STANDARD CODE OF PRACTICE

CP 3003 : Part 1 : 1967

LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

Part 1. Rubber

Incorporating amendment issued July 1973 (AMD 1216) and May 1978 (AMD 2598)

THE COUNCIL FOR CODES OF PRACTICE

BRITISH STANDARDS INSTITUTION

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LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART 1. RUBBER

This part of the Code of Practice has been prepared by a committee convened by the Codes of Practice Committee for Mechanical Engineering. Having been endorsed by the Council for Codes of Practice, it was published under the authority of the General Council on 8th September, 1967.

First published, April, 1964.
First revision, September, 1967.

This Code of Practice makes reference to the following British Standards and Codes of Practice:

BS 490.	Rubber conveyor and elevator belting.
BS 499.	Welding terms and symbols. Part 1. Welding, brazing and thermal cutting glossary.
BS 639.	Covered electrodes for the manual metal-arc welding of mild steel and medium-tensile steel.
BS 693.	General requirements for oxy-acetylene welding of mild steel.
BS 903.	Methods of testing vulcanized rubber. Part A20. Determination of hardness (micro-test).
BS 1500.	Fusion welded pressure vessels for use in the chemical, petroleum and allied industries.
BS 1515.	Fusion welded pressure vessels (advanced design and construction) for use in the chemical, petroleum and allied industries.
BS 1856.	General requirements for the metal-arc welding of mild steel.
BS 2035.	Cast iron flanged pipes and flanged fittings.
BS 2594.	Horizontal mild steel welded storage tanks.
BS 2654.	Vertical mild steel welded storage tanks with butt-welded shells for the petroleum industry.
BS 2719.	Methods of use and calibration of pocket type rubber hardness meters.
CP 102.	Protection of buildings against water from the ground.

CP 2007. Design and construction of reinforced and pre-stressed concrete structures for the storage of water and other aqueous liquids.

British Standard Codes of Practice are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this Code of Practice:
Committee references MECP/7, MECP/7/1
Draft for comment 66/14935

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SUB-COMMITTEE MECP/7/1: RUBBER LININGS

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BRITISH STANDARD CODE OF PRACTICE CP 3003

LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

Part. 1. Rubber

1. GENERAL

1.1 SCOPE

1.1.1 This part of the Code gives guidance to manufacturers, lining contractors and users of rubber-lined vessels and equipment on the various types of lining available and on the selection, design, application, maintenance, inspection and testing, together with recommendations on the design of the items to be lined. This part excludes brushed-on and sprayed-on rubber coatings.

1.1.2 In this Code the word ' shall ' indicates a requirement that is to be adopted in order to comply with the Code while the word ' should ' indicates a recommended practice.

NOTE 1. In place of the customary, but incorrect, use of the pound and kilogramme as units of force the units called a pound-force (abbreviation lbf) and kilogramme force (abbreviation kgf) have been used in this Code. They are the forces which when acting on a body of mass one pound, one kilogramme, give it an acceleration equal to that of standard gravity.

NOTE 2. Where metric equivalents are stated, the figures in British units are to be regarded as the standard. The metric conversions are approximate. More accurate conversions should be based on the tables in BS 350, ' Conversion factors and tables '.

1.2 DEFINITIONS

For the purposes of this part of the Code, the following definitions apply:

(1) *Bleeding*. The diffusion of an ingredient from a rubber compound to the contents of a vessel.

(2) *Button*. A small superimposed disk integral with the lining proper used as a flat area for testing hardness.

(3) *Edge wheel*. A hand tool, comprising a wheel with a narrow smooth edge for consolidating a joint.

(4) *Mix*. A mixture of rubber and compounding ingredients.

(5) *Scarfed joint*. An overlapped joint formed by chamfering the edges of the sheets to achieve as smooth a contour as possible.

(6) *Tiecoat*. A thin layer of adhesive solution used to hold the rubber in contact with the substrate until the bond between rubber and metal is developed during vulcanization.

(7) *Vulcanization*. A process in which rubber, through a change in its

chemical structure, is converted to a condition in which the elastomeric state exists over a greater range of temperature; in some cases the process is extended so that the substance becomes rigid.

1.3 EXCHANGE OF INFORMATION

1.3.1 Early consultation and exchange of information should be arranged between all parties concerned with the design, use, manufacture and erection of the vessels and equipment to be lined, and the lining contractor. Adequate and accurate scale drawings should be available to all parties concerned.

1.3.2 Consultation is desirable on:

(1) Site conditions which may affect this particular work and the availability of services for site vulcanization.

(2) Safety measures to be taken during lining on site.

(3) Construction of equipment to be lined, location of welds, joints and supports and the finish of the surface to be lined.

(4) Nature and concentration of media for which vessel or equipment is required.

(5) Operating, and other relevant temperatures and pressures.

(6) Other factors influencing material stress, e.g. expansion, vibration, or impact of contents on lining.

(7) Presence of abrasives in contents, and potential local erosion of fluids.

(8) Internal or external installation and means of access, lifting facilities, etc.

(9) Where necessary, the nature of the surface finish required of the lining.

(10) Required service life.

2. MATERIALS

2.1 PROPERTIES OF RUBBER LININGS

2.1.1 The physical and chemical properties of rubber linings vary widely, according to the type of rubber used and the amount and type of filler and vulcanizing agent present in the mix. The temperature range for which a particular lining is suitable will depend on the operational conditions and on the environment.

2.1.2 Rubbers can be mixed in anti-static form, i.e. having a low surface electrical resistance; if suitably connected to earth, the possibility of a charge of static electricity building up is obviated.

2.1.3 The properties of the individual types of rubber used for linings are given in 2.2 to 2.9 inclusive. Information on the hardness testing of rubber is given in BS 903* and BS 2719†.

* BS 903, ' Methods of testing vulcanized rubber ', Part A20, ' Determination of hardness (micro-test) '.

† BS 2719, ' Methods of use and calibration of pocket type rubber hardness meters '.

2.2 NATURAL RUBBER (SOFT)

2.2.1 Vulcanized natural rubber compounds are resistant to most inorganic chemicals with the exception of strong oxidizing agents such as chromic and nitric acids. They resist attack by certain organic compounds, including alcohols and most esters. They should not be used in the presence of aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, mineral oils and certain vegetable oils.

2.2.2 By selective mixing, rubber can be given various physical and chemical properties, for example range of hardness and ozone and abrasion resistance, and can operate continuously over the temperature range −30°C (−22°F) to +90°C (+ 194°F).

2.2.3 Conventional rubber linings are unlikely to contain more than a small percentage of sulphur or other vulcanizing agents and the properties will be influenced by the filler content and type.

2.3 EBONITE

2.3.1 Ebonites generally have a higher chemical resistance than natural rubber, in particular to chlorine gas and most aliphatic carboxylic acids.

2.3.2 Ebonites can be produced from natural rubber, synthetic polyisoprene, polybutadiene, styrene-butadiene rubber, nitrile rubber or blends thereof, by incorporating sufficient sulphur to saturate substantially the sites available for crosslinking. Ebonites are used normally in the range 0°C (32°F) to 100°C (212°F); for lower temperatures plasticizers should be incorporated.

Certain synthetic rubbers may be added as plasticizers to give a flexible ebonite.

2.4 STYRENE-BUTADIENE RUBBER

Although the characteristics of styrene-butadiene rubbers differ among themselves, their properties are broadly similar to those of natural rubber when compounded for the same duty (see 2.2).

2.5 POLYCHLOROPRENE (NEOPRENE)

Neoprene possesses greater resistance than natural rubber to heat, ozone, oxidizing conditions and sunlight, and also has a marked resistance to most oils. It should not, however, be used in conjunction with halogenated and aromatic hydrocarbons. Certain grades of neoprene can be used continuously in the temperature range −20°C (−4°F) to +105°C (+ 221°F); it cannot be mixed to form an ebonite.

2.6 BUTYL RUBBER

Butyl rubber is a copolymer of isobutylene and isoprene. It possesses greater resistance than natural rubber to heat and oxidizing acids and is highly impermeable to gases; while this is basically an advantageous property for a lining material, it also means that great care is required to avoid trapping solvents or air when applying the lining. Butyl rubber should not be used in the presence of free halogens, petroleum oils or halogenated or aromatic hydrocarbons. When suitably mixed, butyl rubber has a lower water absorption than most other rubbers and it can be used in the temperature range −20°C (−4°F) to + 120°C (+ 248°F).

2.7 NITRILE RUBBER

2.7.1 Nitrile rubbers are copolymers of acrylonitrile and butadiene.

2.7.2 Polymers which contain the higher ratios of acrylonitrile to butadiene are particularly resistant to swelling by mineral oils and fuels; similarly, gas impermeability is increased. This is, however, accompanied by deterioration in low temperature properties and loss of resilience. Nitrile rubber should not be used with phenols, ketones, strong acetic acid, most aromatic hydrocarbons and nitrogen derivatives.

2.7.3 The resilient nitrile rubbers can be mixed to give physical and mechanical properties equivalent to those of natural rubber and can be used in the temperature range −20°C (−4°F) to + 110°C (+ 230°F).

2.7.4 Nitrile rubbers can form ebonites which have good heat resistance and outstanding resistance to swelling by certain organic solvents.

2.8 CHLOROSULPHONATED POLYETHYLENE*

2.8.1 Chlorosulphonated polyethylene is a synthetic rubber with excellent resistance to heat, ozone and oxidizing chemicals, and has good abrasion resistance. It can be mixed for outstanding resistance to oxidizing chemicals such as sodium hypochlorite solutions, to sulphuric acid and to sulphuric acid saturated with chlorine, etc.; it has good resistance to most oils, lubricants and aliphatic hydrocarbons, but is unsuitable for use with esters and ketones. It can operate continuously over the temperature range −5°C (+ 23°F) to + 120°C (+ 248°F).

2.8.2 It is one of the few synthetic rubbers that can be mixed in any colour without loss in mechanical properties.

* Available commercially under the registered trade mark ' Hypalon '.

2.9 COPOLYMERS OF HEXAFLUOROPROPYLENE AND VINYLIDENEFLUORIDE*

NOTE. These materials possess properties which are of great interest to designers and users of certain types of chemical plant. They are, however, in the early stages of development, and *it is therefore essential that early discussion be held* between the intending user and the lining contractor whenever it is proposed to use them.

2.9.1 Copolymers of hexafluoropropylene and vinylidenefluoride are synthetic rubbers with outstanding resistance to both heat and fluids. They can be used over a wide temperature range in continuous service up to 200°C (392°F).

2.9.2 These materials have excellent resistance to oils, fuels, lubricants, carbon tetrachloride, most concentrated acids and to many aliphatic and aromatic hydrocarbons such as toluenes, benzene, xylene. They should not, however, be used in contact with low molecular weight esters and ethers, ketones, certain amines, hot anhydrous hydrofluoric and chlorosulphonic acids.

2.9.3 These materials also have good ozone resistance and can be used in contact with many corrosive gases, e.g. bromine, chlorine, but they are attacked by ammonia and are not suitable for use with high pressure steam.

3. DESIGN OF VESSELS AND EQUIPMENT

3.1 GENERAL

3.1.1 Interior surfaces and fittings. The surfaces which are to be covered with rubber shall be easily accessible and free from pitting or other physical imperfections. Interior fittings should be designed to allow safe and easy movement of the operator or, if this is not possible, a manhole should be provided in each section of the vessel being lined.

3.1.2 Access to vessel and ventilation. The design of all vessels and equipment shall allow for adequate access and venting of fumes evolved during the preparation of the surface and the application of the adhesive.

In completely enclosed vessels there shall be at least one manhole which shall be not less than 18 in (450 mm) long and 18 in (450 mm) wide, or (if circular) not less than 18 in (450 mm) in diameter and one additional branch not less than 3 in (76 mm) bore. The method of ventilation shall be the subject of agreement at the tendering stage between the lining contractor and the user and shall ensure that, in no case, can pockets of stagnant air occur.

3.1.3 Clearances. When calculating clearances, allowance shall always be made for the thickness of the lining or covering.

3.1.4 Branches and outlets. All branches should be flanged and the lining taken over the flange face to prevent the ingress of liquor behind the lining.

* Available commercially under the registered trade mark 'Viton'.

3.1.5 Surface contours. Sharp changes of contour in the surface to be covered shall be avoided wherever possible and such changes shall be finished to a suitable radius; in all cases this shall be such that the internal radius of the lining is not less than ⅛ in (3·2 mm).

3.1.6 Heating. Any steam coil or immersion heater used for heating the contents of the vessel shall be situated not less than 4 in (102 mm) from the rubber-lined surface to avoid local over-heating. When heating by steam injection care shall be taken to avoid direct impingement of steam on the rubber surface.

3.2 FABRICATED MILD STEEL VESSELS

3.2.1 Fabrication and testing. Mild steel vessels should be fabricated and tested in accordance with recognized standards of good design and practice; riveted construction should not be used. For guidance on these requirements, reference may be made to BS 1500, BS 1515, BS 2594 and BS 2654*.

3.2.2 Welded joints. Welding shall be in accordance with BS 693† or BS 1856‡. Lap joints should be avoided wherever possible; butt welds, in both butt joints and tee joints, shall not be made with a single run of the electrode or blowpipe, for sheet thicknesses of ⅛ in (3·2 mm) and above. Welds shall be ground smooth and flush on the side to be covered and, wherever possible, should be made from the side to be covered. Where, due to design or other reasons, the latter is not possible the root should be chipped out and a sealing run used, see Fig. 1.

Corner joints may be avoided by butt welding flanged plates, as shown in Fig. 2.

Attention is drawn to the fact that the use of ' iron powder ' electrodes to BS 639§ makes possible the production, in a single run, of concave fillet welds which require the minimum amount of dressing.

NOTE. Definitions and illustrations of different types of joints, welds and preparations are contained in BS 499, ' Welding terms and symbols ', Part 1, ' Welding, brazing and thermal cutting glossary '.

3.2.3 Surface contours. External angles and the edges at the junction of plates should be removed by the most convenient means and the surface ground smooth

* BS 1500, ' Fusion welded pressure vessels for use in the chemical, petroleum and allied industries '.
BS 1515, ' Fusion welded pressure vessels (advanced design and construction) for use in the chemical, petroleum and allied industries '.
BS 2594, ' Horizontal mild steel welded storage tanks '.
BS 2654, ' Vertical mild steel welded storage tanks with butt-welded shells for the petroleum industry '.

† BS 693, ' General requirements for oxy-acetylene welding of mild steel '.

‡ BS 1856, ' General requirements for the metal-arc welding of mild steel '.

§ BS 639, ' Covered electrodes for the manual metal-arc welding of mild steel and medium-tensile steel '.

Fig. 1. Sealing run in a welded butt joint

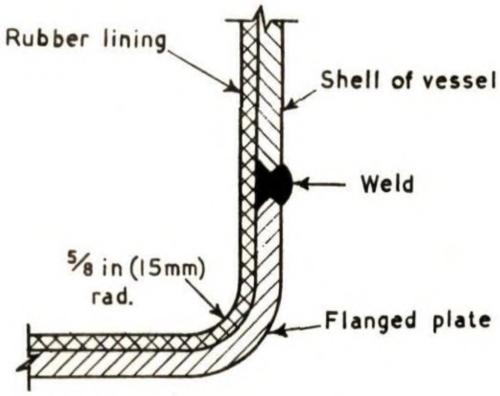


Fig. 2. Butt-welded flanged plate

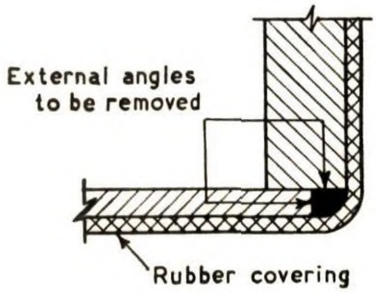


Fig. 3. Rounding of external angles

to the required radius. Where corner and tee joints are unavoidable, they shall be fillet welded and ground smooth and concave to the required radius (see Fig. 3). Care should be taken not to reduce the thickness of the metal below the design thickness or to reduce the dimensions of welds (especially fillet welds) below those required for adequate strength. To meet this requirement it may sometimes be necessary to deposit additional weld metal.

3.2.4 Branches and outlets. All branches and outlets should be designed as flanged pipes to allow the rubber lining to cover the flange face. Typical flanged joints are illustrated in Fig. 4. Where small bore branches are necessary they should be adequately stiffened with gussets.

Pads should be avoided wherever possible, but are sometimes necessary in place of small bore branches to prevent damage during handling and erection. Fixing holes in pads shall not penetrate the shell of the vessel (see Fig. 5).

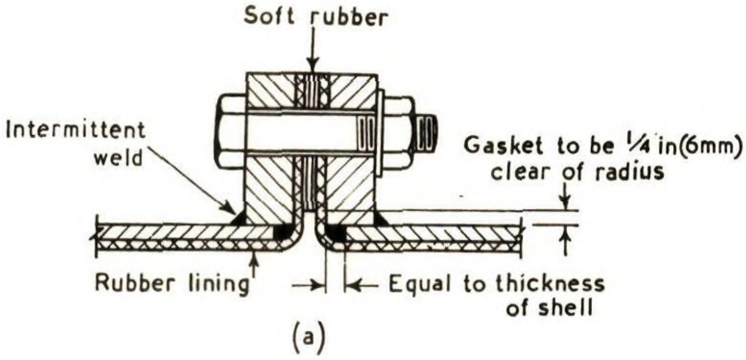
3.2.5 Sectional tanks. Mating flanges of sectional tanks should be square and plumb, and sections should be made to avoid distortion when bolted together. Fig. 4 shows recommended flanged joints. If the flange faces have to withstand very high loads, the method of finishing the flange joint shown in Fig. 4*c* should be employed in preference to those shown in Fig. 4*a* and Fig. 4*b*. Normally, soft rubber gaskets should be interposed between lined flanges. In certain cases internal strapping may be required.

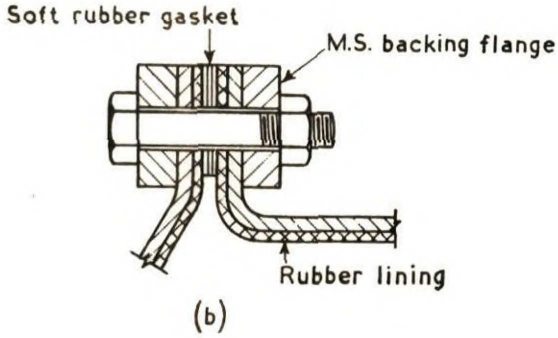
3.2.6 Trapped air. In constructing vessels it is necessary to ensure that there are no pockets, pits, or surface irregularities, including those at joints, to avoid the possibility of air being trapped between the lining and the surface. Typical methods of avoiding air being trapped in welded joints are shown in Fig. 6; this problem should not, however, arise if due regard is paid to the quality of the welding. Where vent holes are essential and where the user so requires, such vent holes shall be plugged after the lining has been accepted.

3.2.7 Autoclave vulcanizing. If it is intended to vulcanize the lining in the manufacturer's autoclave, the overall dimensions to which the vessel or its sections should be designed will be determined by the size of the autoclave.

3.2.8 Rigidity. The lining contractor shall be informed of the amount of flexing liable to take place in the tank so that allowance can be made in the type of rubber to be used. With very rigid ebonites and similar linings, it is necessary to ensure that adequate stiffness is incorporated in the design to avoid any defects.

Adequate provision shall be made in design to withstand the pressures involved where it is intended to pressurize the vessel to effect vulcanization.





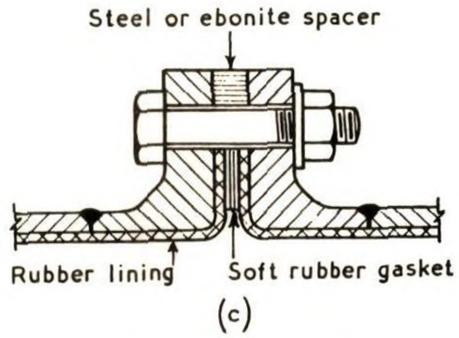


Fig. 4. Typical flanged joints

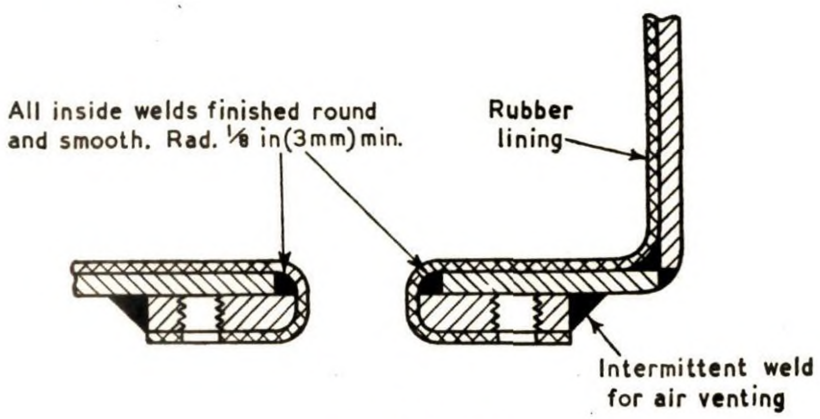


Fig. 5. Outlet pads

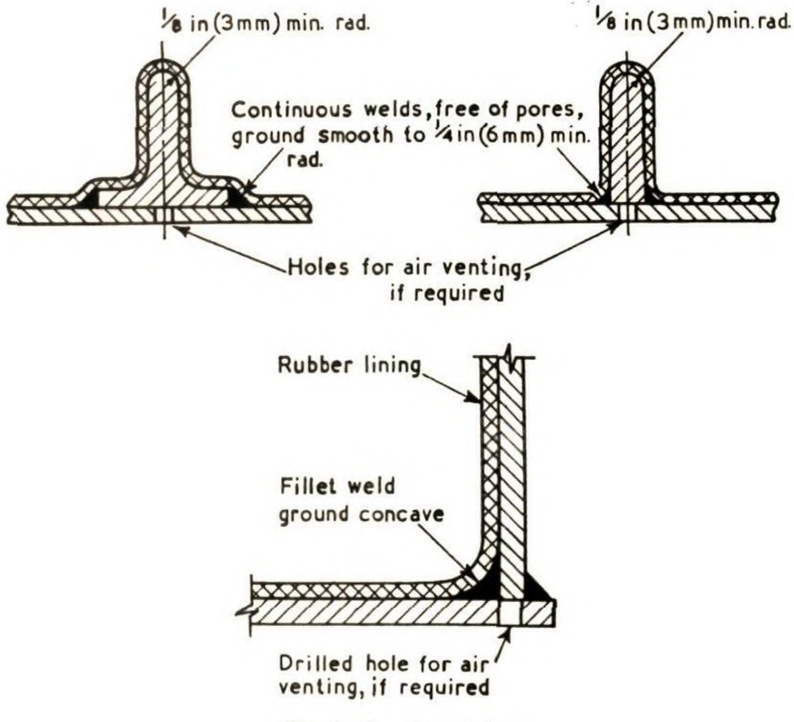


Fig. 6. Air release holes

3.3 MILD STEEL PIPES AND FITTINGS

3.3.1 Pipes and fittings shall have smooth and easily accessible surfaces. Lining of surfaces with sharp projections and surface irregularities shall be avoided.

Where welding is used, internal welds shall be ground flush with the parent metal to ensure a continuous smooth surface.

Screwed fittings are not acceptable for rubber lining.

Flat-faced flanges shall be used and welded on square to the pipe or fitting; the weld on the front face shall be continuous and rounded convex to a radius of not less than ⅛ in (3·2 mm). Fillet welds at the rear of flanges shall be interrupted to allow the escape of air trapped between the pipe and the flange base.

The lining contractor shall advise the user when the surface finish of the pipe and fittings make them unsuitable for lining.

3.3.2 Piping arrangements should wherever possible be designed using standard pipes and fittings and the following requirements shall be complied with:

3.3.2.1 *Straight pipes.* The maximum lengths of straight pipe, measured between flange faces, which can be satisfactorily lined are given in Table 1.

TABLE 1. MAXIMUM LENGTHS OF STRAIGHT PIPE FOR SATISFACTORY LINING

Nominal bore		Maximum length between flanges	
in	mm	ft	m
1	25	9	2·7
1½	38	9	2·7
2	51	12	3·7
2½	64	12	3·7
3 and over	76 and over	20	6·1

3.3.2.2 *Bends and elbows.* The dimensions of elbows and 90° bends which can be satisfactorily lined are given in Fig. 7 and Table 2. For bends having arms of equal lengths, the maximum length of both arms is *L*.

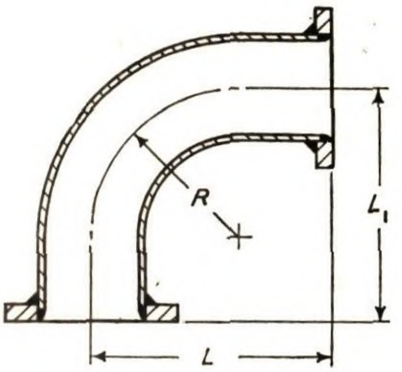


Fig. 7. Bends and elbows

TABLE 2. DIMENSIONS OF BENDS AND ELBOWS FOR SATISFACTORY LINING

Nominal bore		R (min.)		L (max.)		L1 (max.)	
in	mm	in	mm	ft in	mm	ft in	m
1	25	2¾	70	0 6	152	2 6	0·76
1½	38	3	76	0 7½	191	4 0	1·22
2	51	3¼	83	0 9½	241	5 2½	1·59
2½	64	3¾	95	0 11½	292	5 0½	1·54
3	76	4	102	1 1	330	6 0	1·83
4	102	4¾	120	1 5	432	6 0	1·83
6	152	6½	165	2 0	610	6 0	1·83
8	203	8¼	210	2 0	610	6 0	1·83
10	254	10	254	2 0	610	6 0	1·83
12	305	11¾	298	2 0	610	6 0	1·83
14	356	13½	343	2 0	610	6 0	1·83
16	406	16	406	2 0	610	12 0	3·66
18	457	18	457	2 0	610	12 0	3·66
20	508	20	508	2 0	610	12 0	3·66
22	560	22	560	2 0	610	12 0	3·66
24	610	24	610	2 0	610	12 0	3·66

3.3.2.3 ***Reducing pipes.*** The dimensions of concentric and eccentric reducing pipes which can be satisfactorily lined are given in Fig. 8 and Table 3. The bore of a reducing pipe shall change gradually without steps.

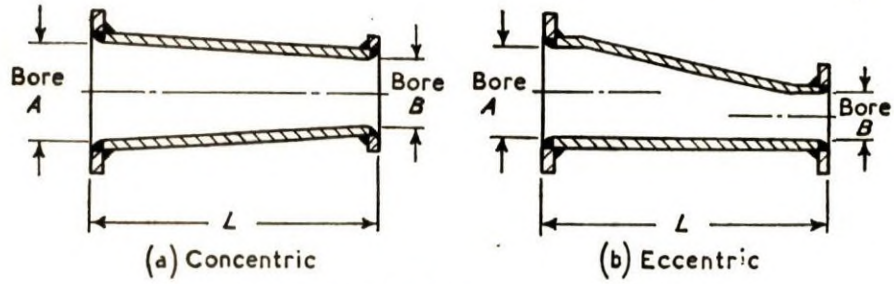


Fig. 8. Reducing pipes

TABLE 3. DIMENSIONS OF CONCENTRIC AND ECCENTRIC REDUCING PIPES FOR SATISFACTORY LINING

Nominal bore *A*		Nominal bore *B*		Length *L*	
in	mm	in	mm	in	mm
1½	38	1	25	6	152
2	51	1½	38	8	203
2½	64	2	51	8	203
3	76	2½	64	8	203
4	102	3	76	10	254
6	152	4	102	12	305
8	203	6	152	12	305
10	254	8	203	12	305
12	305	10	254	18	457
14	356	12	305	18	457
16	406	14	356	18	457
18	457	16	406	24	610
20	508	18	457	24	610
22	560	20	508	24	610
24	610	22	560	24	610

3.3.2.4 *Tee pieces, crosses and branch pipes.* The dimensions of tee pieces, crosses and branch pipes which can be satisfactorily lined are given in Fig. 9 and Table 4.

3.4 CAST IRON VESSELS

3.4.1 Cast iron presents difficulty in lining due to porosity, mould marks, and the effect of grain size in the casting. These factors increase the possibility of air inclusion.

3.4.2 Castings shall be constructed of close grained iron and shall be substantially free from cavities and porosity. If any of these defects appear after

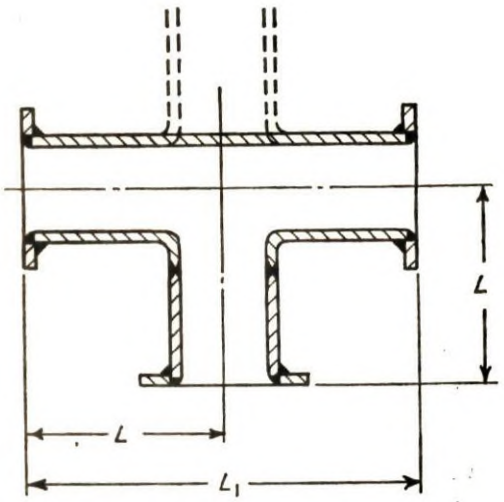


Fig. 9. Tee pieces, crosses and branch pipes

TABLE 4. DIMENSIONS OF TEE PIECES, CROSSES AND BRANCH PIPES FOR SATISFACTORY LINING

Nominal bore		*L* (max.)		L_1 (max.)	
in	mm	in	mm	ft	m
1	25	4	102	9	2·7
1½	38	4½	114	9	2·7
2	51	5	127	12	3·7
2½	64	5½	140	12	3·7
3	76	6	152	20	6·1
4	102	7	178	20	6·1
6	152	9	229	20	6·1
8	203	11	279	20	6·1
10	254	13	330	20	6·1
12	305	15	381	20	6·1
14	356	17	432	20	6·1
16	406	19	483	20	6·1
18	457	21	533	20	6·1
20	508	23	584	20	6·1
22	560	25	635	20	6·1
24	610	27	686	20	6·1

casting they shall be left untreated. The remedying of any defects after shot-blasting shall be agreed between the manufacturer and the lining contractor. All surfaces should be free from fins, sharp projections, etc.

3.4.3 In order to reduce the possibility of surface blowholes forming, it is preferable that the face to be covered is the lower one when the casting is made.

3.4.4 When very large, heavy or complex castings are to be lined it is essential that the advice of the lining contractor be sought at an early stage.

3.5 CAST IRON PIPES AND FITTINGS

The requirements given in 3.3 apply also to cast iron pipes and fittings. Cast iron pipes and fittings manufactured to BS 2035* are of suitable dimensions for lining.

3.6 ALUMINIUM AND ALUMINIUM ALLOY VESSELS

3.6.1 The general construction details and principles already given for mild steel vessels (see 3.2) will apply to vessels constructed of aluminium or aluminium alloys. All vessels shall be fusion welded; riveted construction is not acceptable. In view of the softer nature of this metal and its alloys it is recommended that the design shall provide for maximum rigidity (see BS 1500 : Part 3)†.

3.6.2 Full details of the alloy shall be given to the lining contractor for confirmation that rubber linings can be satisfactorily bonded and a sample of the alloy shall be provided to the lining contractor if called for.

3.7 CONCRETE VESSELS

3.7.1 At present, no Code of Practice exists for concrete vessels that are subsequently to be lined, but CP 2007‡ gives some guidance on the design and construction of concrete structures intended for the storage of water and other aqueous liquids. Vessels should be shaped so that the lining can be taken over the edges, and down the outside for not less than 3 in (76 mm).

3.7.2 Concrete surfaces should be reasonably smooth and free from surface imperfections and dust. This can be achieved by one of the following methods:

3.7.2.1 By casting the concrete against specially smooth formwork and taking precautions to ensure that it is fully compacted and that no leakage of mortar takes place between the joints in the formwork. Any blowholes in the surface

* BS 2035, 'Cast iron flanged pipes and flanged fittings'.

† BS 1500, 'Fusion welded pressure vessels for use in the chemical, petroleum and allied industries', Part 3, 'Aluminium'.

‡ CP 2007, 'Design and construction of reinforced and prestressed concrete structures for the storage of water and other aqueous liquids'.

should be made good with an approved filler. The use of parting agents on shuttering should be avoided.

3.7.2.2 By casting the concrete against normal formwork (metal or timber) and rendering the surface.

3.7.3 The concrete should be properly cured by being allowed to dry out slowly. The time of drying will depend upon the actual conditions, but should be not less than 28 days for structural concrete or 7 days for a Portland cement rendering.

3.7.4 For rendered finishes a sand/cement mix approximately 3 : 1 should be applied to keyed surfaces, to a thickness of not less than ⅜ in (10 mm). Care should be taken to ensure adequate adhesion between the rendered finish and the under surface.

Alternatively, an approved cement/latex composition not less than ⅛ in (3·2 mm) thick may be applied.

The lining contractor should be informed of the method used.

The rendering should be cured for an appropriate time depending upon the type of cement used.

3.7.5 Unless the moisture content of the concrete is sufficiently low, the adhesion of the rubber lining will not be good enough. The moisture content to be achieved before lining should, therefore, be the subject of agreement between the user and the lining contractor.

The moisture content may be measured by the use either of meters which measure the electrical resistance between two points on the surface or of hygrometers which are arranged to measure the humidity of a sample of air in close contact with the concrete. An example of the latter type is described in Appendix A.

All vessels situated partly or wholly below ground level should be protected against the permeation of external moisture by the application of a suitable protective membrane to the external surfaces. Detailed guidance is given in CP 102*.

3.8 RENDERED BRICKWORK VESSELS

Similar conditions apply in the structural design of the brickwork vessel as in the case of concrete vessels. All corners and edges should be rounded off to approximately ¼ in (6·4 mm) radius. Rendering should be carried out as for concrete vessels.

3.9 MISCELLANEOUS MATERIALS

Equipment made from wood, copper or alloys with a high copper content such as brass, and steel alloys, may be accepted for lining or covering, but it is recommended that the advice of the lining contractor be sought in such cases.

* CP 102, 'Protection of buildings against water from the ground'.

4. DESIGN OF LININGS

4.1 SELECTION OF MATERIAL

4.1.1 General. The selection of the rubber lining and its method of application shall be based on information supplied by the user. Full details of the duties shall, therefore, be submitted to the lining contractor and shall include:

4.1.2 The nature of the materials to be handled. Full analysis of the materials to be handled shall be given, including constituents present in trace quantities. It is imperative that these trace quantities be stated as they may have a deleterious effect on the life of the lining out of all proportion to the amounts present. Materials which may promote photochemical reaction, solvents, etc., shall be included as these may have a major effect on the service life of the lining. It may also be important to ascertain whether contamination or discoloration of the material by the rubber can occur.

4.1.3 The temperature. The temperature of the materials to be handled:

(1) The normal operating temperature.
(2) The maximum and minimum temperature.
(3) The cycle of temperature variation.

4.1.4 The degree of vacuum or pressure

(1) The normal operating pressure.
(2) The maximum and minimum pressures.
(3) The cycle of pressure variation.

4.1.5 The cycle of operations. Whether batch or continuous process.

4.1.6 Abrasion and erosion. Details of the amount, particular size and physical characteristics of the suspended matter, together with rates of flow shall be stated.

4.1.7 Mechanical damage

(1) *Construction hazards.* The lining contractor shall be informed of any anticipated difficulties involved in the handling and final siting of the equipment.

(2) *Operational hazards.* The lining contractor shall be informed of any vibration of the equipment, and the possibility of any mechanical damage.

4.1.8 The immersion condition

(1) Whether the lining will be constantly or intermittently immersed.
(2) Whether the vessel will be partially filled or completely filled.
(3) In partially filled vessels whether the liquid contains dissolved corrosive gas which will be liberated inside the vessel.

4.2 QUALITY OF RUBBER

4.2.1 The grade of rubber shall be agreed with the lining contractor and shall be such that the lining contractor is prepared to state that it will satisfy the chemical and physical conditions specified as regards any agreed service life, non-staining properties and deterioration by prolonged contact with the contents of the vessel.

It is recommended that the selection of the type of rubber be made in accordance with the general principles of Section 2.

4.2.2 The lining contractor shall be prepared to supply a reference number for the approved mix and samples of the vulcanized rubber sheet for test and future reference in case of dispute, and shall not change the mix in any way except by agreement with the user.

4.2.3 After calendering, certain rubber compositions shrink on vulcanization. It is apparent that if this happens during the vulcanization process, faulty joints may be caused in the lining. To overcome this problem, preshrinking of the sheet is necessary. Preshrinking can be carried out in the factory or on site, before tailoring, by placing the sheet on a hot-plate maintained at about 60°C (140°F) for a period of approximately 15 min.

4.3 THICKNESS OF RUBBER

4.3.1 Generally, the thickness of the lining should be ⅛ in or 3/16 in (3·2 mm or 4·8 mm), but in cases where there is likelihood of severe chemical reaction (e.g. surface oxidation), abrasion or mechanical damage, the thickness may be increased to ¼ in or ⅜ in (6·4 mm or 9·5 mm). Linings up to ¼ in (6·4 mm) can be applied as a single layer; above this thickness they should be applied in two or more layers. In special cases involving simple design, linings above ⅜ in (9·5 mm) can be applied.

4.3.2 The sheets should be prepared by calendering as follows:

Thickness of lining		**Minimum** *number of* **plies**
in	mm	
1/16	1·6	2
⅛ to 3/16	3·2 to 4·8	3
¼	6·4	4

Where sheets or pipes are produced by extrusion the ply process cannot be used, but the other requirements of the Code should be complied with.

4.3.3 The thickness tolerance on the nominal dimensions should be ± 10%.

4.4 BONDING

The adhesion of rubber bonded to metal will depend on the following factors:

4.4.1 Duty. See 4.1.

4.4.2 Method of vulcanization. The method of vulcanization will depend on the nature and size of the equipment to be lined. It is desirable that whenever possible vulcanization should be carried out in an autoclave, but under certain circumstances other methods may be satisfactorily employed, e.g. exhaust steam, hot water or hot air. Vulcanizing at lower temperatures and pressures may give rise to lower adhesion values.

4.4.3 Adhesives used. It is not possible to generalize on adhesives, many of which are complex mixtures of undisclosed composition. Some lining contractors use proprietary adhesives; others use their own formulation.

The choice of the adhesive combination used will be determined by the other clauses in this section and by the duty. The laboratory adhesion test, described in 6.3 will give guidance on this choice.

4.4.4 Nature of base material and type of rubber used. The three types of rubber most generally used for lining work are natural rubber, neoprene and butyl rubber and there is normally little difficulty in bonding them to mild steel. It may be difficult to obtain adhesion values of the same order as obtained with mild steel when applying linings to other materials, such as wood, aluminium and concrete. Where required by the user for specific reasons, the lining contractor should supply bonded samples using the identical materials employed on the equipment, to show the level of adhesion obtained before and after exposure to the same conditions of use. It is important that the samples be vulcanized in a similar way to that which will ultimately be employed on the equipment to be lined.

4.5 FLANGES

The rubber lining on the outer edges of flanges should be finished flush to prevent the lining being rubbed or peeled off during transit.

5. METHODS OF LINING

5.1 LINING OF METAL VESSELS

5.1.1 Surface preparation. The surface to be lined shall be thoroughly cleaned; this can be achieved either by sweating with live steam or by cleaning with a flame or solvent. The thoroughly cleaned surface is then grit blasted to remove rust and scale.

5.1.2 Typical lining procedure.

5.1.2.1 The usual method of applying the rubber lining is as follows:

Adhesives are applied immediately to the metal surface, prepared as in 5.1.1, as an even coating, solvent being allowed to evaporate. Any necessary preshrinking of the rubber is carried out before hand-tailoring the sheet to fit the surface to be lined; that side of the sheet which will be in contact with the adhesive is wiped with a rubber solvent to clean its surface and to increase its tack. As soon as the solvent has evaporated, and while the sheet still retains its surface tack, the sheet is applied to the metal.

Care is necessary in positioning the rubber sheets accurately. One method of achieving this involves the temporary use of a sheet of cloth between the rubber and the base metal; the cloth is removed when the rubber is in its correct position and the air behind the rubber is forced out.

5.1.2.2 The recommended method of joining unvulcanized sheets is by using overlap bevel (i.e. scarf) joints, as described in 5.2.1. Alternative joints are described in 5.2.2 and 5.2.3.

5.1.2.3 Vulcanized sheets should be joined by strapped joints (see 5.2.2).

5.1.2.4 Joints between rubber pipe linings and the rubber on the flange faces should not protrude either to restrict the bore of the pipe or to prevent efficient sealing between the flange faces of adjacent lengths.

5.1.2.5 Before vulcanizing, the lining is examined in accordance with 6.6; if found satisfactory the lining is then vulcanized by heat treatment to produce the required physical and chemical properties.

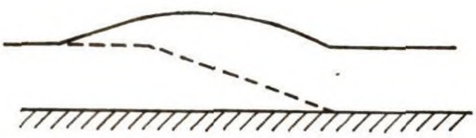
5.2 JOINTS

5.2.1 Overlap bevel joints. Overlap bevel joints which are made only in unvulcanized material shall be produced by skiving the edges of the sheets. The total contacting surface between the two sheets shall be a minimum of four times the sheet thickness, but shall not exceed 1¼ in (32 mm) at any one point. In the case of linings of ¹⁄₁₆ in (1·6 mm) the contacting surface shall not exceed ¾ in (20 mm). The contacting surface should consist of overlap and scarf, typical examples of which are shown in Fig. 10.

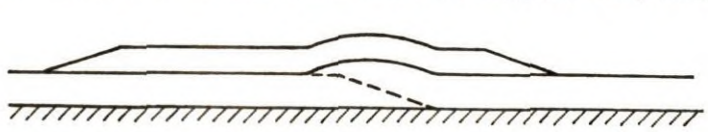
When requested by the user overlap joints should be made so that the overlap follows the direction of liquid flow.

5.2.2 Strapped joints. In strapped joints, the sheets are skived and joined, and a chamfered strap, is then centrally aligned over the joint. The maximum path to earth through the composite joint should not exceed 1¼ in (32 mm). The thickness of the strap may be up to ¹⁄₃₂ in (0·8 mm) less than that of the lining, subject to it being not less than ¹⁄₁₆ in (1·6 mm). The type of joint is illustrated in Fig. 10*c*.

a. Seam in ⅛ in (3 mm) sheet, ⅜ in (9·5 mm) long scarf, ⅜ in (9·5 mm) overlap



b. Seam in ¼ in (6 mm) sheet, ¾ in (19 mm) long scarf, ⅜ in (9·5 mm) overlap



c. Strapped seam in ⅛ in (3 mm) sheet;
scarf ⅜ in (9·5 mm) long overlap ⅛ in (3 mm), strap 1¼ in × 3/32 in (32 mm × 2·4 mm)

Fig. 10. Joints in rubber linings

5.2.3 Flush joints. Flush joints are used for the staggered joints in the double lining method of application. In special cases it can also be used with double layers of unvulcanized rubber similarly applied but afterwards heat vulcanized.

5.3 INTERRUPTED VULCANIZATION

By agreement between the lining contractor and the user vulcanization may be interrupted to detect faults which, if present, may be repaired. The vessel then undergoes further heat treatment to complete the vulcanization, after which final inspection and electrical tests are carried out in accordance with Sections 6 and 7.

5.4 LINING IN SITU

5.4.1 When lining in situ the method of applying the rubber sheet follows the same general pattern as in the lining contractor's works and the metal surfaces shall be prepared by grit blasting. Surface preparation for small areas may be carried out by grinding where grit blasting is impracticable.

5.4.2 The method of vulcanizing in situ depends on the design and equipment, its overall dimensions and facilities on site. On very exposed sites where vulcanization is carried out by heating, care should be taken to minimize heat losses from the equipment.

5.4.3 If the edges of flanges are blanked off, under-vulcanization may occur at the flange faces; a satisfactory method of vulcanizing should therefore be agreed between the user and the lining contractor.

One of the following methods may be used:

(1) Equipment may be lined with unvulcanized sheet and steam vulcanized by using the vessel as its own vulcanizer, subject to the limitations stated in 3.2.6 and 3.2.8.

(2) Unvulcanized material is applied to the surface to be lined and is vulcanized with exhaust steam, hot air or hot water.

(3) A layer of unvulcanized accelerated sheet is applied to the sides to be lined using a vulcanizing adhesive. On this is applied a layer of semi-vulcanized sheet using the same adhesive. The joints between the panels of the secondary lining are staggered so that they do not coincide with those of the first lining and are finally sealed with a strapping of the unvulcanized material. No applied vulcanization is carried out, but the accelerated material vulcanizes under normal working conditions. Alternatively, suitably selected rubbers may be allowed to vulcanize under normal atmospheric conditions.

5.5 LINING OF NON-METALLIC SURFACES

Concrete and wooden structures, etc., can be lined under certain circumstances. The practice adopted is in general similar to the methods of 5.1 to 5.4. Vulcanization by heating may in some instances be detrimental to the vessel. In such cases the method of vulcanization should be agreed with the lining contractor.

5.6 GASKETS

When rubber gaskets are used in contact with a rubber lining, and one surface of the gasket is adhered to a seating, the other surface should be lightly rubbed with colloidal graphite to prevent the gasket and the lining binding together.

6. ACCEPTANCE TESTS

6.1 STANDARD OF QUALITY OF THE COMPOUND

Normally, lining contractors have their own control procedures for maintaining the quality of the compound; where the user wishes to carry out additional tests on the physical properties or the composition of the rubber lining, reference should be made to BS 903*.

6.2 QUALITY OF SHEET

The sheet should be examined to ensure that:

(1) It is free from blisters and any other imperfection which would seriously affect the performance of the lining.

* BS 903, '*Methods of testing vulcanized rubber*'.

(2) It has been prepared in accordance with Section 4. The thickness tolerance on nominal dimensions should be ± 10%.

6.3 LABORATORY ADHESION TEST

6.3.1 Where requested by the user, checks for adhesion of the lining to the metal, concrete or rendered brickwork shall be carried out on samples prepared in the laboratory using the same combination of solutions and conditions of vulcanization as detailed in 4.4.

6.3.2 Soft rubber may be tested to check the bond strength in shear using a 1 in (25 mm) wide test strip. There is no generally accepted method for adhesion tests, which vary from lining contractor to lining contractor, but guidance can be obtained from the test given in Appendix B. This test should be performed at a temperature of 20 ± 5 degC (68 ± 9 degF) and not less than 24 hours after vulcanization.

6.3.3 The minimum load figures obtained in the laboratory on various types of rubber cured by different methods of vulcanization are given in Table 5. Under these loads the rate of separation shall not exceed 1 in/min (25 mm/min).

TABLE 5. MINIMUM LABORATORY TEST LOADS FOR VULCANIZED RUBBER

Type of rubber	Metals				Concrete and rendered brickwork	
	Pressure vulcanization		Vulcanization by hot water or steam at atmos. pressure			
	lbf	kgf	lbf	kgf	lbf	kgf
Natural rubber (soft)	20	9·1	15	6·8	5	2·3
Polychloroprene (neoprene)	20	9·1	15	6·8	5	2·3
Butyl rubber	20	9·1	15	6·8	5	2·3
Chlorosulphonated polyethylene	15	6·8	15	6·8	5	2·3

6.4 QUALITY OF VESSEL OR STRUCTURE TO BE LINED

When the lining contractor purchases the equipment to be lined, it is his responsibility to ensure that it is correct dimensionally and that it has been subjected to and has passed the correct physical tests. Where the user purchases the equipment he is responsible for these checks; however, under these circumstances the lining contractor should advice the user when the surface finish of the equipment makes it unsuitable for lining.

6.5 HARDNESS TESTS

6.5.1 Hardness testing shall be carried out on completion of vulcanization. If after initial testing any further vulcanization is required, the lining should be retested and shall meet the agreed hardness (agreed by lining contractor and the user) at all points.

6.5.2 Hardness testing shall be carried out on a flat smooth surface. In vessels where readings cannot be taken on the surface of the lining, when requested buttons should be provided in positions to be agreed between the user and the lining contractor. If the surface is too tough, a light local scraping or buffing may be carried out to facilitate testing.

6.5.3 The hardness of soft or medium hard rubbers shall be measured with a portable hardness meter calibrated in accordance with BS 2719*, and of hard rubbers (ebonites) with a meter having a Shore D scale. Readings shall conform to the specified hardness of the compound within $\pm$ 5°. A minimum of three hardness readings shall be taken for each square yard or square metre of lining. Where a reading is outside the agreed range, further readings shall be taken on the same panel to establish the general level of hardness. Where repairs have been carried out or where water marking is visible, the areas concerned shall be separately tested.

6.6 TESTS FOR CONTINUITY OF LINING

6.6.1 Visual inspection. Inspection for visual defects shall be carried out over the entire surface in a good light and attention should be given to any areas of mechanical damage, sharp cuts, blisters, lack of adhesion and poor seaming.

6.6.2 High-frequency spark test.

6.6.2.1 A high-frequency spark discharge should be directed at the lining. Where a defect occurs in the lining the discharge is earthed producing a strong bluish-white continuous spark. The surface of the lining shall be clean and dry when the test is carried out. A long residence time may puncture the lining, and care shall, therefore, be taken to select the correct spark length and to ensure that the probe moves continuously over the lining.

A typical instrument and method of setting up for this test is described in Appendix C.

6.6.2.2 Linings 3/32 in (2·4 mm) thick or above should be checked for continuity and freedom from pinholes by combing over the entire surface with a suitable high-frequency probe, adjusted to give a spark length of not less than 1¼ in (32 mm). Linings 1/16 in (1·6 mm) thick should be tested in the same manner, but with a spark length of not less than ¾ in (20 mm).

* BS 2719, ' Methods of use and calibration of pocket type rubber hardness meters '.

6.6.2.3 If it is necessary to carry out any machining of hard rubber (ebonite) linings or machining and/or descaling of the vessel the electric spark test should again be applied to the lining to ensure that it has not been damaged in any way.

6.7 THICKNESS OF LINING

When called for by the user, the thickness of the covering shall be checked in the areas specified. Where direct measurement is not possible it shall be carried out using a suitable thickness meter.

6.8 HYDRAULIC TESTING OF LINED VESSELS

When required by the user, a hydraulic test, at an agreed pressure and for an agreed time, shall be applied to the lined equipment, in the manner specified by the user. The joint rings used for this test shall be of the same material and to the same dimensions as those specified for the final service conditions. During the pressure test no leakage should occur. *As altered July 1973* *As amended May 1978*

6.9 VACUUM TESTING OF LINED VESSELS

When required by the user or where the operating conditions require a lined vessel to operate under vacuum, a vacuum test shall be carried out by evacuating the lined vessel with the appropriate joint rings to the specified vacuum. The vacuum shall be maintained for the specified period, (normally 1 hour), and by the method previously agreed between the user and the lining contractor. The lining shall be subsequently reinspected for defects. *As amended May 1978*

6.10 RESISTANCE TO 'BLEEDING' BY THE LINING

When contamination of the contents by the lining material is detrimental check tests should be carried out previously by the user on samples of the compound supplied by the lining contractor, as recommended in Section 4. This normally avoids lengthy soaking periods for the lined or covered articles to assess the degree of contamination.

7. INSPECTION AND REPAIRS

7.1 INSPECTION

7.1.1 To ensure the satisfactory operation of lined plant and equipment over a period of years, the user should cause periodic inspections to be made to ensure that the lining is sound. The frequency of these inspections will depend on the nature of the materials being handled; when they are very corrosive to the shell of the equipment frequent inspections may be necessary. Annual inspections of all linings should be carried out. On carrying out these inspections, damage to the lining should be avoided by suitably covering footwear and ladders. It is advantageous to wear rubber boots and in very large vessels with ebonite linings, walkways should be laid to avoid excessive flexing.

7.1.2 Visual inspection should be carried out as in 6.6.1. Areas where adhesion has broken down, and which have not developed into an obvious blister, can generally be detected by light tapping and listening for hollow sound.

7.1.3 All suspected areas of the lining should be checked for continuity by the high-frequency spark test described in 6.6.2. If the equipment contains very corrosive liquors it may be considered necessary by the user that the whole of the lining should be checked in this manner.

7.2 *REPAIRS*

Repairs to the lining can generally be done in situ by skilled labour. The method employed depends upon the type of the original lining, extent of repairs, and the facilities available and should always follow the recommendations of the lining contractor. The following is the usual method:

The defective and adjacent lining are thoroughly neutralized, cleaned and dried. In some cases, it may be necessary to treat the whole of the lining. All loose and defective rubber is cut away, the exposed edges of the lining bevelled and the shell of the equipment buffed clean.

The area exposed is cleaned with a suitable solvent and any excess is allowed to evaporate. The adhesive solutions are then applied, according to the lining contractor's instructions, and allowed to dry.

The patch of new sheet, which has been previously cut to shape and made 'tacky' by the application of the solution or adhesive, is then applied, in accordance with the lining contractor's instructions, to the prepared area and rolled down firmly with an edge-wheel to exclude any air. In areas where tension is likely to develop, e.g. struts, etc. the patch is tightly wrapped. The patch is then vulcanized in accordance with 5.4.

The repaired area should be checked for hardness and continuity in accordance with Section 6.

In some cases, minor repairs can be done by the user, but this should be only after consultation with the lining contractor.

In the case of wooden and concrete vessels, the surface of the exposed material should be dry enough to ensure satisfactory adhesion.

APPENDIX A

HYGROMETER-TYPE APPARATUS FOR MEASURING MOISTURE CONTENT

A.1 A simple form of instrument for measuring moisture content measures the relative humidity of a pocket of air in equilibrium with the surface of the material to be lined (Fig. 11); a commercial model is available. It consists of a paper hygrometer in a vapour-tight mounting (comprising copper sheet mounting ring and glass plate) housed in a well-insulated box. Provision is made for sealing the edges of the instrument against the surface to be tested (plasticine is a convenient material for this purpose) and for reading the hygrometer scale whilst the instrument is in position. The dimensions, shape and materials used in the construction of the instrument may be varied to suit the resources available, so long as these essentials are complied with.

A.2 After the instrument has been sealed firmly to the surface to be tested, a period of not less than 4 hours should be allowed to elapse for the entrapped air to reach moisture equilibrium with the material before the reading is taken.

A.3 A longer period is preferable and can sometimes be obtained conveniently by placing the instrument in position overnight and taking the reading in the morning.

If readings are to be taken at several points with only one instrument available subsequent positions may be covered by impervious mats (bitumen felt, polythene sheeting, etc.) about 3 ft (1 metre) square, laid down when the instrument is placed in its first position, to speed up the later readings.

APPENDIX B

METHOD OF TEST FOR ADHESION (PEEL TEST)

NOTE. This test is based on that given in BS 490 : 1951, ' Rubber conveyor and elevator belting '.

B.1 The apparatus for this test is illustrated in Fig. 12.

B.2 Four test pieces, each 1 ± 0·02 in (25·4 ± 0·5 mm) wide and not less than 12 in (305 mm) long, are cut from the lining to be used, using a sharp tool which leaves clean edges. The test pieces are bonded and vulcanized in the same way as they would be applied to the vessel. The rubber is separated at one end of the test piece for a distance of about 3 in (76 mm). The backing plate (a) is suspended from a support (b) on the vertical back board (c). The loaded scale pan (d), held by a light spring (e), is equal to the specified load.

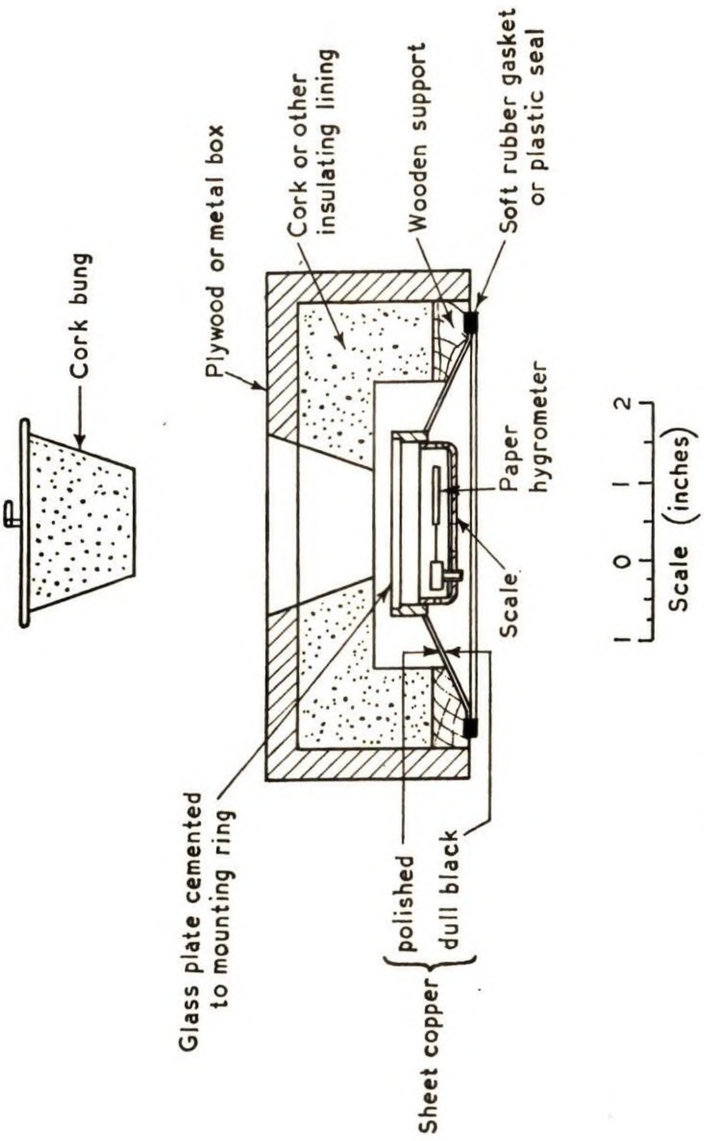


Fig. 11. Apparatus for measuring moisture content

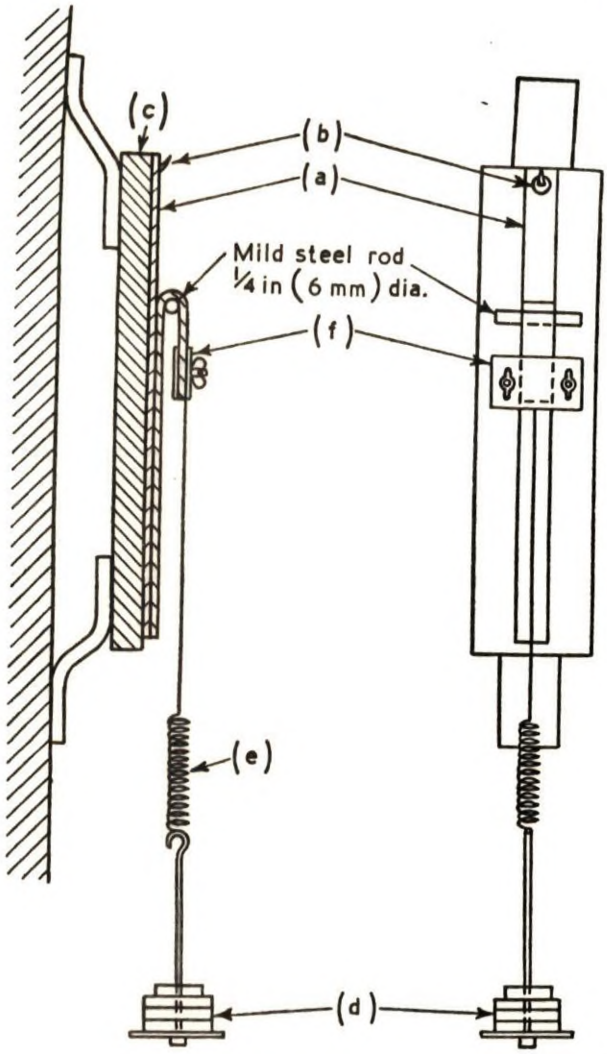


Fig. 12. Adhesion test apparatus

B.3 Under these conditions, the rate of separation is taken as the average during the continuous four minute period under load, or where this is not practicable, during the separation of at least 4 in (102 mm) length of the test piece.

APPENDIX C

SPARK TESTING EQUIPMENT

C.1 Description of apparatus. The spark test equipment used to test rubber linings consists of a mains or d.c. operated generator or interrupter, to which is added a Tesla coil within a tuned circuit. The Tesla coil operates at its best at a fairly high frequency and is capable of generating very high peak a.c. voltages. When applying tests to rubber linings an a.c. high voltage, high frequency spark discharge of 150–300 kc/s should be utilized. The adjustment of the test output voltage is achieved by measuring the length of the spark in air, by means of an adjustable spark gap assembly.

The simple form of spark gap assembly consists of two vertical pillars, one metal and one of insulating material fixed to an insulated base. Near the top of each of the pillars is situated a horizontal ⅛ in (3 mm) diameter metal rod. The rod on the insulated pillar is fixed, whilst the one on the metal has a fully adjustable horizontal traverse. This traverse is such to afford the rods to touch i.e. closed position and be fully adjustable to an open 1½ in (40 mm) gap.

C.2 Choice of electrode. With high frequency spark testing, it is advisable to avoid excessively large electrodes, due to the a.c. inductive loss through the coating. The larger the electrode therefore, the more diminished the initial preset applied voltage.

However, this ' inductive loss ' is not too critical when testing large ' joint free ' surfaces, as for this type of application excessive voltage is unnecessary, for any faults or porosity present would be directly through the thickness of the lining material, e.g. 1/16 in, ⅛ in, 3/16 in (1·6 mm, 3 mm, 5 mm) etc. An *L* or *T* shaped electrode with at least a 6–8 in (150–200 mm) wide working edge is recommended for this type of testing.

When testing ' overlap ' joints (as with rubber linings) a pointed or ' tipped ' electrode should be used to ensure a minimum loss of applied voltage and thus maximum effective test ' concentration '. It is important when ' joint ' testing, to employ a sweeping down movement always moving, never stopping too long in one position, otherwise too much strain will be applied to the dielectrical strength of the joint and adjacent areas of lining, thus increasing the risk of dielectric breakdown.

It should be noted, that electrodes are available having both a flat section for flat surfaces and tips for joints, this enables both types of tests to be conducted without having to reset the output control.

C.3 Method of test. The metal pillar is connected to earth and the adjustable rod is moved to a gap width simulating the required spark length. The tip of the probe of the high frequency spark tester should then be placed on to the fixed $\frac{1}{8}$ in (3 mm) diameter rod. The output control of the spark tester should then be increased until sparking is *just* obtained across the present gap. To ascertain the peak a.c. voltage, it can be assumed that every 0·04 in (1 mm) length of spark would be equal to 1700 V.

When the electrode of the high frequency unit is applied to a surface having *no faults*, a bluish corona discharge will be observed.

Faults or porosity will be recognized by the passage of a bright spark and the dying out of corona discharge. In addition, an audible change of note will be heard, from a buzzing corona, to a crackling noise with each spark drawn to the fault.

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