TECHNICAL SPECIFICATION

STANDARD VERTICAL TANKS - FIELD ERECTION AND TESTING

DEP 64.51.01.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the erection and testing of standard vertical tanks, including both field erected and prefabricated tanks. For the design of these tanks reference is made to DEP 34.51.01.31-Gen. (which also covers the prefabrication of tanks) and BS 2654.

This DEP is a revision of the DEP with the same number dated June 1983.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/"Shell" Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "C", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants and exploration and production facilities and, where applicable, in supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (9).

2. DEFINITIONS

2.1 GENERAL DEFINITIONS

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

2.2 SPECIFIC DEFINITIONS

For the definition of the following terms used in this DEP, see DEP 34.51.01.31-Gen.:

Climate, cold;
Climate, temperate;
Climate, very cold;
Climate, warm;
Medium high tensile steel.

3. GENERAL

3.1 RECEIPT AND STORAGE OF MATERIALS

The erection contractor shall inspect and keep stock of all materials delivered at site and be fully responsible for their safekeeping.

All fittings, valves, plates, etc., shall be properly laid out on wooden supports clear of the soil. Special care shall be taken that damage does not occur to joint faces of valves and flanges or to bevelled ends of fittings.

3.2 PREPARATION OF MATERIALS

All materials shall be examined and repaired as necessary at the site before being erected, to ensure that any damage incurred in transit is made good to the satisfaction of the Principal.

3.3 MANUAL GAS CUTTING

Manual gas cutting may be used for trimming the corners of bottom or roof plates where two lapped joints will intersect, and for cutting openings (where permitted by DEP 34.51.01.31-Gen.) for fittings positioned on site.

Manual gas cutting shall not be used for any other purpose without the approval of the Principal.

4. ERECTION

4.1 ERECTION METHODS

4.1.1 General

The main methods of erecting welded vertical tanks are outlined in this section and illustrated in Appendix 1.

Welded vertical tanks can be erected satisfactorily in several ways; no single particular system of erection procedure is specified for use.

Erection contractors normally have their own specific individual method which they have adopted as the result of experience, and have developed the erection technique most suitable for economical working and good workmanship by their field crews. Provided that the erection contractor employs a method which is known to give good results and that the recommended sequences of erection and welding are followed, the method may be deemed satisfactory.

Contractors shall outline their method of erection for approval by the Principal before a contract is placed. The most well-known methods of erection are described below.

4.1.2 Progressive assembly and welding

In the progressive assembly method, the bottom plates are assembled and welded first. Thereafter the shell plates are erected, held in place, tacked and completely welded. This shall be done course by course, working upwards to the top curb angle. No course shall be added as long as the previous course has not been entirely welded.

The erection and completion of the roof framing and roof plates then follow (see Appendix 1).

4.1.3 Complete assembly followed by welding of horizontal seams

In the complete assembly method, the bottom plates are assembled and welded first. Thereafter the shell plates are erected, held in place, tacked and only the vertical seams completely welded, leaving the horizontal seams unwelded. This shall be done course by course, working upwards to the top curb angle. No course shall be added as long as the vertical seams of the previous course have not been entirely welded.

The erection and completion of the roof framing and roof plates then follow.

Finally the horizontal seams are welded, working upwards from the bottom course or downwards from the top curb angle. See Appendix 1.

4.1.4 Jacking-up method

Some contractors employ a system of erection in which the bottom plates are completed, the top course is erected on the bottom plates, the roof framing and sheeting are completed and a number of jacks are then assembled around the structure. By means of these jacks, the completed top course together with the roof framing and sheeting is lifted to a height sufficient to insert the next lower course. The jacking method and the supporting of the partly erected shell shall have no adverse effect on the roundness of the shell.

The welding is completed at each stage of lift until all courses of the shell plates have been inserted and the finished height is reached.

The final operation is the welding of the bottom course to the bottom plates.
See Appendix 1.

4.1.5 Flotation method

The flotation method is used for floating roof tanks. After the completion of the bottom plating and erection and welding of the two lower courses of the tank, the floating roof is assembled on the tank bottom and completed. The tank is then filled with water and, using the floating roof as a working platform, the third and subsequent courses are

erected and welded, water being pumped in as each course is completed.

Regular checks on the vertical alignment and roundness are required to ensure compliance with (4.5) and (4.7).

This method may only be used at locations where soil settlement is very limited and with the agreement of the Principal. The predicted soil settlements of the soil investigation report shall be taken into account.

A small crane is usually erected on the floating roof for hoisting the shell plates into position. See Appendix 1 and the note under (4.2).

4.1.6 Off site assembly

This method may only be used with the agreement of the Principal; it is suitable for hazardous locations and/or locations close to existing tanks already storing light products. Tanks can be prefabricated and moved to their permanent site, either by:

- Assembly of the tank in the workshop. The maximum dimensions depend on the possibilities and limitations with respect to transport. Generally this method shall be limited to tanks with diameters up to 12 metres.
- Assembly of the tank on a temporary foundation at a safe location nearby. The complete tank is then moved to its permanent foundation, e.g. by crane, on rollers or by air cushion.

The water test shall be carried out when the tank is standing on its permanent foundation.

4.2 WIND BRACING

During erection, tanks shall be safeguarded adequately against distortion or damage due to wind pressure by the provision of suitable steel wire guys, temporary girders or braces.

There should be at least one guy every 8 m of circumference. These shall remain in place until welding of the shell plates and erection of the roof framing has been completed, or, with open top tanks, until the wind girder has been completed. Particular attention shall be given to the reliability of the anchor blocks for the guys especially in weak, muddy soils.

A recommended system for tank guying is illustrated in Appendix 2.

NOTE: In high wind areas the flotation method is a good protection against tank shells collapsing because of the effect of wind gusts during construction. For this reason the flotation method could be used in a modified manner for the erection of fixed roof tanks. The detailed erection procedure shall, however, be described in detail and agreed by the Principal before the contract is placed.

4.3 ERECTION HOLES AND ATTACHMENTS

Holes shall not be made in platework to assist in erection.

Lugs, nuts, clamps, and other devices to assist in erection may be attached to the tank plates by welding, but all such attachments required only for the purposes of erection shall ultimately be removed and any noticeable projections of weld metal remaining shall be carefully ground or chipped away.

Plates shall not be gouged or torn in the process of removing attachments, and any indentations caused thereby shall be filled with weld metal and ground flush with the plate surface.

4.4 SETTING OUT BOTTOM COURSE OF SHELL PLATES

In setting out the bottom course of shell plates, allowance shall be made for the contraction of the joints during welding. While the plates are being plumbed and checked for circularity, and before they are tack-welded to the bottom, they shall be

held in position by metal clamps or other devices attached to the bottom plates.

A suitable method is illustrated in Standard Drawing S 51.043.

4.5 CHECKING OF ALIGNMENT

Before final welding of the bottom course of shell plates begins, a check should be made to ensure that the alignment of the plates and the width of the gaps between them are correct, and that any inaccuracies after welding will be within the tolerances stated below. If the tolerances are expected to be exceeded, the plates shall be re-aligned before final welding begins. Care shall be taken to minimize lack of circularity or distortion between the top and bottom of the tank shell, whether due to welding or any other cause. Rectification by cutting of shell plates is not permitted.

After the first course has been erected and welded, the internal radius, measured horizontally from the centre of the tank to any point on the inside of the tank shell, shall not vary from the nominal internal radius by more than the following:

Tank diameter (m)	Maximum deviation from nominal internal radius (mm)
$\leq$ 12.5	13
> 12.5 $\leq$ 45	19
> 45	25

4.6 ROOF FRAMING

Before erection of the roof framing begins, the tank shell shall be checked for uneven settlement, and any misalignment of the top of the shell shall be corrected before the roof members are positioned.

Temporary supports for the erection of the roof framing shall not be removed until the erection of the main and secondary framing is complete. With dome roofs, the temporary centre support shall not be removed until radial rafters, purlins and bracings are erected, completed and welded, and all roof sheets are tack-welded into position. The positioning of the roof trusses shall be done very accurately to prevent misalignment.

When assembling roof sheets on the framing, excessive asymmetric loads shall be avoided and not more than three roof sheets shall be stacked at any one point.

For dome roofs, the roof sheets shall be assembled symmetrically, working from the centre outwards.

The strength of erection poles used for temporary support of the roof structure shall be checked by calculation for the maximum load to be carried.

In particular the resistance to buckling shall be checked. The erection contractor shall make a calculation showing strength and safety of the erection poles to be used.

4.7 SHELL TOLERANCES

4.7.1 Verticality of the tank shell

After completion, the shell shall not be out of vertical by more than the following:

Tank diameter (m)	Maximum deviation from vertical
≤ 12.5	1 in 400
> 12.5 ≤ 30	1 in 350
> 30 ≤ 45	1 in 300
> 45	1 in 250

These tolerances shall apply to the tank shell as a whole and should also be used as a guidance for each individual course.

4.7.2 Local deviation from the design form

Local deviation from the design form for the shell (horizontally and vertically) shall not exceed the following when measured over a gauge length of 2.5 m remote from weld seams:

Plate thickness (mm)	Maximum local deviation from the design form (mm)
≤ 12.5	16
> 12.5 ≤ 25	13
> 25	10

Such deviations from the design form shall be gradual over the gauge length, without any sharp changes in form.

4.7.3 Tolerances at horizontal and vertical shell seams

At horizontal and vertical shell seams the shell profile shall not deviate from its design form by more than the following, measured over a gauge length of 1 m:

Plate thickness (mm)	Maximum deviation from the shell profile at weld seams (mm)
≤ 12.5	10
> 12.5 ≤ 25	8
> 25	6

4.7.4 Tolerances for misalignment of plates at butt welded joints

Plates to be joined by butt welding shall be matched accurately and retained in position during the welding operation. Misalignment of the centre line of the plates shall not exceed the following:

	Plate thickness, t (mm)	Maximum misalignment (mm), whichever is the lesser	
Completed VERTICAL JOINTS	≤ 19	0.1 t	1.5
	> 19	0.1 t	3.0
Completed HORIZONTAL JOINTS	≤ 8 (upper plate)	0.2 t	1.5
	> 8 (upper plate)	0.2 t	3.0

4.7.5 Top of tank shell

The tank shell shall be checked for circularity, dimensions and level before the wind stiffener(s) and roof members (fixed roof tank) or the secondary and primary wind girders (floating roof tank) are erected.

4.8 FLOATING ROOF TOLERANCES

The differences in the gap between the shell and the periphery of the roof on completion of erection of the roof shall not exceed ± 13 mm from the nominal gap.

At any elevation of the roof other than that at which it was erected, this difference in nominal gap shall not exceed ± 50 mm unless a different value has been agreed with the Principal for a particular seal design.

5. FOUNDATIONS

5.1 CHECKING OF FOUNDATIONS

For a tank to have a shell which is truly circular and free from buckles and flat spots, the foundation shall remain level as the tank shell is erected. For this reason the foundation shall be checked, not only at the commencement of erection but also several times during the various stages of tank erection. The measurements shall be stated in a report. This final report shall be handed to the Principal for maintenance purposes.

Whichever type of construction is chosen, the surface immediately under the shell plates shall be laid so that the difference from a mean level does not exceed plus or minus 6 mm in 10 m and plus or minus 12 mm between any two points around the circumference. Uneven foundation and settlement can result in the shell assuming an oval shape at the top, causing the floating roof to stick.

An indication that the tank is settling unevenly is the appearance of gaps in the circumferential seams, and departure of the shell from the perpendicular. If these signs appear, no attempt should be made to close the gap by pulling with the key plates and wedges or cutting of plates. The tank level should be checked and corrected by levelling, if necessary. If the gap is due to inaccurate plate fabrication, plate edges should be built up with weld metal, and the joint welded.

Tank foundations are mostly finished off with a sand-bitumen mix as a waterproof seal coat; steel plates should be placed temporarily across the edge of the tank foundation to protect it whilst the bottom plates are being dragged into position.

5.2 ACCEPTANCE OF FOUNDATIONS

Before erection starts the Contractor shall check the foundations of the tanks for height, shape and level and will subsequently accept the base and take over responsibility for it.

This also includes the responsibility for its appearance and final shape after completion of tank erection. If soil settlement is observed the Contractor shall inform the Principal immediately.

The Contractor shall be made aware of the predicted soil settlements stated in the soil investigation report.

5.3 CONCRETE FOUNDATION RINGS UNDER THE SHELL

Concrete foundation rings under the tank shell shall be used only when required as downward load to compensate for the uplift caused by internal pressure and for wind, e.g. for BHC and BHD tanks.

Where this condition does not exist concrete foundation rings should not be used as they create a hard spot under the tank shell which may result in settlement problems, particularly in locations with weak soil.

Concrete rings are also a handicap when relevelling or the jacking-up of tanks is required.

If concrete foundation rings are used, the top of the ring shall be covered with a bitumen layer of at least 5 mm thick.

5.4 CONCRETE RAFTS

If concrete rafts are used as a foundation, the top of the concrete raft shall be covered with a layer of sand-bitumen mixture of at least 50 mm.

5.5 ANCHOR BOLTS

The anchor bolts should be designed such that they can be fixed to the tank shell and

the concrete foundation after the erection of the tank, in order to prevent damage to the anchor bolts during erection.

6. WELDING

6.1 WELDER QUALIFICATION

All welding of tank plates, steel framing, structural attachments and mountings shall be carried out by welders or welding operators who have been qualified in accordance with BS 2654 or, if approved by the Principal, an equivalent standard such as ASME IX. The welders and welding operators shall be issued with a welding certificate which includes a photograph, and copies of the certificate shall be available on the site.

6.2 WELDING PROCEDURE QUALIFICATION

Each welding procedure shall be qualified in accordance with BS 2654 or, if approved by the Principal, an equivalent standard such as ASME IX.

For automatic welding, also see (6.12).

6.3 SEQUENCE OF WELDING

The sequence employed both for the tack welding and final welding of the bottom, shell and roof plates shall be arranged to minimize the distortion due to weld shrinkage. The sequences shall be approved by the Principal before erection starts.

Typical welding sequences for tank bottoms, tank shells and tank roof sheets are shown in Standard Drawings S 51.041 and S 51.043. Particular attention shall be given to the welding of the butt-welded seams in the annular plates where these pass under the shell plates, to ensure that full penetration is obtained.

A typical method for positioning shell plates and a typical welding sequence for shell plates and a recommended method for positioning shell plates on the tank bottom annular plates is illustrated on S 51.043.

6.4 WEATHER CONDITIONS

Welding shall not be carried out when the surfaces to be welded are wet; nor when rain, sleet, snow or hail is falling or high winds are blowing, unless the welder or welding operator and the work are properly shielded.

When the air temperature is below 0 °C, the base metal at either side of the joint shall be preheated before welding is started.

For carbon steel the metal shall be at a temperature warm to the hand for a distance of not less than four times the plate thickness, or 75 mm whichever is the greater, in any direction from the joint to be welded.

During the course of the welding operation, this preheat temperature shall be maintained in the specified area.

For medium high tensile steel the requirements for preheating are specified under (6.14).

6.5 WELDING CONSUMABLES

Electrodes and welding wire shall be stored in their original packets or cartons in a dry place adequately protected from weather effects.

Similar precautions shall be taken in the storage of flux for submerged-arc welding.

If electrodes become damp but are not otherwise damaged they may be used only after being dried out in a manner approved by the electrode manufacturers. Any electrodes which have areas of the coating broken away or damaged shall be discarded.

Basic low-hydrogen electrodes shall be used for shielded metal arc welding.

An oven shall be available at the welding site to ensure the use of dry electrodes in

accordance with the recommendations of the electrode manufacturer.

6.6 TACK WELDS

Tack welds used in the assembly of the vertical joints of tank shells and horizontal joints to be manually welded shall be removed and shall not remain in the finished joint.

Tack welds in the bottom, shell-to-bottom, roof and automatically welded horizontal joints of the tank shell and other joints, need not be removed provided they are sound and the subsequent weld runs are thoroughly fused into the tack welds.

6.7 PLATE EDGE JOINTS

The plate edge joints which may be used are specified in DEP 34.51.01.31-Gen. and will be shown on the detail drawings of the supplier of the tank material.

If automatic welding is used, the erection contractor shall specify the details of plate edge preparation and shall inform the manufacturer of the tank materials as soon as possible to arrange accordingly.

6.8 WELDING PROCEDURE

The welding procedure shall be as follows:

- In multi-layer welding each layer of weld metal shall be thoroughly cleaned of slag and other deposits before the next layer is applied. All completed welds shall be freed from slag, brushed and thoroughly cleaned before final inspection and subsequent painting.
- The reverse side of double-welded vertical butt joints shall be back-chipped, ground or flame-gouged before the application of the first run of welding on this side, in a manner which will leave the exposed surface accessible and satisfactory for the fusion of the weld metal to be added. At the discretion of the Principal this requirement may be relaxed when the back of the metal run is smooth and free from crevices which might entrap slag, and when the Principal is satisfied that the required weld quality will be maintained. If back-gouging is applied, grinding to bright metal is required.
- There shall not be any undercutting of the base metal.
- The weld metal on both sides of all butt joints, except offset faces of horizontal joints of unequal plate thickness, shall be built up in the form of an overlay so that all the finished face in the area of fusion shall extend above the surface of the adjoining plates to a height of not more than 1.5 mm.
- The edges of all welds shall merge with the surface of the adjoining plates without a sharp angle.

6.9 BOTTOM PLATE JOINTS

All bottom plate joints shall be welded in accordance with the details described in DEP 34.51.01.31-Gen. See also Standard Drawing S 51.040.

If bottom plates are butt-welded a minimum plate thickness of 6 mm is required and a backing strip shall be used which is at least 60 mm wide and 8 mm thick.

It shall be checked that all locations where supports for accessories (e.g. heating coils, roof drains, vacuum breakers, etc.) are welded to the bottom, or will be touching the bottom, are provided with a suitable pad plate to prevent leakage. The pad plates shall be round or at least have rounded corners. The pad plate thickness shall be at least equal to the bottom plate thickness.

6.10 BOTTOM TO SHELL PLATE JOINT

The shell plates shall be continuously welded on both sides to the annular plates in

accordance with the details described in DEP 34.51.01.31-Gen. See also Standard Drawing S 51.040.

6.11 SHELL BUTT JOINTS

Shell butt joints shall be of a full penetration design (see 7.5.1).

All seams shall be welded from both sides of the plate.

In single-vee or single-bevel butt joints, the vee or bevel shall be made on the outside of the tank unless otherwise agreed by the Principal.

6.12 AUTOMATIC WELDING

6.12.1 Horizontal seams

Automatic flux-cored arc welding, gas metal arc welding and submerged-arc welding may be used if it has been proved in the welding procedure tests that the welding process produces full penetration and full fusion.

The welding procedure tests shall be executed in a test frame on plates with a minimum length of 3 m under restrained conditions. After depositing the root layer(s), this (these) layer(s) shall be inspected for cracks.

6.12.2 Vertical seams

Approval of the Principal is required for the application of automatic welding processes. The welding procedure test shall show that full fusion is consistently obtained.

6.13 MAXIMUM HARDNESS

To prevent the possibility of sulphide stress corrosion, for tanks which may contain water and H_2S, the hardness of the weld metal, heat affected zone and base metal shall not exceed 248 HV10. This applies to all welds below the first horizontal seam.

The hardness measurements shall be taken on the welding procedure test plate on a cross section over the weld. The hardness shall be measured in the weld metal, heat-affected zone and base metal.

6.14 PREHEATING FOR MEDIUM HIGH TENSILE STEEL

All seams of plates over 19 mm in thickness shall be preheated throughout to a temperature between 50 °C and 100 °C.

For temporary welds, tack welds and manual repairs on plates over 19 mm in thickness, these plates shall be preheated to a temperature of approximately 100 °C. See also (6.4).

7. INSPECTION

7.1 GENERAL

The Principal shall at all times have free access to all parts of the site while the work covered by the contract is in progress.

The erection contractor shall afford him all reasonable facilities for ensuring that the work is being carried out in accordance with the requirements of this DEP.

7.2 INSPECTION DURING WELDING

All site welding shall be subjected to visual inspection by competent welding inspectors of the contractor as the welding progresses, and any faults or bad practices shall be corrected as soon as possible.

Particular attention shall be paid to the vertical and horizontal joints in the shell plates, butt joints in bottom annular plates and other joints that pass under the shell plates.

All these joints shall be thoroughly de-slagged by chipping and brushing, and visually examined between each run of weld metal for faults such as lack of fusion, surface cracks, slag inclusions and undercutting. Inspection shall also be performed to confirm that double-vee or double-bevel joints have been properly back-gouged before welding the second side.

7.3 FINISHED WELD INSPECTION

All welds shall be inspected visually in accordance with (7.4). The use of sectioning, trepanning or other destructive methods of testing welds is not permitted.

Radiographic inspection is required for all tanks of medium high tensile steel and for those tanks of carbon steel for which a joint efficiency factor of 1.00 has been used.

For tanks of carbon steel for which a joint efficiency factor of 0.85 has been used, the radiographic inspection is not required in temperate and warm climates and is only required for cold climates and very cold climates.

If radiography is so required, the minimum extent shall be as follows:

	THINNER PLATE THICKNESS (mm)	EXTENT OF RADIOGRAPHY
VERTICAL butt welds	$\leq$ 13	5% of the vertical seam length
	> 13 < 25	10% of the vertical seam length
	$\geq$ 25	20% of the vertical seam length
HORIZONTAL butt welds	$\leq$ 13	2% of the horizontal seam length
	> 13	5% of the horizontal seam length
bottom annular plate butt welds	All	All welds (from the outer edge of the annular plate to a point 250 mm inside the tank)
Shell tee junctions	> 19	All (horizontal direction)

NOTE: the minimum length of a radiograph shall be 0.3 m. The number of radiographs shall be based on an effective length of 0.3 m per radiograph.

7.4 VISUAL INSPECTION

All welds shall be visually inspected.

Visual inspection shall show that the following requirements are met:

- the weld is made in accordance with the design requirements;
- the profile of fillet welds is such that leg lengths are equal within 1.5 mm and the surface of the weld is slightly convex and free from overlap at the toes of the weld;
- the profile of butt welds is uniform, slightly convex and free from overlap at the toes of the weld;
- the height and spacing of ripples are uniform;
- there shall be no undercutting of the parent metal, except that on horizontal butt joints and fillet welds, an undercut not exceeding 1 mm in depth shall not be cause for rejection;
- there are no pronounced lumps or cavities caused by starting or finishing a weld bead;
- the surface of the weld is free from cavities and trapped slag, and does not display any porosity.

7.5 RADIOGRAPHIC ACCEPTANCE CRITERIA

Welds shall comply with BS 2654 except where otherwise stated below.

7.5.1 Incomplete penetration

Local incomplete penetration is acceptable provided that:

- it shall not be longer than 10% of the thickness of the thinner plate;
- it shall not be located within 150 mm of a tee joint;
- the total length of incomplete penetration between two adjacent tee-joints shall not be longer than 75 mm.

7.5.2 Slag inclusions

Inclusions shall be assessed both individually and collectively in accordance with the following, in which t = thickness of thinner plate:

	PARAMETER	MAXIMUM PERMITTED DIMENSION OF THE PARAMETER	NOTES
INDIVIDUAL INCLUSIONS	length	2/3 t	length > 19 mm is not permitted, regardless of t. length < 6 mm is acceptable, regardless of t.
ADJACENT INCLUSIONS OF ANY INDIVIDUAL LENGTH	aggregate length in a weld length of 6t	t	inclusions are considered to be adjacent if they are aligned and are separated by no more than 3 times the length of the longer inclusion

7.6 REPAIRS TO WELDS AND ADDITIONAL RADIOGRAPHY

7.6.1 Vertical seams

If any of the defects exceeding the limits defined in (7.5) are found in a vertical seam, two additional spots in the same seam shall be examined in order to determine the limits of the defective welding.

These spots shall be on either side of the original spot at locations to be indicated by the Principal.

If the weld at either of the additional spots fails to meet the acceptance criteria (7.5) the vertical weld seam shall be fully radiographed.

7.6.2 Horizontal seams

If any of the defects exceeding the limits defined in (7.5) are found in a horizontal seam, two additional spots in the same seam shall be examined in order to determine the limits of the defective welding.

These spots shall be on either side of the original spot at locations to be indicated by the Principal.

If the weld at either of the additional spots fails to meet the acceptance criteria (7.5) additional spots shall be examined until the limits of the defective welding are determined.

7.6.3 Repairs and re-examination

All defective joints which have been repaired by welding shall be radiographed and shall conform to the acceptance criteria (7.5).

7.7 RETENTION AND RECORDING OF RADIOGRAPHS

The erection contractor shall record all films with their identification marks, on a diagrammatically developed elevation of the shell plates. The defects shown on the radiographs shall be indicated on this diagram.

At the completion of erection at site all radiographs and their records shall be handed over to the Principal.

7.8 RADIOGRAPHIC TECHNIQUES

For carbon steel plates, gamma-ray or X-ray apparatus may be used as sources of radiation. For medium high tensile steel plates an X-ray apparatus shall be used. The technique shall comply with ASME Section V, article 2, SE 142.

The type of film shall be class I or class II. Intensifying salt screens shall not be used. The radiographic technique used shall detect any differences in metal thickness to within 2% of the total thickness of the section under examination.

As a guide to the degree of definition and contrast achieved, and in order to determine whether the minimum radiographic sensitivity is being attained, a penetrameter or image quality indicator shall be used.

Identification markers which will show on the film shall be placed adjacent to the weld at each spot examined. Their locations shall be marked accurately near the weld on the outside surface of the tank, in order that any defect appearing on the radiograph may be accurately located.

7.9 ULTRASONIC INSPECTION

For automatic vertical welding, 100% ultrasonic inspection shall be applied in addition to the required radiographic inspection. The technique used shall be in accordance with ASME Section V, article 23, SA 577.

8. TANK TESTING

8.1 TANK BOTTOMS

After welding of the bottom plates has been completed, all welds shall be tested using a vacuum box to verify that the tank bottom is free from leaks.

The test shall be made before water is let into the tank for hydrostatic testing. The test should be made as soon as possible after welding of the bottom, removal of slag, and wire brushing, but before any surface coating is applied.

A partial vacuum (0.65 bar (abs)) shall be created by means of a hand or motor-driven vacuum pump. For the detection of leaks, soap suds or a similar substance shall be applied to all joints.

After jacking-up of a tank for relevelling, or after transport of a prefabricated tank, the tank bottom shall again be tested for leaks using a vacuum box.

8.2 TANK SHELLS

The shells of fixed roof tanks shall be hydrostatically tested after completion of the roof. The shells of open top or floating roof tanks shall be tested after completion of the wind girder.

For fixed roof tanks, testing shall be done by filling the tank with fresh water to the level of the top leg of the top curb angle, and noting any leaks over a period of at least 24 hours. For open top tanks and floating roof tanks the maximum test water level shall be approximately 150 mm below the top of the shell. For floating roof tanks erected by the flotation method, the shell shall be tested during erection.

The hydrostatic test procedure shall be in accordance with Appendix 3.

8.3 FIXED ROOFS

After the tank shell has been tested with water, the roof shall be tested by pumping air under the roof plates while the tank is still full of water. The influence of sudden barometric changes and possible condensation during the night shall be considered.

Non-pressure tank roofs shall be tested to a pressure of 7.5 mbar (ga), and pressure roof tanks to a pressure equal to the maximum internal pressure rating.

For the detection of leaks, soap suds or similar substance shall be applied to all joints.

Alternatively, the roof weld seams may be tested by the vacuum box method.

8.4 FLOATING ROOFS

8.4.1 Centre deck of pontoon-type roofs

The weld seams of the single centre deck plates shall be checked for liquid tightness by the vacuum box method or by applying penetrating oil.

8.4.2 Pontoon of pontoon-type roofs

Before the top plates of the pontoons are installed all fillet welds shall be tested for tightness, using penetrating oil, having been already thoroughly cleaned of slag and dirt.

In testing the welds at the bottom corners of the bulk heads, particular care shall be taken since the bulk heads are normally shaped at these points to clear the longitudinal weld between the bottom and the side walls. The gaps so formed in the corners shall be closed thoroughly, otherwise leaks in one compartment will allow the oil to penetrate into the adjacent compartments.

8.4.3 Air testing of pontoon compartments

If specified by the Principal, after the completion of the floating roof the liquid-tightness of each individual pontoon compartment shall be checked by applying compressed air at a pressure of 7 mbar (ga). To detect the presence of leaks the fillet welds shall be covered with soap suds or similar substance.

8.4.4 Double deck roofs

The pontoon, the lower centre deck and the concentric rings shall be tested for tightness in the same manner as specified for the pontoon of pontoon-type roofs in (8.4.1) and (8.4.2).

8.4.5 Water test

During the hydrostatic test of the tank shell the pontoon compartments and centre deck shall be checked frequently for leaks. To prevent rain water from entering the pontoon compartments and thus negating the value of the test, manhole openings should be kept covered.

A similar tightness check should also be made during the first filling with product, as the roof will immerse deeper in oil than in water.

8.4.6 Roof drains

Drain pipe systems of storm water drain valves shall be tested with water to a pressure of 3.5 bar (ga).

During the flotation test, the roof drain valve shall be kept open and observed for leakage of tank contents into the drain lines.

8.5 REPAIR OF LEAKS

All leaks detected during testing shall be repaired to the satisfaction of the Principal by welding. Upon completion the entire tank shall be tight and free from leaks.

For leaking shell seams, bottom-to-shell welds, annular plate welds and bottom plate welds, the defective area shall be cut out and repaired by welding.

Repairs in shell seams shall be performed with the test water level at least 300 mm below the point being repaired.

8.6 RETESTING

After all defects have been repaired the repaired welds shall be reinspected by the methods previously described in (7).

The tank shall then be retested hydrostatically. In retesting, the controls specified in Appendix 3 may in some cases be unnecessary and shall be agreed with the Principal.

8.7 SAFETY PRECAUTIONS

The following safety precautions shall be taken:

- A product connection shall not be made to any tank for any purpose until the tank is accepted to be filled with product by the Principal.
- Roof manholes shall be open while filling or emptying a fixed roof tank for test purposes, so that the tank is not damaged by excessive vacuum or pressure loading.

8.8 PAINTING

Painting shall be in accordance with DEP 30.48.00.31-Gen., with a paint system approved by the Principal.

The requisition shall state the system required.

9. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to Standard Drawings	DEP 00.00.06.06-Gen.
Painting and coating of new construction projects	DEP 30.48.00.31-Gen.
Standard vertical tanks - Selection, design and fabrication	DEP 34.51.01.31-Gen.

STANDARD DRAWINGS

NOTE: The latest edition of Standard Drawings can be found in DEP 00.00.06.06-Gen.

Welding details	S 51.040
Welding sequences	S 51.041
Typical welding sequences for shell plates	S 51.043

AMERICAN STANDARD

ASME boiler and pressure vessel code:

Section V	-	Nondestructive examination	ASME V
Section IX	-	Qualification standard for welding and brazing procedures, welders, brazers, and welding and brazing operators	ASME IX

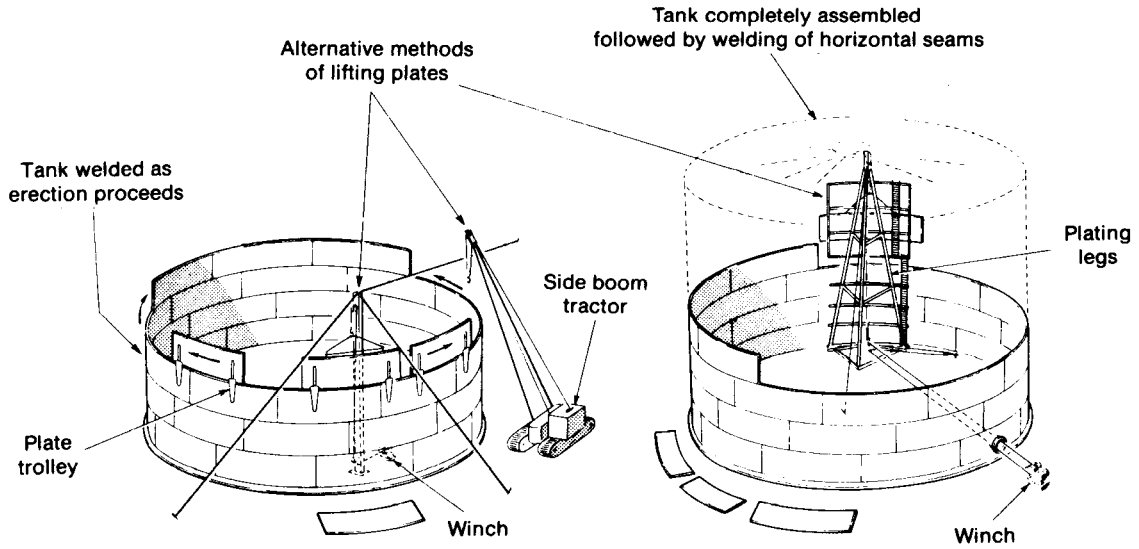
Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017, USA.

BRITISH STANDARD

Vertical steel welded storage tanks with butt welded shells for the petroleum industry — BS 2654

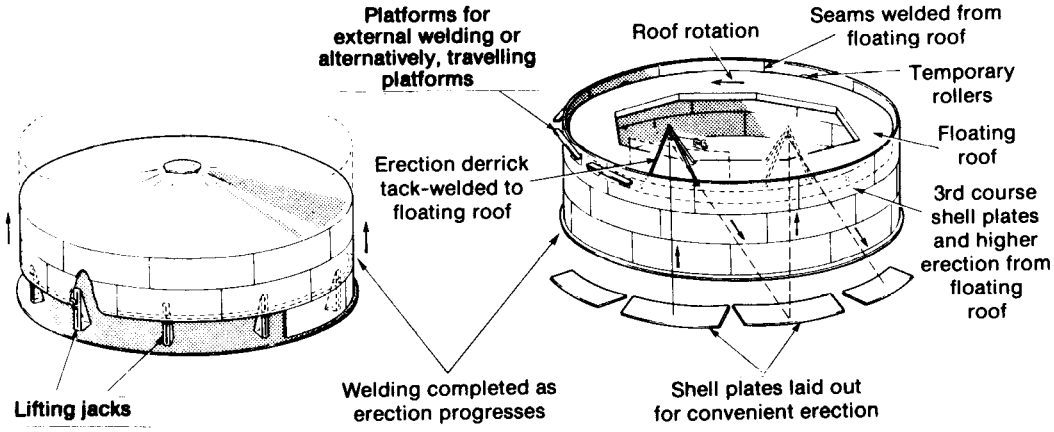
Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
England, United Kingdom.

APPENDIX 1 METHODS OF TANK ERECTION



PROGRESSIVE ASSEMBLY AND WELDING

COMPLETE ASSEMBLY FOLLOWED BY WELDING OF HORIZONTAL SEAMS

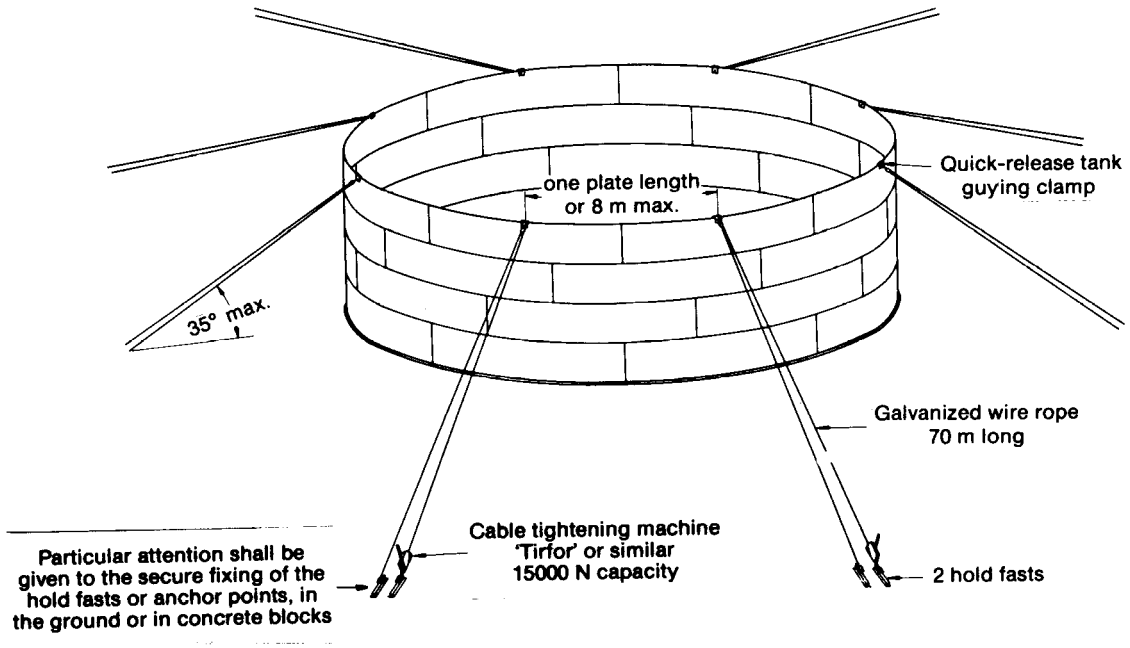


JACKING-UP METHOD

FLOTATION METHOD

Note for all methods:
Vertical seams shall always be completely welded before erection of a following course is started to prevent buckling of tank shell by wind gusts.

APPENDIX 2 RECOMMENDED SYSTEM FOR TANK GUYING



The system of guying shown is recommended for all vertical storage tanks in course of construction and should be installed on the erection of the third course shell plates and progressively moved up to the top edge of the uppermost course of plates as erection proceeds.

12 mm diameter galvanized wire ropes are used to form a double guy approximately 30 m long. This passes through a snatch block attached to the quick-release clamp on the shell plate.

The efficiency of the anchorage is fully developed only when the angle between the guy and ground is not greater than 35°.

The guy rope should be taut and in line with the centre of the tank at the point where it is connected.

TABLE OF DISTANCES TO GIVE ANGLE OF 35° FOR GUY

Height above ground level	Min. distance from tank to anchorage
m	m
3.0	4.6
4.6	6.7
6.1	8.8
7.6	11.2
9.1	13.1
10.7	15.2
12.2	17.7
13.7	19.8
15.2	22.0
16.8	24.0
18.3	26.0

APPENDIX 3 HYDROSTATIC TESTING PROCEDURE

1. GENERAL

The required water quality shall be agreed with the Principal.

Storage tanks placed on clay, silty or sandy subsoil should be filled in four stages. The duration of, and the interval between, the various stages depends on the subsoil conditions and the settlement behaviour during hydrostatic testing.

Soil data and settlement and stability calculations shall be available before the tank is tested.

The settlement behaviour during and after hydrostatic testing shall be monitored.

2. TESTING RATE

In this section, "H" is the final filling height.

Table 1 summarises the required maximum filling rates and monitoring periods between stages.

Stage 1

The tank shall be filled to 0.5 H at a maximum filling rate of '**a**' metres per day. The filling period in any one day shall not be less than 3 hours and shall not be more than 18 hours. At the end of each filling period, for the remaining hours in the day's total of 24 the foundation shall be allowed to equilibrate, consolidate and be monitored.
At the end of stage 1, there shall be a further equilibration and monitoring period of '**X' hours** before the commencement of stage 2.

Stage 2

The tank shall be filled from 0.5 H to 0.67 H at a maximum filling rate of '**b**' metres per day. The filling period in any one day shall not be less than 3 hours and shall not be more than 16 hours. At the end of each filling period, for the remaining hours in the day's total of 24 the foundation shall be allowed to equilibrate, consolidate and be monitored.
At the end of stage 2, there shall be a further equilibration and monitoring period of '**Y' hours** before the commencement of stage 3.

Stage 3

The tank shall be filled from 0.67 H to 0.83 H at a maximum filling rate of '**c**' metres per day. The filling period in any one day shall not be less than 3 hours and shall not be more than 16 hours. At the end of each filling period, for the remaining hours in the day's total of 24 the foundation shall be allowed to equilibrate, consolidate and be monitored.
At the end of stage 3, there shall be a further equilibration and monitoring period of '**Z' hours** before the commencement of stage 4.

Stage 4

The tank shall be filled from 0.83 H to 1.00 H at a maximum filling rate of '**d**' metres per day. The filling period in any one day shall not be less than 3 hours and shall not be more than 14 hours. At the end of each filling period, for the remaining hours in the day's total of 24 the foundation shall be allowed to equilibrate, consolidate and be monitored.
At the end of stage 4, the tank shall be left full and shall be monitored for at least 4 more days.

TABLE 1 Filling rates and Monitoring periods

	Maximum filling rate (m/d)				Monitoring period between stages (hours)		
Subsoil conditions underneath tank pad	Stage 1 (**a**)	Stage 2 (**b**)	Stage 3 (**c**)	Stage 4 (**d**)	**X**	**Y**	**Z**
Soft clay or silt	2	1	0.75	0.5	48	48	48
Stiff clay	2	1.25	0.75	0.5	36	36	48
Clayey, silty sand	2.5	1.25	0.75	0.5	24	36	48
Sand	2.5	1.5	1	0.75	12	12	24
Weathered rock, cemented soil	-	-	-	-	-	12	48
Sound rock	-	-	-	-	-	-	24

3. MEASUREMENT OF TANK BOTTOM PROFILE BEFORE HYDROSTATIC TEST

The tank bottom profile shall be measured and recorded before starting to fill the tank.

4. MEASUREMENT OF SETTLEMENTS DURING TESTING

Measurement of the tank shell settlements should be taken from at least 8 points, evenly spaced around the circumference at a distance of 12 metres maximum. In accordance with the filling rate of at least 3 hours per day, the following daily schedule of measurements shall be applied:

- prior to the filling period;
- just after the filling period;
- 2 hours after the filling period (optional, depending on the results);
- 5 hours after the filling period.

Also during each equilibration period between the various stages, and during the period when the tank is full after completion of stage 4, and during the draining of the tank, three measurements should be taken daily.

NOTE: For sound rock, weathered rock and cemented soil, the measurements may be limited to:
(i) prior to hydrostatic testing,
(ii) monitoring period (Z) between stages 3 and 4, and
(iii) end of stage 4.

5. SETTLEMENT BEHAVIOUR DURING TESTING

The measured daily settlement rate during the equilibration and monitoring periods X, Y and Z, and during the period when the tank is full (i.e. after completion of stage 4) shall diminish with time (i.e. the settlement rate after the second stage shall be less than that after the first stage).

If settlement rates do not diminish, the tank shall be emptied until settlement stops, and a geotechnical engineer shall be consulted.

6. EMPTYING OF THE TANK AFTER THE HYDROSTATIC TEST

Before the test water is pumped or drained from the tank, adequate measures shall be taken to avoid a vacuum condition inside the tank. For fixed roof tanks, all roof vents and manholes shall be open. For floating roof tanks, check the roof bleeder vents at the floating roof. Special care should be taken if the test water is drained by gravity.

7. MEASUREMENT OF TANK BOTTOM PROFILE AFTER THE HYDROSTATIC TEST

After the test, about 25 cm of water should be left inside the tank to ensure that tank bottom is in contact with its foundation profile.

The tank bottom profile shall then be measured. The measured values shall be verified against the settlement predictions and recorded in the tank maintenance file.

The results may require corrective action to be taken as follows, which shall be recorded in the tank maintenance file.

a) Fixed and Floating Roof Tanks

Jacking and relevelling the foundation in case of local settlement and/or tilting.

b) Floating Roof Tanks

Correction of roof support leg lengths.

8. FILLING RATE (PRODUCTS) AFTER HYDROSTATIC TESTING

In the event of poor settlement results during hydrostatic testing, a geotechnical/foundation engineer shall be consulted prior to the first operational filling. The Principal may require some limitations in the filling rate for the first few operational fillings.