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Full document details: BS 2654-3:1968

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BRITISH STANDARD 2654: Part 3: 1968
UDC 665.6:621.642.3-111.1:669.14:621.791.052.6

SPECIFICATION FOR

VERTICAL STEEL WELDED STORAGE TANKS

WITH BUTT-WELDED SHELLS

FOR THE PETROLEUM INDUSTRY

PART 3

HIGHER DESIGN STRESSES

(supplementary requirements)

BRITISH STANDARDS INSTITUTION

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Price 15/– net

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THIS BRITISH STANDARD, having been approved by the Petroleum Equipment Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 23 September 1968.

SBN: 580 00341 8

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 4000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price 15s. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 15. Mild steel for general structural purposes.
BS 427. Method for Vickers hardness test.
BS 968. High yield stress (welding quality) structural steel.
BS 1501/6. Steels for use in the chemical, petroleum and allied industries.
BS 1515. Fusion welded pressure vessels for use in the chemical, petroleum and allied industries.
BS 2600. General recommendations for the radiographic examination of fusion welded butt joints in steel.
BS 2654. Vertical steel welded storage tanks with butt welded shells for the petroleum industry.
Part 1. Design and fabrication.
Part 2. Site erection, inspection and testing.
BS 2762. Notch ductile steel for general engineering purposes.
BS 3706. Mild steel for general engineering purposes.
BS 4360. Weldable structural steels.
CP3. Code of basic data for the design of buildings, Chapter V. Wind loads.

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

CO-OPERATING ORGANIZATIONS

The Petroleum Equipment Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government department and scientific and industrial organizations:

*British Steel Industry
*Council of British Manufacturers of Petroleum Equipment
Federation of British Rubber and Allied Manufacturers
*Gas Council
Ministry of Power
*Oil Companies' Materials Association

The scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

British Chemical Plant Manufacturers' Association
Chemical Industries Association
Engineering Equipment Users' Association
Institution of Chemical Engineers
Institution of Gas Engineers
Tank and Industrial Plant Association
Welding Institute

The following BSI references relate to the work on this standard:
Committee reference PEE/12. Draft for comment 66/26241.

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BRITISH STANDARD SPECIFICATION FOR

VERTICAL STEEL WELDED STORAGE TANKS, WITH BUTT-WELDED SHELLS, FOR THE PETROLEUM INDUSTRY

Part 3. Higher design stresses (supplementary requirements)

FOREWORD

This part of this British Standard, prepared under the authority of the Petroleum Equipment Industry Standards Committee, provides a design basis for oil storage tanks with design stresses beyond the scope of Part 1, and for oil storage tanks where higher strength steels are used for the shells.

Part 3 of this standard is further appropriate to very large tanks not previously provided for by Part 1 of this standard, in addition to the range of tanks already in common use.

Part 3 of this standard is applicable only when specified by the purchaser.

SPECIFICATION

1. SCOPE

The purpose of this part of this British Standard is to permit the use of higher design stresses in calculating the thickness of the shell. These stresses are based upon the use of notch ductile steels with guaranteed minimum yield strengths, as defined in BS 4360*. The notch ductility and composition requirements are modified and amplified by the provisions of Clause 3.

It is acceptable for some courses of the shell to be designed in accordance with Part 1 of this standard when other courses are designed in accordance with Part 3, except that in such a case the welds joining the two parts shall meet the requirements of Part 3, and furthermore the requirements of Clause 5 shall be met (i.e. no course shall be constructed at a thickness less than the thickness of the course above).

The application of this standard is limited to a minimum design metal temperature of −10°C (see also Clause 2). Shells designed on this basis shall incorporate all the provisions of this part of the standard. All the requirements of BS 2654 Parts 1 and 2† shall apply unless modified or amplified by the requirements of Part 3.

2. DESIGN INFORMATION REQUIRED

In addition to the requirements listed in Appendix B of Part 1, where appropriate, the purchaser shall state the minimum and maximum design metal temperatures, the conditions for the hydrostatic test (see Fig. 1), the specific gravity of the liquid to be stored, corrosion allowance, if required, and the nature and magnitude of any additional external forces (see 8.6). Unless otherwise specified the minimum design metal temperature shall be assumed to be the lowest one day mean ambient temperature in the locality where the tank is to be installed, plus 10 degC, or the minimum temperature of the contents, whichever is the lower. It is recommended that, for storage tanks constructed for service in the United Kingdom, where the shell temperature is controlled by the ambient conditions, the minimum design metal temperature shall not exceed 0°C.

*BS 4360, 'Weldable structural steels'. See Appendix A.

†BS 2654, 'Vertical steel welded storage tanks, with butt-welded shells, for the petroleum industry', Part 1, 'Design and fabrication'. Part, 2 'Site erection, inspection and testing'.

3. MATERIALS

3.1 Specifications. All materials used in the manufacture of storage tanks in accordance with Part 3 of this standard shall be in accordance with the appropriate specifications listed except as modified or amplified by the provisions of this standard. This shall not preclude the use of otherwise suitable material where so agreed between purchaser and manufacturer.

Roof plates Bottom plates Rolled sections	See Clause 6 of BS 2654: Part 1: 1965*
Shell plates	BS 4360, and the additional requirements of 3.2 to 3.7 inclusive.
Annular plates	See Clause 4

3.2 Steelmaking processes. Steels shall be made by the open hearth, electric furnace or top oxygen blown process. Bessemer steels shall not be used. Semi-killed or fully-killed steel may be used provided that all the requirements of this standard are met. Rimming steel shall not be used.

3.3 Chemical composition. For plates thicker than ¾ inch the carbon equivalent calculated from the ladle analysis using the formula:

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

shall not exceed 0·43%, and by check analysis using the formula: $C + \frac{Mn}{6}$ shall not exceed 0·43%.

For steels stronger than grade Fe 44 the phosphorus plus the sulphur shall not exceed 0·08%.

The nitrogen content shall not exceed 0·01% except that for non-ageing steels the maximum nitrogen content may, by agreement between purchaser and manufacturer, be increased to 0·02%.

*BS 2654, 'Vertical steel welded storage tanks, with butt-welded shells, for the petroleum industry', Part 1, 'Design and fabrication'.

3.4 Notch ductility. The selection of materials for shell and bottom annular plates shall take into account the requirements of 3.4.1 to 3.4.4 together with Fig. 1 and its notes.

3.4.1 Plates weaker than or equal to grade Fe 44, ½ inch thick and thicker. These plates shall be impact tested and show not less than 20 ft lb Charpy-V at +20°C or at the test temperature indicated in Fig. 1, whichever is the lower. Plates with a specified minimum yield strength not exceeding 30 kg/mm² and less than ¾ in thick need not be tested if the design metal temperature is +10°C or above.

3.4.2 Plates stronger than grade Fe 44 up to and including Fe 52, ½ inch thick and thicker. These plates shall be impact tested and show not less than 30 ft lb Charpy V at −5°C or at the test temperature indicated in Fig. 1, whichever is the lower.

3.4.3 Plates stronger than grade Fe 52, all thicknesses. These plates shall be impact tested and show not less than 30 ft lb Charpy-V at −15°C or at the test temperature indicated in Fig. 1, whichever is the lower.

3.4.4 Reinforcing plates. The notch ductility requirements for reinforcing plates shall be determined by reference to their maximum thickness. If such plates exceed 1½ in thick they shall show not less than 20 ft lb CV at −50°C, irrespective of the minimum design metal temperature.

3.5 Other requirements. It is recommended that, when purchasing steel for this application, reference is made to the appropriate national steel standard, for the purpose of specifying additional requirements not included herein, e.g., dimensional tolerances, etc.

3.6 Information to be provided by the steelmaker. The steelmaker shall state the condition of supply of all plates, e.g. as rolled, normalized, quenched and tempered, etc. and the normal composition of the steel.

The ladle analysis for each cast shall be reported with values for all products specified in 3.3 and for any deliberate additions e.g. aluminium, niobium, boron, vanadium, etc.

3.7 Information to be provided by the steel purchaser. The purchaser of the steel shall specify in his order to the steelmaker that the plates are to meet the requirements of BS 2654 Part 3.

4. BOTTOM DESIGN: ANNULAR PLATES

The minimum thickness of annular plates shall be in accordance with Clause 11 in Section Three of Part 1 of this standard, it being assumed that the materials of the annular plates and bottom course of shell plating are to the same material specification. However, if these parts are chosen of differing specifications then the thickness of annular plating should be determined by these rules using an equivalent bottom course of shell plating of the same material specification as the annular plating. If this computation results in an equivalent shell thickness greater than 1½ in then the annular plate shall be of the same material as the bottom course of shell plate material.

5. SHELL DESIGN

The requirements of this clause supersede those of Clause 14*b* in Part 1 of this standard.

The following formulae shall be used in calculating the minimum thickness of shell plates, the joint efficiency factor E being taken as 1·00 providing all the rules of this standard are applied, and that the strength of the weld is shown to exceed that of the plate (see Part 2, Section Six, Clause 32) otherwise the joint efficiency factor E shall be 0·85.

$$t = \frac{2{\cdot}6\,D\,(H-1)}{S\,E}$$

except that, when any course is made from material having a lower yield strength than the material in the lower adjacent course, then the thickness of the upper course shall be calculated using the modified formula $t = \frac{2{\cdot}6\,D\,H}{S\,E}$, and furthermore no course shall be constructed at a thickness less than that of the course above, irrespective of the materials of construction.

When a tank is to contain a liquid with a specific gravity greater than 1·00 the thickness t obtained from the formula shall be multiplied by the specific gravity.

The following symbols have been used in the above design formulae:

t = Calculated min. thickness (in), not to exceed 1½ in.

H = Height from bottom of course under consideration to top of roof curb angle (ft).

D = Tank diameter (ft).

E = Joint efficiency factor.

S = Course design stress, being the lower of 37 500 or ⅔ of the material minimum yield strength at room temperature for all tank courses (lbf/in²). Where the operating temperature is over 150°C, consideration shall be given to the effect of that temperature on the yield strength.

Where tanks are designed to contain corrosive products or for any other reason a corrosion allowance is required, the amount of this allowance shall be specified by the purchaser and all calculations to determine plate thicknesses and shell stiffening requirements under the action of wind and/or internal vacuum conditions shall exclude this corrosion allowance.

6. SHELL JOINTS (HORIZONTAL)

All horizontal seams for a distance of 6 inches at either side of each vertical seam (T-junctions), shall have full penetration and complete fusion.

The procedure used for welding portions of the girth seams between the T-junctions, shall be that qualified (see 10.3). However, it is recognized that in practice, continuous full penetration may not always be achieved between T-junctions. This need not necessarily be cause for rejection, provided that the lack of full penetration is intermittent, longitudinal in nature, and does not exceed approximately 10% of the thickness of the thicker plate joined.

Some discretion is recommended against rigorous rectification of lack of penetration, since repair welds may introduce possible hazards greater than the original defect.

7. WIND GIRDERS

7.1 Open top tanks shall be provided with a primary stiffening ring to maintain roundness when the tank is subjected to wind loads. This primary ring shall be located at or near the top of the top course, and preferably on the outside of the tank shell.

7.2 Self-supporting fixed roof tanks with roof structure are considered to be adequately stiffened at the top of the shell by the structure, and a primary ring is not therefore considered necessary.

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