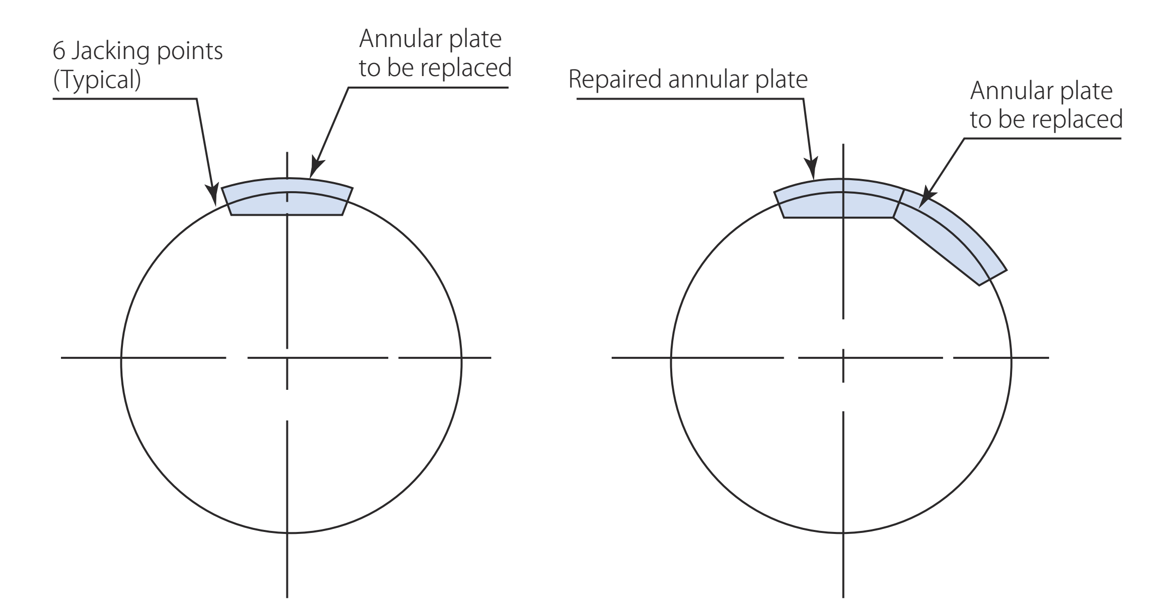

Figure C-4 Sequential tank jacking

C.1.3.6 Tank Re-levelling

Tank re-levelling, which requires the tank to be empty and clean, consists of local jacking at tilted or depressed sections of the shell/bottom perimeter, using hydraulic jacks or air-bags, to bring the sections back up to their proper, horizontal level. Provided the gaps formed between tank bottom and pad are is less than 50mm, they can be packed with clean sand and adequately sealed with sand–bitumen mix. Where gaps are greater than 50mm, filling should be done with crushed graded stone with a thin sand top layer. The tank pad shoulder should be finished with a slope as in EEMUA 183, Appendix VII, Figure I-2.

C.1.4 Number of jacks required

The number of jacks required needs to be adequate to lift the weight of the entire tank, allowing for the additional force needed to overcome adhesion between tank bottom and foundation. The jacks need to have adequate reserve capacity to perform this task and the maximum lifting capacity of each jack should be verified.

The maximum spacing between jacks is determined by the stiffness of the shell. If the spacing is too great, the bending stresses in the shell can cause deformations in the upper shell courses. The maximum spacing between two support points (jacks or timbers) should be 6m or more when it is proved to be safe and verified by means of calculations; special care should be taken. For tanks with a severely corroded shell, and or severely corroded annular section of the bottom a closer spacing may be required.

C.1.5 Jacking of fixed roof tanks

Jacking of a fixed roof tank with a self-supporting roof structure up to a diameter of approximately 34m can be done with jacks equally spaced around the circumference.

Jacking of a fixed roof tank with a self-supporting roof structure greater than 34m diameter requires guy wires installed from the roof–shell connection to the tank bottom to control the sag of the latter. With the guy wires installed, the tank can be lifted with jacks equally spaced around the circumference.

Jacking of a fixed roof tank with a column-supported roof structure requires a cutout to be made in the tank bottom and jacks placed under the columns. These column jacks need to be operated in concert with the shell jacks. Methods exist for supporting the columns with guy wires, but great care needs to be exercised with such a system as the framing can easily become unstable with the possibility of 'corkscrewing' down.

C.1.6 Jacking of floating roof tanks

C.1.6.1 Pontoon floating roof

Jacking of pontoon type floating roof tanks with a diameter up to around 34m can be done with jacks equally spaced around the circumference. The limited sag of the bottom of the lifted tank ensures sufficient support for the roof legs, and keeps the roof deflection within allowable limits.

Jacking of pontoon type floating roof tanks over 34m diameter requires special measures to support the roof structure. Triangular support brackets are attached to the inner surface of the first shell course to form a horizontal sliding support for the roof edge. The support brackets should be placed under the pontoon bulkhead plates. (See Figure C-5).

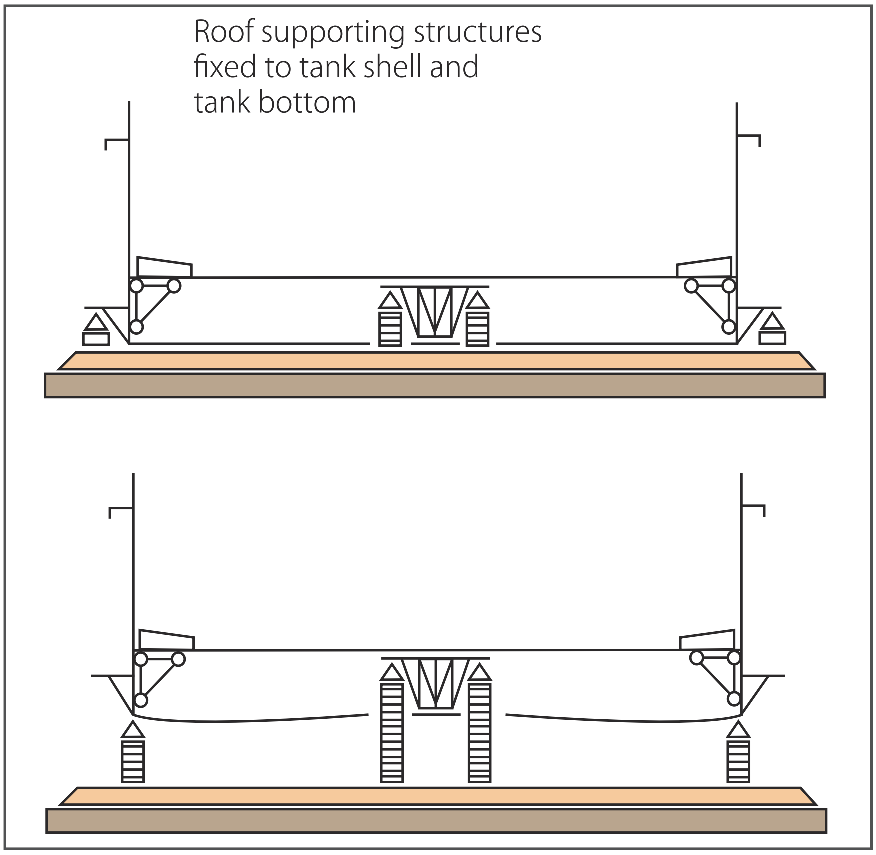

Figure C-5 Two stage jacking of floating roof tank

Besides attaching triangular support brackets to the shell, the deflection of the roof and bottom plates needs to be controlled by temporary lattice girders connecting the roof and bottom plates. These temporary support structures are located in between extra jacking supports, which are equally spaced in a ring around the roof centre. In this way the tank shell, bottom and roof are jacked simultaneously. It should be noted that the centre jacking supports require a temporary opening through the tank bottom plate.

C.1.6.2 Double-deck floating roof

For double-deck floating roofs, the jacking procedure is, in principle, identical to the jacking of a pontoon roof. For tanks larger than approximately 34m diameter, additional supports are also required around the roof centre. The space between top deck and bottom deck should be packed with wood directly above the jacking positions.

C.1.6.3 Radially reinforced floating roof

Jacking of radially reinforced floating roof tanks, normally with a diameter over 50m, is similar to that for tanks with a pontoon type floating roof. However, special attention should be given to maintaining the downward slope of the roof and radial beams during the jacking operation and when placing the tank on its new foundation.

C.1.7 General requirements

The general requirements for ensuring a safe and successful jacking operation are:

- Selection of an experienced jacking contractor;
- Jacking contractor to perform site survey including level measurements;
- Jacking contractor to submit detailed method including calculation of overturning stability under wind conditions. In addition, the contractor should demonstrate by means of calculations that the tank integrity (shell and roof structure) will be maintained during jacking. Special attention should be given to tanks with corroded shell plates, i.e. more jacking points may be required to reduce vertical bending stresses;
- After jacking, a vacuum box test of the tank bottom and internal shell-to-bottom fillet weld should be performed, followed by a full hydrostatic test;
- Maximum ground load of 125 kN/m^2 per jack shall not be exceeded;
- Jacking operation should be stopped immediately when excessive ground settlement under jacks occurs;
- Adequate roof draining should be assured during and after jacking a floating roof tank under all circumstances.

C.1.8 Acceptance criteria after jacking

Tolerances on level and verticality should be in accordance with Section 6.5.1, and on roundness in accordance with Section 11.5.3.

C.2 Typical repair solutions for tank foundations

C.2.1 Erosion of shoulder

The shoulder of an elevated tank pad should be well maintained to prevent damage or erosion by rain or wind, particularly rain flowing down the tank which can penetrate into the foundation. Any damage to the surface of the sealing coat, or breakdown of the sand–bitumen mix of that part of the foundation which projects beyond the base of the tank, should be repaired before the underlying foundation becomes damaged.

C.2.2 Minimum width of shoulder

The shoulder should have sufficient width to provide lateral support for the foundation material under the tank. The width of the shoulder will depend on tank height, tank diameter and elevation of tank pad above grade. An insufficient shoulder width may cause the shoulder to slip away when the tank is fully loaded, creating a very serious safety risk.

C.2.3 Minor edge settlement

Even with relatively minor settlement, the outer edge of the bottom plates of a vertical tank will settle at a level below the surface of the sealing layer of the foundation shoulder. This results in the formation of a channel around the periphery of the tank in which rainwater collects. In such cases, the surface of the projecting part of the foundation should be trimmed, and a new sealing layer of sand–bitumen mix laid with a surface sloping away from the toe of the tank bottom to provide proper drainage.

C.2.4 Major edge settlement

With major edge settlement, the level of the tank bottom may sink until access to connections in the bottom course of the shell becomes difficult, and proper drainage of the foundation becomes impossible. If such a settlement occurs, it may be necessary to restore the level of the tank bottom by lifting the tank and building a new shoulder to the original (and satisfactory) design, to prevent future major edge settlements.

C.2.5 Differential settlement along periphery

When differential settlement or tilting of the shell has reached the limit specified in Chapter 6 (main text), it will be necessary to make the foundation and tank level again. This is done by jacking the tank and repairing the foundation. It will usually mean raising the elevation of the foundation under the shell to the level of the highest point. It is recommended that the entire tank is jacked to a level of 2 to 2½m above the tank foundation to permit proper placement and compaction of the fill material.

C.2.6 Deformations of bottom due to settlement

Deformations of the tank bottom, as described and illustrated in Chapter 6, need to be made good when the acceptable limits are exceeded. In some cases the foundation may need to be reshaped. In other cases, additionally, parts of the bottom may need to be replaced. Repairs can be made from inside the tank by removing some of the bottom plates or by jacking the tank to repair the foundation.

C.2.7 Installation of impervious membrane

The installation of an impervious membrane requires the tank to be jacked to a level of 2 to 2½m above the foundation.

C.2.8 Test requirements

A full hydrostatic test is always required after jacking the tank and/or major foundation repairs (see Chapter 15).

C.3 Typical repair solutions for tank bottoms

C.3.1 Local repairs by welding and/or with welded-on patch plates

The description below is in line with API 653, except for patch plates welded on in the critical zone.

Widely scattered pits can be repaired by filling them with weld material. However, they may be ignored if allowed under Section 7.4.

The patch plates covered by this subsection are welded-on patch plates (see Figure C-6).

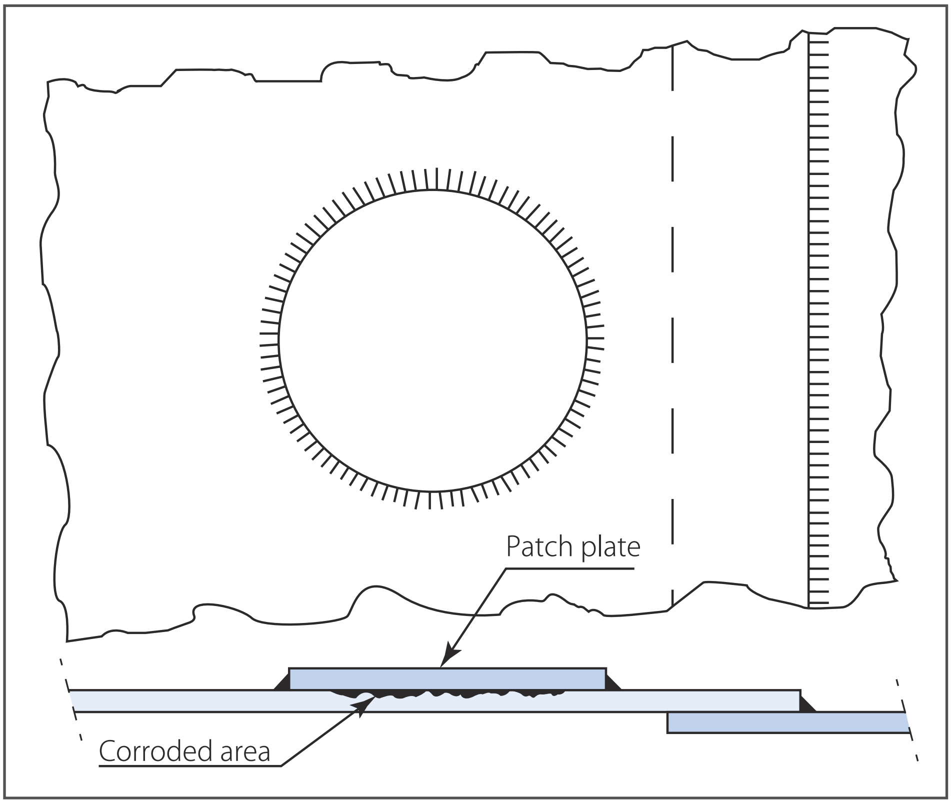

Figure C-6 Typical welded-on patch plate

Patch plates can be used for small, corroded spots inside the tank. The shape can be circular or rectangular. In the latter case, rounded corners are recommended.

Patch plates should have the same thickness as the bottom plates. The dimension (diameter/side) must not be less than 300mm. Patch plates may be placed over existing patches.

Patch plates should not be welded on at locations that show local or global deformation due to settlement. This means that welding patch plates to tank bottoms still undergoing settlement is not recommended.

It is important that patch plates are not used nor local welding of pits is carried out within the critical zone, i.e. in the peripheral area 150mm radially inwards from the tank shell. In this area as per section 15.2.4.4 repair shall only be executed with tombstones plates or by replacing of the annular section.

The thickness of the bottom plate under the perimeter of a patch-plate should meet the requirements of Section 7.4 (main text). The use of patch plates that do not meet those requirements may be permitted provided that the repair method has been reviewed and approved by a qualified and experienced Tank Integrity Assessor. The review needs to consider brittle fracture, stress due to settlement, stress due to shell-bottom discontinuity, metal temperature, fracture mechanics and the extent and quality of non-destructive examination.

The above also applies to the repair of sumps located within the critical zone.

C.3.2 Replacement of an annular plate segment

The method described below can be followed using the sequential jacking method (see C.1.3.5):

1 Determine the location and extent of the annular plate segment that is to be replaced. Mark the location of the radial cuts to be made, and determine the required circumferential length and radial width of the replacement segment. Its circumferential length should be made 1mm longer than that of the segment to be cut out, to allow for weld shrinkage.
2 Remove the existing corner welds between the tank shell and annular plate over the length of plate to be replaced, plus an additional 500mm at either end.
3 Where the radial weld seams of the new segment cross the tank shell, the bottom of the shell plate should be welded to the annular plate with a full penetration 'K' weld over a length of approximately 150mm. The weld preparation should be made by air gouging, in accordance with Figure C-7.
4 Remove all existing welds between the bottom plate and the existing annular plates, either by air gouging or grinding. Flame cut away the existing annular plate segment exactly on the radial lines marked for the new seams, and prepare these cut edges with 45° weld preparation.

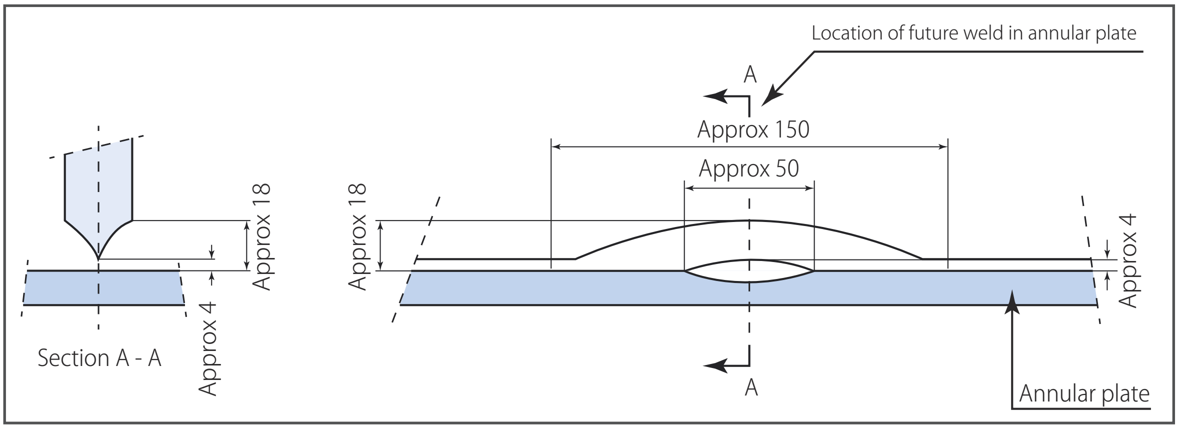

Figure C-7 'K' seam where new annular plate radial welds cross rank shell

5 Fit the new annular plate segment, which may be equipped with backing strips at the new radial weld seams to allow for one-sided welds. Since the inserted segment is 1mm longer than the cut segment, it will not lie flat until weld shrinkage has taken place.

6 The welding sequences to be employed for the various welds of the new annular plate segment are as shown in Figure C-8.

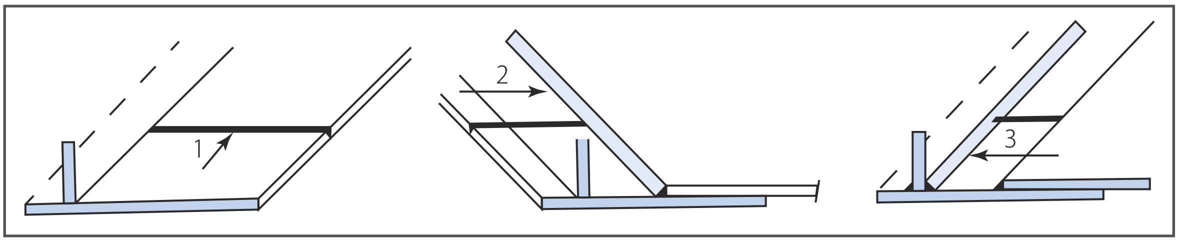

Figure C-8 Welding sequence for annular plate replacement

7 When welds 1 and 2 (Figure C-8) have been completed (including NDT), the new corner welds between the tank shell and the annular plate should be restored, including the special 'K' welds where the shell crosses the annular plate radial seams.

8 Welding of the new corner plate should be made according to a block sequence as specified in the scheme illustrated in Figure C-9. This scheme is designed to balance weld shrinkage and avoid distortion of the annular plate. The first and second weld layers are made from the inside of the tank by two welders working simultaneously from either end of the inset plate towards its centre. Then the third and fourth weld layers are made from the outside of the tank. In this case they are made by the two welders working together, one from one end and the other from the centre of the insert as illustrated in Figure C-9. This latter method is repeated inside and out, sequentially, according to the number of weld layers required in the procedure to reach the specified throat thickness. Figure C-10 gives a pictorial view of the welding sequence.

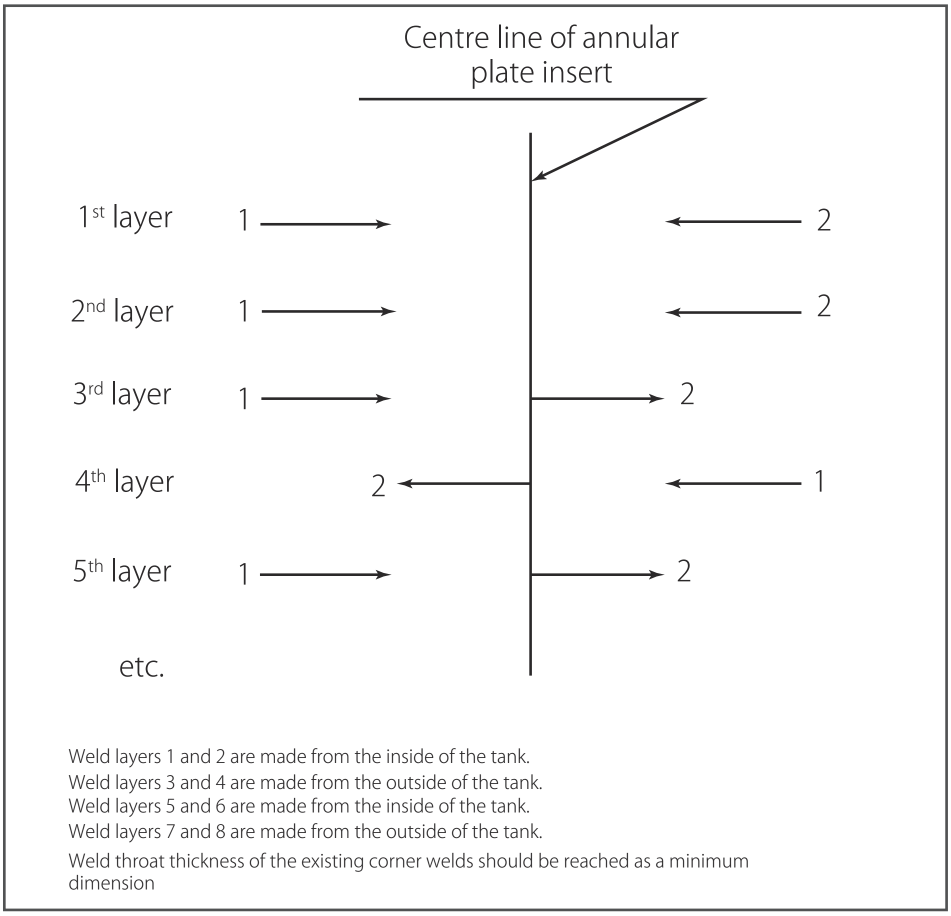

Figure C-9 Welding sequence for shell-to-bottom junction

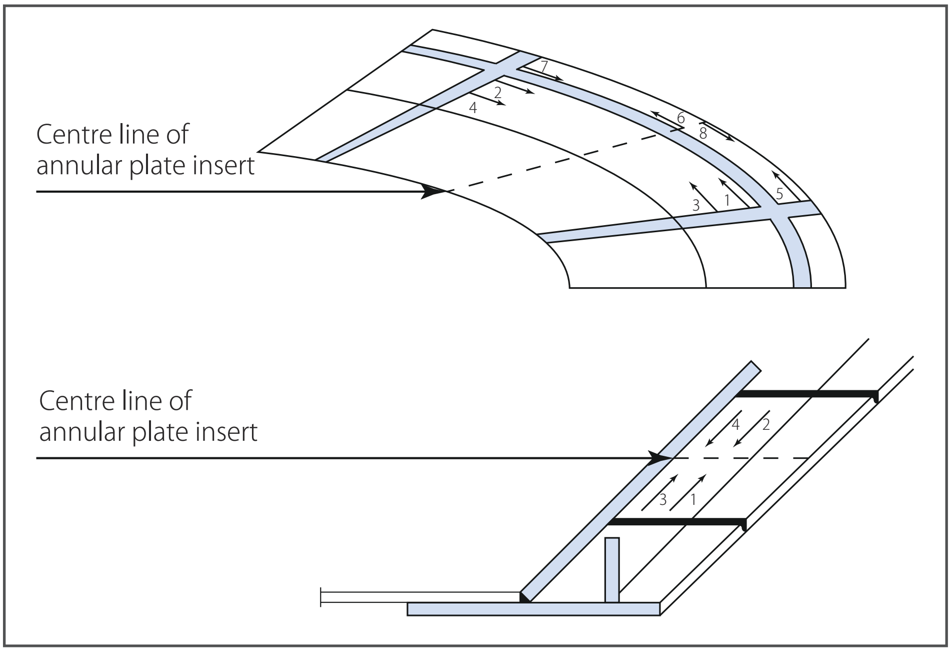

Figure C-10 Explanation of welding sequence for shell-to-bottom junction

C.4 Typical repair solutions for tank shells

C.4.1 General

Each spot showing excessive corrosion should be evaluated for a proper repair. The way a corroded area is repaired should be based on international standards. The repair flow chart, Figure 8-17 will be of assistance for establishing a proper repair procedure for each corroded spot; see also Figure C-13.

When repair of a buckled tank shell is deemed necessary, this should always be done using insert plates. Because buckled areas are generally larger in size than corroded spots, the shell needs to be supported by extra beams when a buckled area is repaired. Sometimes large indentations can be repaired by filling the tank with liquid where there has been no major plastic deformation.

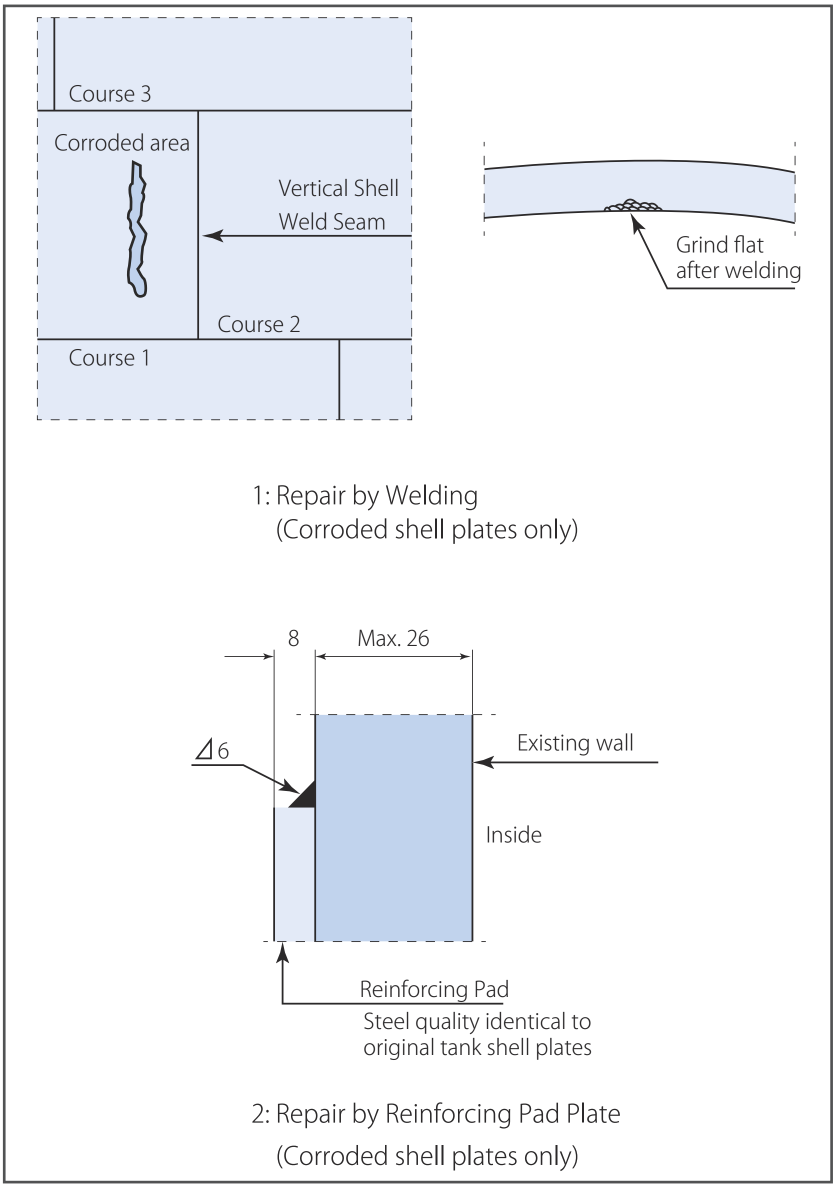

Figure C-11a Repair solutions for shell plates

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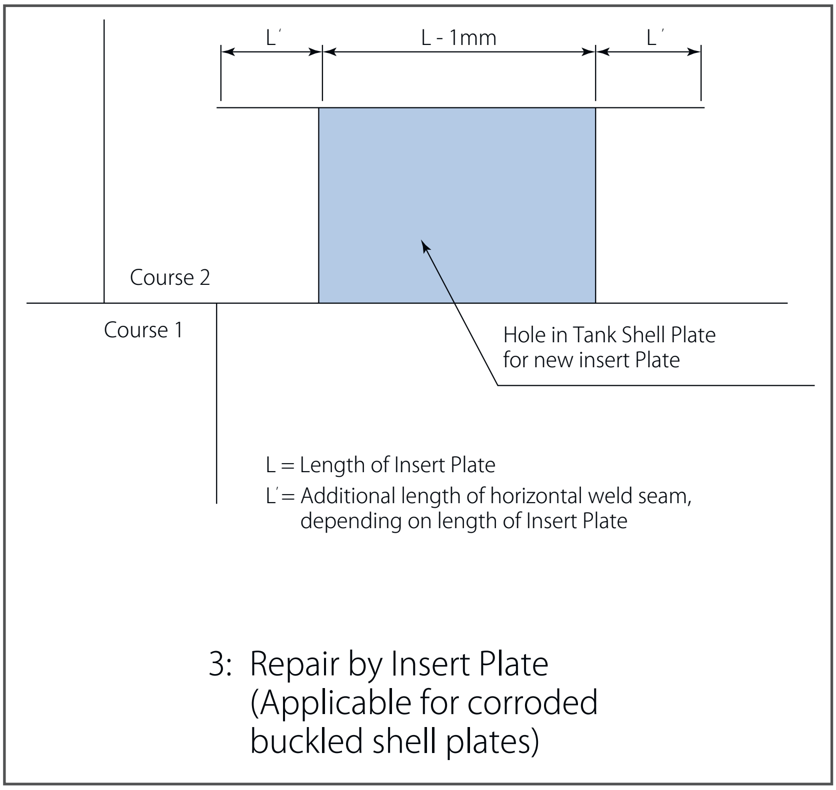

Figure C-11b Repair solutions for shell plates
(continued from previous page)

C.4.2 Repair procedure using insert plates

C.4.2.1 General

For repair welding and welding of insert plates, the procedure below is recommended:

1 The edges of the hole need to be of undamaged material. Normally a distance of 300mm is maintained between the visible damage and the cuts. The cuts are extended in the horizontal direction, and the insert plate is made with an 'overlength', to cope with shrinkage due to welding. See Table C-1 below for the values of the extension and the overlength.

Table C-1 Overlength of insert plates

Length of Insert Plate (L) [m]	Extended Length (L') (mm)	'Overlength' (ΔL) (mm)
1	150	0.5
2	250	1.0
3	350	1.5
4	450	2.0
etc.	etc.	etc.

2 In the vertical direction, the insert plate is cut approximately 3mm smaller than the hole, depending on the welding details.
3 The vertical seams of the insert plate are welded first, whilst pushing the insert plate into the opening (see Figure C-12).
4 For material equivalent to S355 (see Section 2.4.1) exceeding 20mm in thickness, the locations of welding should be preheated to approximately 75°C.

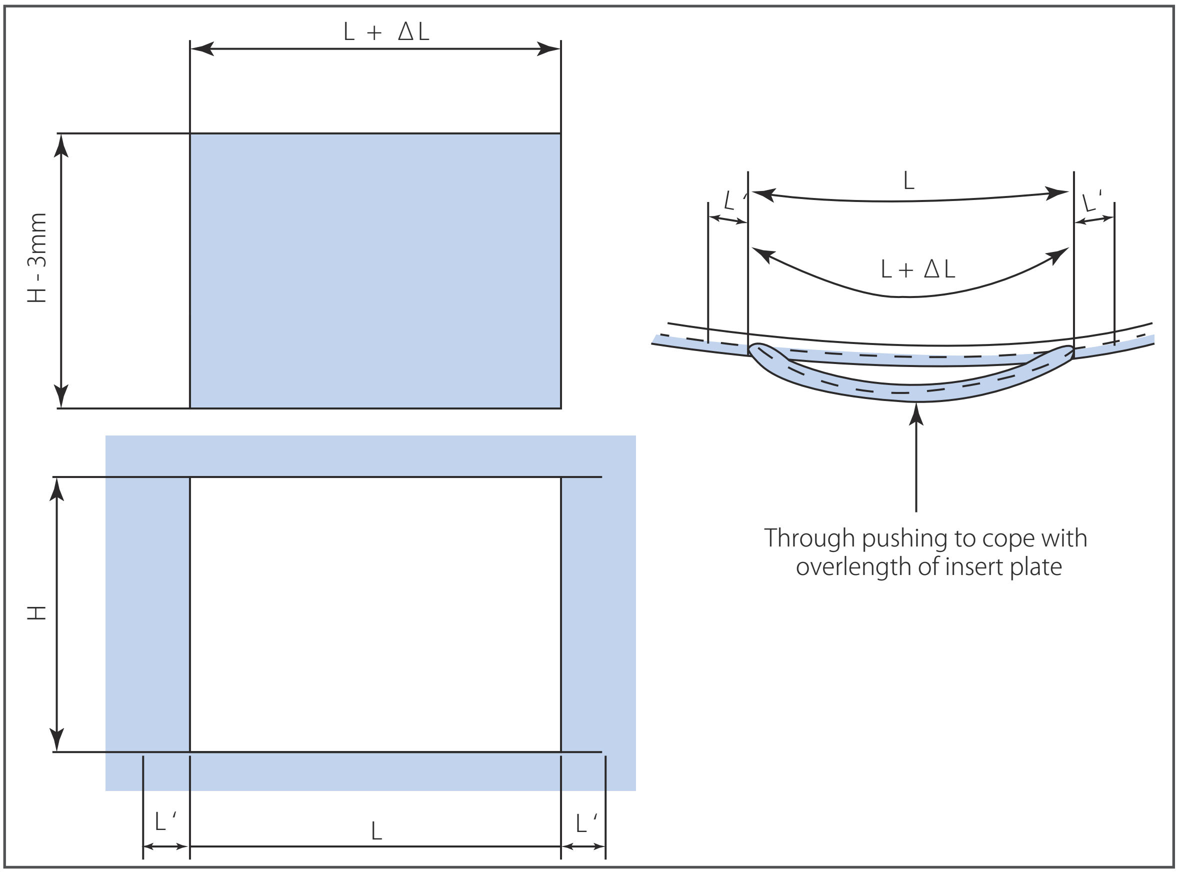

Figure C-12 Sizes of cuts and insert plates

C.4.2.2 Removing the damaged shell plate

Once the dimensions of the section to be cut out have been determined, the bottom horizontal seam is cut first. Then the two vertical seams are cut, working upwards from the bottom. Finally the upper seam is cut, starting from the edges and working towards the centre.

C.4.2.3 Welding sequence for insert plate

The vertical seams are welded first, followed by the horizontal seams. The sequences shown in Figure C-13 should be followed.

