
Code of practice for
The lining of vessels and equipment
for chemical processes: copper
and copper alloys

Code de bonne pratique pour le garnissage des récipients et équipements pour les
procédés chimiques: cuivre et alliages de cuivre

Richtlinien für die Bekleidung von Behältern und Apparaten für chemische Verfahren:
Kupfer und Kupferlegierungen

Contents

	Page		Page
Foreword	Inside front cover	Section six. Inspection, welding procedure, testing, maintenance and repair	
Cooperating organizations	Back cover	22. General comments	8
Section one. General		23. Inspection	8
1. Scope	1	24. Welding procedure and welder approval tests	8
2. References	1	25. Testing of vessels	9
3. Exchange of information	1	26. Maintenance and repair	10
Section two. Materials for linings		Table	
4. General comments on materials	1	1. Recommended filler metals	7
5. Coppers	2	Figures	
6. Aluminium bronze	2	1. Typical methods of lining	11
7. Copper nickel alloys	2	2. I-section insert for new concrete tank	13
8. Other copper alloys	2	3. Typical pipe connections through concrete tank wall	14
Section three. Design of vessels and equipment to be lined		4. Typical joints in linings for timber vessels	15
9. Design considerations	2	5. Capped joint (with attachment between lining and substrate)	15
10. Materials for vessels	3	6. Backing groove joint (without attachment between lining and substrate to avoid dilution)	15
Section four. Design of linings		7. Inserted backing strip joint (without attachment between lining and substrate to avoid dilution)	15
11. General factors affecting design	4	8. Single joggle joint	16
12. Types of lining	4	9. Double joggle joint	16
13. Thickness of lining	4	10. Unsupported cover strap joint	16
Section five. Fabrication techniques		11. Joggled cover strap joint	16
14. General comments on fabrication techniques	5	12. Supported cover strap joint	16
15. Preparation of materials	5	13. Plug weld to attach sheet to substrate	16
16. Sheet and strip lining	5	14. Use of steel backing bar to prevent dilution in shell closing welds	16
17. Separate fabricated lining	5	15. Weld procedure: limited dilution tolerable (access from both sides)	17
18. Lining by surfacing	6	16. Alternative weld procedures to restrict dilution at clad interface (access from both sides)	17
19. Integral cladding	6	17. Alternative weld procedures to eliminate dilution at clad interface	17
20. Filler metals	7		
21. Metallurgical effects at the dissimilar metal weld interface	7		

This code of practice represents a standard of good practice and therefore takes the form of recommendations. Compliance with these recommendations does not confer immunity from relevant statutory and legal requirements.

Foreword

This code of practice has been prepared under the direction of the Pressure Vessel Standards Committee at the request of industry.

The committee responsible for the detailed requirements in the code of practice acknowledges the assistance of the Copper Development Association and its committee which prepared the initial draft.

British Standard Code of practice for

The lining of vessels and equipment for chemical processes: copper and copper alloys

Section one. General

1. Scope

This code offers guidance on the design, manufacture and use of vessels and equipment lined with copper and copper alloys for chemical processes. This code does not offer guidance on the selection of any particular alloy or method of lining to meet specific operating conditions. It covers the lining methods described in (a), (b) and (c) below, which may be used singly or in combination.

- (a) Linings in the form of sheets or strips applied to vessels and equipment of steel construction by the use of welding. Sheet, strip or tube material may also be used for the fabrication of linings which may be loose, mechanically attached, or welded to a vessel of steel or other material.
- (b) Vessels manufactured from plates previously clad with the required lining material. Such plates can be obtained integrally clad with copper and a range of copper alloys.
- (c) Vessels and equipment lined with a continuous surface of weld metal.

Other methods including electrodeposition, spraying and sinter-coating which may also be used for lining of vessels and equipment, are not detailed in this code.

The use of the general term 'copper' throughout this code includes copper alloys as well as copper unless specifically stated otherwise.

2. References

The titles of the standards publications referred to in this code are listed on the inside back cover.

3. Exchange of information

3.1 Where appropriate, early consultation and exchange of information should take place between all parties concerned in the design, manufacture, inspection and use of vessels and equipment.

3.2 Consultations should cover:

- (a) design and construction of equipment or vessel to be lined, including welding procedures, location of welds, design of branches and fittings, joints and internal supports for any loose equipment to be fitted later;
- (b) whether a lining or integrally clad plate should be used;
- (c) nature and concentration of media for which the vessel or equipment is to be used;
- (d) operating temperature and pressure ranges;
- (e) whether vessel will be subject to vacuum;

- (f) other factors influencing stresses on lining e.g. expansion, contraction, vibration, erosion;
- (g) velocity of contents and abrasive characteristics to be met, especially at points of their entry to the vessel;
- (h) means of access of lining materials and installation crew and equipment, lifting facilities etc.;
- (i) where existing vessel has been in service on site, details of site conditions that may affect this work being carried out in situ;
- (j) safety measures on site;
- (k) surface finish of the vessel to be lined;
- (l) surface finish of the completed lining;
- (m) inspection and testing of the lining and vessel, including welding procedure tests and welders' approval tests;
- (n) whether the vessel is to be internally or externally heated;
- (o) media other than working media to be used, e.g. steam or chemical agent for cleaning;
- (p) start up and shut down conditions.

Section two. Materials for linings

4. General comments on materials

The various coppers and copper alloys used for the fabrication of liners, either loose, or as metallurgically bonded clad steel plate, are, with certain exceptions, covered by BS 1977, BS 2870 to BS 2875 and BS 4608.

These standards detail chemical composition, temper conditions, mechanical properties associated with the various tempers, and dimensional tolerances.

The thermal and electrical conductivities of the range of coppers and copper alloys vary widely, being highest for the three 'high conductivity' grades of copper and lowest for the high nickel, cupro-nickel alloys.

The corrosion resistance of the various coppers and copper alloys can be broadly classed as 'good to excellent'. The coppers are all virtually equal in this respect and are classed as 'good'. The aluminium bronzes and cupro-nickel alloys are generally superior to the coppers, and also may be operated at considerably higher sustained temperatures and in the presence of more aggressive media. Maximum permitted fluid velocities are also higher for the copper alloys than for the coppers.

With the exception of the oxygen-bearing tough pitch grades of copper, and single phase aluminium bronzes greater than approximately 6 mm in thickness, the coppers

and most copper alloys are readily weldable when using the correct established technique and filler metal. Recommended filler metals are listed in table 1.

5. Coppers

British Standard specifications cover seven different grades of copper. The three high conductivity grades (C101, C102, C103) are normally only considered for lining and cladding applications where the highest electrical conductivity is required. The two tough pitch grades (C101, C102) contain oxygen, which can give rise to embrittlement if they are exposed to reducing gases at elevated temperatures. The cuprous oxide present tends to migrate to grain boundaries in the heat affected zone of fusion welds, lowering ductility and impact strength. If some lowering of these properties is permissible, satisfactory welded joints can be made in these grades of copper.

For the same reasons, the other two tough pitch grades (C104, C105) are not normally considered for lining and cladding applications.

The two remaining grades (C106, C107) are both deoxidized with phosphorus, the only difference between them being the arsenic addition made to C107. This raises the annealing temperature slightly, but for the majority of applications, where the operating temperature does not exceed 200 °C, the arsenic-free grade, C106, is normally suitable.

6. Aluminium bronze

The aluminium bronzes are characterized by high strength, good corrosion resistance in a variety of media and operating conditions, and retention of strength, oxidation and corrosion resistance at elevated temperatures.

The alloys are of two main types.

- (a) Single phase alloys containing up to 8 % aluminium. Three alloys of this type are included in British Standard specifications, designated CA101, CA102 and CA106. The first is available as sheet and strip and the other two as plate.
- (b) The complex alloy containing 8.5 % to 10.5 % aluminium, together with iron, nickel and manganese. This is available as plate and is designated CA105. It is not recommended as an explosively bonded clad steel composite.

7. Copper nickel alloys

The cupro-nickels are characterized by good corrosion and erosion resistance in a range of media, especially seawater, coupled with moderate strength and good weldability. The two most widely used alloys are the 90/10 (CN102) and 70/30 (CN107) compositions, both containing additions of iron and manganese. Both alloys are available as sheet, strip and plate.

8. Other copper alloys

Subject to their suitability for the proposed fabrication procedure and service conditions, other copper based alloys may be used.

Section three. Design of vessels and equipment to be lined

9. Design considerations

9.1 General. In general it is recommended that vessels to be fitted with a copper lining should be of welded construction from carbon, carbon manganese or low alloy steel plates, using butt joints wherever possible although other materials and methods of fabrication may be used as required.

The inner surfaces of welds should be ground off flush and smooth in order to ensure that the lining plates can bed down with good contact against the inner walls of the vessel over the whole area.

Irrespective of the type of lining the vessel itself should be designed in accordance with an appropriate standard or code of practice for the operating conditions as defined in 3.2. Reference may be made to BS 2594, BS 2654, BS 3274 and BS 5500 for guidance on these standards or to BS 1500 : Part 1* or BS 1515* which have been withdrawn, if relevant.

It is usual practice to design the vessel to meet the required strength considerations ignoring any contribution to strength which may be made by the copper lining, irrespective of the type and method of attachment of the lining. Also it is usual practice not to make any corrosion allowance in assessing the thickness of the vessel.

Consideration should be given to both thermal and mechanical stresses which may be set up in the vessel and the lining under the operating conditions and during manufacture and testing. In particular due account should be taken of the difference in coefficient of thermal expansion between the copper lining and the vessel material. A further example is heat treatment after welding of an integrally lined or weld deposit lined vessel which could have a detrimental effect on both the vessel and lining material.

The drawing of the vessel should give full details of construction including any holes through the shell required for test purposes and the proposed method of lining should be shown. Test and 'tell-tale' holes should be drilled through the shell before the lining is applied.

In designing flanged openings in the shell it is important to consider relative movement of the shell and branch lining caused by differential expansion, elastic distortion due to pressure or localized plastic deformation during pressure test. Where the duty of the vessel is mechanically severe it is essential to ensure flexibility at the intersection of shell and branch, to eliminate sharp changes in section on the shell and to avoid welds in the lining at points of maximum stress. For duties that are mechanically less severe these precautions are not so necessary, and simpler and less expensive designs may be satisfactory.

The design of all vessels and equipment should 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 should have a minimum diameter *after lining* complying with the requirements

*Withdrawn May 1978.

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 should be the subject of agreement at the tendering stage between the lining contractor and the user and should ensure that in no case pockets of stagnant air may occur. This would normally require at least one additional branch not less than 75 mm in diameter.

Sheet or strip lining should not be used when an external jacket for heating or cooling the contents of the vessel is required. Internal coils or separate heat exchangers should be used with this form of construction. If the vessel is required to have good heat transfer properties or withstand vacuum conditions then it is recommended that clad metal or weld surfacing techniques be used.

9.2 Internal fittings. Where internal fittings such as supports or brackets are required it is normal practice to fabricate these items from solid copper alloy of the same specification as the lining material. Where these fittings are to be fixed to the vessel wall and are required to carry a significant load it is desirable to fix them in position before commencing lining, using a welding technique which will minimize dilution of the weld metal by the shell material. The lining can then be arranged as a shield so that the weld metal attaching the lining to the fitment will be undiluted. Internal fittings may be attached direct to the lining when the vessel is constructed from integrally clad plate or a weld surfacing technique has been used, provided the integrity and strength of the bond between the lining and the vessel is ensured before and after welding.

9.3 External fittings. Special care should be taken in designing the fittings which break through the shell of the vessel such as manholes, branches, sight glasses etc. Normally a suitable method of lined construction is used for these components. The design of these items should take into account the requirements of the operating conditions.

9.4 Flanged openings. Linings of flanged openings should extend into the gasket sealing surface. Typical methods are shown in figures 1(a) to 1(d). The acceptability of the various methods depends upon operating conditions and economic considerations. It is good practice to ensure gasket sealing under stringent operating conditions by lining the branch connections before attachment to the vessel. This will enable the joint face to be machined after welding.

10. Materials for vessels

10.1 Carbon and low alloy steels. Carbon and low alloy steels are the most suitable materials from which a vessel should be constructed if it is to be subsequently fitted with a lining. Consideration should be given to the possible effects of the lining operation on the properties of the vessel material.

The surfaces to be lined should be smooth, clean and free from scale. Iron grit blasting is recommended. The vessel should preferably be of welded construction throughout, with all the internal welds ground smooth and flush.

10.2 Concrete tanks and similar vessels. These are preferably designed and constructed in accordance with the recommendations of BS 5337 and may be lined with copper.

If anchorage of the lining is necessary other than by adhesive bonding, it can be provided by welding to suitably designed metal inserts embedded in the concrete. Inserts of copper

matching the composition of the lining have the advantage of not reacting appreciably with the concrete and of not contaminating the lining at the weld.

Inserts may consist of lengths of metal having cross sections which mechanically interlock with the concrete (I- or T-section, for example) or pieces spaced at suitable intervals across the concrete surface (see figure 2). The latter is preferable because the presence of a continuous insert in the surface may promote a corresponding crack in the body of the concrete.

In addition, continuous inserts tend to be limited to new construction, because of the difficulty of cutting chases in hardened concrete and subsequently grouting the inserts firmly enough in them.

When a copper lining is to be fitted to an existing tank, anchorage points may be provided by shot-firing suitable copper pins into the concrete at appropriate intervals. Alternatively, holes may be drilled in the concrete to accept inserts made of wood, fibre, plastics or metal, into which copper studs may be screwed. This system may also be used for new construction, but it will usually be simpler and more economical to design copper inserts so that they can be temporarily attached to the formwork before the concrete is cast, and will remain embedded in the hardened concrete when the formwork is dismantled. Inserts of the smallest practical cross section should be used in order to minimize local stresses in the concrete. Because of the possibility of electrochemical corrosion, welding of copper inserts to the steel reinforcement in the concrete should be avoided.

A separating membrane may be desirable if there is a likelihood of the soft copper being punctured by pressure against any hard protrusions in the concrete surface. Any specification for concrete should, of course, emphasize the need for such protrusions to be minimized by correct choice of formwork material and formwork design. This should also ensure that all corners over which the lining is to be formed, bent or worked should be chamfered, radiused or recessed to contain a gasket of suitable material to prevent damage to the copper during such working (see figure 3).

Outlets, drains and inlets passing through concrete should be provided with 'puddle' flanges of adequate size and thickness to ensure that the joint to the lining cannot be strained by external stresses and should preferably be cast in position when the concrete is poured (see figure 3).

If it should be necessary to cast the concrete around the lining, which then has to act as a permanent former, then the lining will have to be adequately supported internally against deformation by pressure from the concrete before it hardens.

10.3 Wooden vessels. New and used vessels of wood may be suitable for lining but attention should be drawn to the danger of crevice corrosion of the lining surface in contact with the wood, if the wood becomes wet. If a used vessel is to be lined it should be thoroughly cleaned, dried and prepared to ensure that the outer surface of the lining is not attacked. A number of backing strips should be screwed or nailed flush with the surface of the used vessel where joints in the lining occur. In the case of new vessels wooden dowels may be fitted in each joint in addition to the bolts to prevent slipping of the timbers. Some methods of lining wooden vessels are shown in figure 4.

Section four. Design of linings

11. General factors affecting design

The design of lining will depend upon a number of considerations, as previously outlined in 3.2, including:

- (a) range of operating temperature;
- (b) range of operating pressure or vacuum;
- (c) corrosive media present;
- (d) size of the vessel to be lined;
- (e) erosion;
- (f) heat transfer requirements;
- (g) accessibility for application of the lining;
- (h) whether lined during or after fabrication of the vessel or equipment, or whether integrally clad plate should be used;
- (i) condition of vessel or equipment if already in service;
- (j) material availability;
- (k) cost.

12. Types of lining

There are several recognized practical methods of lining vessels and equipment with copper involving the use of welding, as listed below.

- (a) Sheet or strip progressively fixed to the surface to be lined, by welding.
- (b) Separate fabricated lining either
 - (1) as a loose insert,
 - or
 - (2) inserted and attached to the substrate.
- (c) Lining with a continuous surface of weld metal.
- (d) Fabricating with plate, previously clad with the required lining material, (integral cladding).

12.1 Sheet and strip linings. This method involves the progressive fabrication of the lining from sheet or strip, by welding at the edges. The edge welds are also used to anchor the lining to the substrate.

The sheet or strip material should be applied in the largest piece that can be conveniently handled for the particular application and should be shaped and contoured to give close conformity with the surface being lined. For convenience, while being held securely in position, the lining may be arc welded to the substrate. If necessary, precautions should be taken to minimize the dilution which will occur during these fixing operations and the edge welding.

The method offers a wide choice of composition and thickness of lining material. However, due to the air space, heat transfer through the lining to the wall is poor.

12.2 Separate linings. A lining in the required alloy may be prefabricated to a shape which suits the vessel or equipment. The lining may be completely loose, or attached to the shell by adhesive bonding or at selected sites by welding. In the latter case, precautions are necessary to minimize dilution. The fit should be as close as possible and may be improved, for example, by expanding the lining into the shell of the vessel. However, heat transfer through the lining to the shell will still be poor.

Consideration should be given to the effects of vacuum working and pressure fluctuation conditions, whether programmed or accidental.

12.3 Surfacing. The surface of a vessel or piece of equipment may be clad by fusion weld surfacing. The choice of fusion welding process depends mainly on the scale of the operation and, to a lesser extent, on metallurgical factors

such as dilution. Surfacing is particularly suitable for cladding heavy sections and shaped surfaces. Because there is a true metallic bond between the cladding and the substrate, the method is ideal for conditions of fluctuating stress and temperature, and where maximum heat transfer is required.

The surface to be clad should be even in contour and suitably cleaned, for example by grit or shot blasting. Depending on composition and thickness, it may be necessary to pre-heat the substrate.

Although, in principle, this method is extremely flexible, detailed surfacing procedures should be established by consultation and where necessary by a programme of welding tests.

12.4 Integral cladding. Steel plate can be obtained which has been clad with the required copper or copper alloy either by roll bonding or explosive bonding, with the exception of aluminium bronze, CA105, in the latter case.

The vessel or piece of equipment has to be designed to suit the specifications of the pre-clad plate, and fabricated by fusion welding.

The method is suitable for conditions of fluctuating stress and temperature. Heat transfer from clad layer to substrate is very good, and contrary to the surfacing method described in 12.3, the clad layer is of uniform thickness, has a good surface finish and does not suffer from dilution problems.

13. Thickness of lining

13.1 General considerations. The thickness of the lining material should be decided by considering the following:

- (a) desired life of vessel;
- (b) corrosion allowance;
- (c) erosion allowance;
- (d) complexity of shape of lining;
- (e) duty of the vessel, particularly with respect to temperature or pressure cycling, including start up and shut down and the possibility of vacuum conditions being encountered;
- (f) method of lining;
- (g) location where lining is to be carried out;
- (h) cost.

Where erosion is expected, such as opposite tangential inlet branches etc., it is good practice to fit a thicker panel to act as a wear plate so that the losses by erosion match those by corrosion elsewhere in the vessel.

13.2 Sheet linings. Normally sheet linings are up to 3 mm thick. Sometimes the thickness is increased for more severe corrosive or erosive conditions. Where the method of fixing is by fusion welding linings thinner than 1.5 mm are not recommended as the application becomes very difficult and the increase in cost exceeds the saving in material.

If the duty allows for very thin linings the resistance spot welding method can advantageously be used. The normal sheet thickness applied with this method is 0.5 mm to 0.85 mm.

13.3 Strip lining. Normally it is adequate for linings to be between 1.5 mm and 3 mm thick. These thicknesses enable the strips to be formed to the contour of dishings and corner radii where dishings and cylinders meet. The longer straight strips on the cylindrical portion of vessels can be pushed into position by hand and tack welded to substrate without accurate prior forming.

It is recommended that strip linings not less than 2 mm thick be used to line floors and walls of vessels where the

welding will be done in the flat, vertical and horizontal-vertical positions. If overhead welding is required, such as for heads in situ, 2 mm is the minimum thickness recommended. Thinner linings require a higher degree of welding skill and this, together with the necessity to be precise with the fitting, greatly adds to the labour costs and often will be more expensive than heavier linings.

13.4 Integral cladding. As a general rule, roll bonded plate is obtainable with cladding thicknesses ranging from 1.5 mm (for plate of total thickness 5 mm) to 3 mm (for plate of total thickness 10 mm to 25 mm), although greater thicknesses (both cladding and total) may be available in certain cases.

For explosive bonded plate, the range of cladding thickness normally available is from 1.5 mm to 10 mm, although 20 mm is obtainable if required. The thickness of the backing plate should be at least 12 mm or twice the cladding thickness, whichever is the greater. There is no restriction on the maximum thickness of the backing.

Section five. Fabrication techniques

14. General comments on fabrication techniques

The fabrication and welding techniques should be chosen to ensure the following conditions.

- (a) A continuous covering of copper of adequate thickness and composition to ensure satisfactory operating life.
- (b) A satisfactory resistance to deformation, buckling or other form of premature failure under the normal specified operating conditions. In addition there should be adequate attachment of the lining to the substrate. The effect of possible vacuum conditions on the lining attachment should also be considered. Integrally clad plate is a suitable choice where vacuum service is required and also where dilution is unacceptable.
- (c) In the case of surfacing, the procedure chosen has to ensure a satisfactory bond to the substrate while controlling the amount of dilution. In the majority of cases excessive dilution of the weld surface by the substrate material will adversely affect corrosion resistance or may result in a brittle zone at the fusion boundary.
- (d) A smooth contoured lining is generally to be preferred for the majority of applications and care should be taken when lining plates are attached in an overlapped manner to ensure that areas where the contents can be retained in a stagnant condition are avoided.

15. Preparation of materials

Before sheet or strip linings or integral clad plates are welded, all surfaces in the proximity of the weld zone should be cleaned. Oil and grease may be removed by a suitable solvent; light rust and debris by wire brushing; scale by grinding or grit blasting. The suppliers of materials have recommended methods for achieving clean conditions, and these should generally be used.

Manual metal-arc welding electrodes should be oven-dried to manufacturers' recommendations.

The surface of the vessel to be lined should be smooth and free from sudden changes in contour, and any blemishes should be made good. In the case of metal vessels, the surfaces to be lined may be rectified by welding and grind-

ing, provided the necessary precautions applicable to the substrate material are taken.

In the case of the relining of wooden vessels, these should be free of corrosive media, to avoid shielding corrosion.

The fabrication techniques for copper-lined concrete and wooden vessels are contained in 10.2 and 10.3.

16. Sheet and strip lining

The maximum size of panels for sheet lining will normally be controlled by the access, although ease of handling may be the deciding factor. Panels should be as large as possible in order to reduce the welding round the edges to a minimum. For strip lining, the size will be determined partly by ease of handling, particularly as regards length, and partly by the spacing between fixing points which the service conditions will allow, this latter factor controlling the width. As a guide, lengths will normally be in the range 500 mm to 1000 mm for site installation (up to 3000 mm in a workshop) and widths 50 mm to 150 mm. Sheets should be joined to the walls by welds along their edges, possibly in combination with plug or arc spot welds, depending upon the required service use. The sheet should be jacked or clamped into position to ensure intimate contact and then welded from the centre progressively outwards until all the arc spot welds have been made. The spacing between the plug/spot welds will also depend upon the service conditions. Such welds may be made by MIG (inert gas metal-arc), TIG (inert gas tungsten-arc) or by manual metal-arc welding where suitable electrodes are available. MIG-spot welding has the advantage that for thin linings no holes through the sheet are required, which saves the cost of drilling or punching and requires less accuracy in positioning the torch. With thicker linings a hole is required, but this will be much smaller (diameter equal to or just greater than the lining thickness) than that needed for conventional plug welding. TIG-spot welding is less advantageous in that a hole is necessary at a smaller thickness of lining and the addition of filler wire has to be made manually; also there may be more dilution. Conventional plug welding requires a hole several millimetres in diameter, which is filled with weld metal by any of the three processes in one or more runs. Where the dilution from the substrate is too high, a capping run can be made over the welds. In a few cases, depending upon the size of the component and the lining alloy, it may be possible to resistance spot weld the lining to the substrate.

The gap between adjacent panels may be filled in various ways. Usually it will be required to weld the edges to the substrate as well as to each other and this can be done by TIG, MIG or manual metal-arc welding. For strip lining, plug welds will not normally be used and at least two edges of each strip have to be welded to the substrate. The choice of techniques will be decided by the service conditions (e.g. pressure, permissible dilution in welds), the cost of making the joint and the lining alloy. Various techniques for attaching the lining to the substrate and for joining successive sheets together are detailed in figures 5 to 13.

17. Separate fabricated lining

It is advantageous to weld as much of the loose lining as possible before insertion in the vessel (or before the vessel is built round the lining if that form of construction has been adopted). This enables the welds to be more easily examined and any specified heat treatment carried out, taking such precautions as may be necessary to prevent collapse of the lining.