BRITISH STANDARD

BS 7777-4: 1993

Flat-bottomed, vertical, cylindrical storage tanks for low temperature service —

Part 4: Specification for the design and construction of single containment tanks for the storage of liquid oxygen, liquid nitrogen or liquid argon

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Pressure Vessel Standards Policy Committee (PVE/-) to Technical Committee PVE/15, upon which the following bodies were represented:

British Chemical Engineering Contractors' Association
British Compressed Gases Association
British Gas plc
Concrete Society
Energy Industries Council
Engineering Equipment and Materials Users' Association
Institution of Gas Engineers
Institution of Mechanical Engineers
Process Plant Association
Thermal Insulations Contractors' Association
Welding Institute

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The following BSI references relate to the work on this standard:
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Contents

Foreword

This Part of BS 7777 has been prepared under the direction of the Pressure Vessels Standards Policy Committee.

Flat-bottomed, vertical, cylindrical storage tanks for liquid oxygen, liquid nitrogen or liquid argon have traditionally been of the double wall, single containment type where the liquid is contained in an inner tank, and an outer container serves mainly to contain the insulation.

These tanks were built in accordance with the following British Standard:

BS 5387:1976, *Specification for vertical cylindrical welded storage tanks for low-temperature service: double-wall tanks for temperatures down to – 196 °C.*

It is still the practice to store liquid oxygen, liquid nitrogen or liquid argon in single containment tanks. This is due to the combination of stored fluid properties, tank size and properties of the materials of construction. It has been decided to revise BS 5387 and rationalize it within BS 7777. This Part of BS 7777, together with BS 7777-1 to BS 7777-3, supersedes BS 5387:1976 which is withdrawn.

This Part covers only single containment, flat-bottomed, cylindrical, stand-alone storage tanks, but is not intended to exclude the use of other storage concepts and designs which have been proven in service.

This British Standard comprises four Parts:

— *Part 1: Guide to the general provisions applying for design, construction, installation and operation;*

— *Part 2: Specification for the design and construction of single, double and full containment metal tanks for the storage of liquefied gas at temperatures down to – 165 °C;*

— *Part 3: Recommendations for the design and construction of prestressed and reinforced concrete tanks and tank foundations, and for the design and installation of tank insulation, tank liners and tank coatings;*

— *Part 4: Specification for the design and construction of single containment tanks for the storage of liquid oxygen, liquid nitrogen or liquid argon.*

NOTE This standard has been written in the form of a practice specification (see clause **6** of PD 6501-1:1982).

To comply with this specification, the user has to comply with all of its requirements. The user may responsibly depart from the recommendations, but would be expected to have good reasons for doing so.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 10, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This Part of BS 7777 specifies requirements for metallic single containment cryogenic tanks for the storage of liquid oxygen, liquid nitrogen or liquid argon, all with an inner tank design temperature of – 196 °C and, operating in the range – 180 °C to – 196 °C.

In addition to the definitive requirements, this standard also requires the items detailed in clause **5** to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisified.

NOTE Where it is not possible to specify requirements which can be verified, but it is considered that the information available requires consideration, commentary and recommendations are added to the text.

2 References

2.1 Normative references

This Part of BS 7777 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this Part of BS 7777 only when incorporated in it by amendment or revision.

2.2 Informative references

This Part of BS 7777 refers to publications that provide information or guidance. The editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 7777, the definitions give in clause **3** of BS 7777-1:1993 apply.

4 Design conditions

Unless otherwise specified in this Part of BS 7777, the tanks shall be designed, fabricated, erected, inspected and tested in accordance with the referenced sections of BS 7777-1, BS 7777-2 and BS 7777-3.

All tanks shall be of the double wall single containment type (see Figures 1c and 1d of BS 7777-1:1993). The outer container shall not be required to hold any liquid resulting from spillage from the inner tank or pipework.

In the case of fixed roof inner tanks, the outer container shall retain the insulation and the purge gas.

In the case of tanks with suspended deck inner roofs, the outer container shall retain the insulation and the product vapour.

A suspended deck tank shall not be used for the storage of oxygen.

Submerged pumps shall not be used in oxygen storage tanks.

Tanks shall be designed to suit the pressure required in service. Tanks without any size restriction shall be designed for internal positive pressures not exceeding 140 mbar[1)] (gauge) and internal negative pressure not exceeding 6 mbar (gauge).

For internal pressures between 140 mbar (gauge) and 345 mbar (gauge) the maximum inner tank diameter shall be 20 m.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE **4**.

Due to the product purity requirements, inner tanks should generally be of the fixed roof type. In exceptional circumstances and with the purchaser's prior agreement a suspended deck inner roof may be considered for the storage of argon or nitrogen.

The outer container should be designed for ambient temperature conditions as an envelope to retain the insulation and an inert purge gas, or in the case of a suspended deck inner roof for nitrogen or argon storage, product vapour, and to prevent at all times the ingress of airborne moisture.

The single containment tank may be surrounded by a low bund wall. The requirement for a bund wall should be determined by local conditions and plant layout.

The overall storage installation should be in accordance with industrial practice (see British Compressed Gases Association CP 20 [1] and CP 22 [2]).

For inner tanks with diameters less than 20 m, *internal pressures up to* 500 mbar *may be used subject to agreement between the purchaser and the contractor.*

[1)] 1 mbar = 10^3 bar = 100 N/m^2 = 100 Pa.

5 Information to be exchanged between the purchaser and the contractor

5.1 Information to be supplied by the purchaser

The following information to be supplied by the purchaser shall be fully documented. Both the definitive requirements specified throughout the standard and the following documented items shall be satisfied before a claim of compliance with the standard can be made and verified:

a) the geographical location of the tank;

b) the diameter and height, or the usable capacity, of the inner tank, including ullage in cold conditions;

c) all relevant properties of the contained fluid, including the specific gravity and permissible boil-off;

d) the design internal positive pressure and internal negative pressure conditions for both the inner tank and outer container;

e) the number of thermal cycles and their magnitude for the evaluation of insulation compaction;

f) the minimum and maximum design temperatures for the outer container and the maximum design temperature for the inner tank;

g) the size, number, type and location of all mountings required (see note);

h) details of flanges for connecting pipework;

i) details of painting and surface preparation;

j) the maximum filling and emptying rates;

k) the quality of water to be used for the hydrostatic test;

l) other specifications to be read in conjunction with this standard;

m) the number of pressure cycles and their magnitudes;

n) the wind design condition if more onerous than that specified in **7.2.3**;

o) seismic loads;

p) cleanliness requirements for all liquids (see clause **12**);

q) additional safety requirements when extra thick plate is required (see **6.3**).

NOTE Attention is drawn to the desirability of minimizing the number of connections required into the bottom courses of the inner tank shell and the inner tank floor.

5.2 Information and requirements to be agreed and to be documented

The following items to be agreed between the contracting parties, which are specified in the clauses referred to, shall be fully documented. Both the definitive requirements specified throughout the standard and the following documented items shall be satisifed before a claim of compliance with the standard can be made and verified:

a) the nature and magnitude of significant loads or moments applied to the tank shell or roof from piping, valves, or other aspects including tank and pipe support settlement (see **7.2.3** and **7.2.4**);

b) the roof slope for a conical roof or the radius of curvature for a dome roof (see notes 1 and 2; see also **6.8.3** and **7.3.3**);

c) the purlin spacing (see **7.1.5.3** of BS 7777-2:1993);

d) the materials to be used in the manufacture of the inner tank (see **6.3**);

e) the requirements for stop valves at the inlet of the relief valves (see **8.2** of BS 7777-1:1993);

f) the requirements for flange design, if different from those specified in BS 1560-3.1:1989 (see **6.9.6**);

g) the relief system design and relieving capacity (see clause **15**);

h) the method for the protection of the shell against wind damage during erection (see clause **9**);

i) the welding processes to be used (see clauses **8** and **9**);

j) additional welding tests required (see **11.11.1** of BS 7777-2:1993).

k) the sequence in which the joints are to be welded (see **11.11.2** of BS 7777-2:1993);

l) the type of inner tank roof to be used (see **6.8.3**);

m) whether production weld test plates are required (see clause **9**);

n) when flexible loops in the interconnecting pipework are not required (see **6.12**);

o) the test procedure (see **11.4**);

p) the positioning of flange joints in the annular space (see **6.12**);

q) the loads imposed on the outer container for pipes and valves (see **7.2.3**).

NOTE 1 The roof slope for a conical roof is normally 1 in 5.
NOTE 2 The radius of curvature for a domed roof is normally 0.8 to 1.5 times the diameter of the tank.

6 Inner tank

6.1 Materials

Type V or type VI steel in accordance with **6.1** of BS 7777-2:1993 or aluminium in accordance with Annex C of BS 7777-2:1993 shall be used.

Impact test requirements for a 9 % nickel steel shall be as given in Table 3 of BS 7777-2:1993.

6.2 Plate and fittings

All plate shall conform to **6.1** and to the test requirements of BS EN 10028-1:1993, BS 1501-2:1988 or BS 1501-3:1990.

Other product forms shall conform to this Part of BS 7777 and to the general and testing requirements of the following standards:

a) for forgings, BS 1503:1989;

b) for piping, BS 3603:1991, BS 3605-1:1991 and BS 3605-2:1992.

6.3 Shell plate thickness

The maximum shell plate thickness shall be in accordance with Table 1.

Table 1 — Maximum shell plate thickness

Material	Maximum shell thickness mm
9 % nickel steel	15
Austenitic stainless steel	15
Aluminium magnesium alloy	30

When material thicknesses are required in excess of those values specified in Table 1, additional requirements, such as more stringent Charpy V-notch test requirements and chemical analysis constraints to maintain the same level of safety, shall be agreed between purchaser and contractor (see **5.2**).

For 9 % nickel steel tanks, the measured thickness at any point 15 mm from the edge of any steel shell, bottom, roof or annular plate shall be not less than the specified thickness less half of the total tolerance given in Table 4 of BS 4360:1990.

COMMENTARY AND RECOMMENDATIONS ON **6.3**. *Local thinning due to rolled-in scattered scale remote from the plate edge on the surface of* 9 % *nickel steel should not be regarded as deleterious provided that the measured thickness is not less than approximately* 90 % *of the calculated thickness of the plate. This is permissible only when design thicknesses are based on weld metal strengths, and not on the plate material strength, which is normally greater.*

6.4 Weld metal

High nickel austenitic weld metal for 9 % nickel steel components shall be subject to Charpy V-notch testing in accordance with BS EN 10045-1:1990 in weld procedure tests.

For the weld procedure test on the weld metal, the average energy value for three specimens shall be not less than 35 J, and no single value shall be less than 75 % of the specified value, at a test temperature of – 196 °C.

Austenitic stainless steel and aluminium shall not be subject to impact tests.

COMMENTARY AND RECOMMENDATIONS ON **6.4**. *For weld metal composition which is the same as* 9 % *nickel plate, additional specialist advice should be obtained.*

If production weld test plates are specified by the purchaser the average energy value for three specimens should be not less than 27 J*, and no single value should be less than* 20 J*, at a test temperature of* – 196 °C.

6.5 Bolting materials

Bolting exposed to atmospheric conditions shall be manufactured from austenitic stainless steel in accordance with BS 1506:1990.

Bolting in the space between the inner tank and outer container shall be manufactured from austenitic stainless steel in accordance with BS 1506:1990, or aluminium alloy in accordance with Table C.1 of BS 7777-2:1993.

NOTE Both stainless steel bolts and aluminium bolts can be used to join stainless steel to aluminium or aluminium to aluminium.

COMMENTARY AND RECOMMENDATIONS ON **6.5**. *Reference should be made to* ***6.1.4*** *of BS 7777-2:1993.*

6.6 Mountings

Permanent attachments, insert plates, nozzle bodies and flanges shall conform to **6.1**.

For 9 % nickel steel nozzles, the distance between the shell or reinforcing pad and any other austenitic stainless steel butt welded pipe or flange shall be

$$d = \sqrt{(rt)}$$

where

d is the distance between the shell or reinforcing pad and the pipe or flange;

r is the radius of the nozzle;

t is the thickness of the nozzle.

COMMENTARY AND RECOMMENDATION ON **6.6**. *Similar alloys of different strengths can be welded together, provided that allowance is made in the design.*

6.7 Loadings

6.7.1 *General*

The inner tank shall be designed to contain the product at a design temperature of – 196 °C.

The tank shall be designed for the most severe combination of the loads specified in **6.7.2** to **6.7.5**.

6.7.2 *Bottom loads*

The tank bottom shall be designed to withstand the total superimposed loads due to the product, the inner tank shell weight and the inner tank roof and its insulation weight, as applicable.

6.7.3 *Shell loads*

The shell shall be designed to withstand the following loads:

a) the weight of the product;

b) the internal vapour pressure, unless the pressure between inner and outer tanks is equalized (e.g. when suspended roof designs are used);

c) the external purge gas pressure, when applicable;

d) the design internal negative pressure, except as provided for in item b);

e) the insulation weight;

f) the insulation pressure (where applicable);

g) loads from the roof;

h) loads imposed by the interconnecting piping between the inner tank and outer container shells;

i) thermal loading;

j) loadings during the hydrostatic test.

6.7.4 *Roof loads*

The roof shall be designed to withstand the most severe combination of the following loads:

a) the weight of the roof and supporting structure;

b) the loads from equipment, connections, etc.;

c) the insulation weight;

d) the internal gas pressure (not applicable to suspended roofs);

e) the design internal negative pressure (not applicable to suspended roofs);

f) the loads imposed during construction and maintenance.

NOTE Loads imposed during construction and maintenance need not be taken in combination with item d) or item e).

6.7.5 *Seismic loads*

Seismic loads shall be considered using the analysis method in accordance with the Annex B of BS 7777-1:1993.

6.8 Tank design

6.8.1 *Bottom design*

The bottom design shall be in accordance with **7.2.3** of BS 7777-2:1993, except that the minimum thickness of bottom plates shall be 5 mm.

6.8.2 *Shell design*

The shell design shall be in accordance with **7.2.4** of BS 7777-2:1993, with the following exceptions.

a) The nominal thickness of shell plates shall be not less than that specified in Table 2, and the maximum material thickness shall be in accordance with **6.3**.

b) All vertical and horizontal seams shall have butt joints with full penetration welds.

Table 2 — Nominal shell thickness

Tank diameter d m	Nominal shell thickness t mm
$d \leq 15$	$t \geq 5$
$15 < d \leq 30$	$t \geq 6$

6.8.3 *Roof design*

The roof design shall be in accordance with **7.2.5** of BS 7777-2:1993 with the following exceptions.

a) For suspended roofs, the only acceptance materials shall be 9 % nickel steel, stainless steel or aluminium alloy.

b) For oxygen service, all overlapping features or crevices that cannot be decontaminated shall be seal welded to prevent any hazard due to contact between oxygen and incompatible contaminents.

NOTE Special attention should be paid to backing bars, plate laps, and supporting structure-to-roof and roof-to-shell connections.

c) The design shall preclude submergence of sealed spaces by cryogenic liquid.

6.9 Nozzle and access opening design

6.9.1 *Shell openings*

Connections to the inner shell shall be kept to a minimum but, where used, connections of 50 mm diameter and above shall be provided with internal shut-off valves.

Shell manholes and shell nozzles shall be in accordance with **7.2.7.2** of BS 7777-2:1993.

6.9.2 *Roof openings*

Roof openings shall be in accordance with **7.2.7.3** of BS 7777-2:1993.

6.9.3 *Bottom openings*

Connections to the inner tank bottom shall be kept to a minimum but, where used, connections of 50 mm diameter and above shall be provided with internal shut-off valves.

COMMENTARY AND RECOMMENDATIONS ON **6.9.3**. *The design of bottom openings should take the following into account.*

a) The entry into the tank should be as close to the shell as possible, but not within the annular plate.

b) The nozzle opening should be reinforced on a replacement of area basis by a double plate or thickened sketch plate.

c) The design should impose negligible bending moment on the inner tank bottom under all conditions of operation, with particular reference to the differential contraction of the inner tank relative to the outer container.

d) In service, the pipe should always be full of product.

e) The assembly should be designed to be prefabricated into the plate and subject to final inspection and testing prior to laying on the base insulation.

f) The unsupported area under the nozzle should be kept to a minimum and the surrounding insulation designed for the higher load imposed on it, and should also be capable of withstanding any tendency to damage at the edges of the hole.

g) The space surrounding the nozzle and pipe should be filled with suitable insulating material sufficient to enable the other requirements of this standard, such as design metal temperature and local heat insulation characteristics, to be met.

h) The nozzle pipe should turn from the vertical to the horizontal within the base insulation and have an exit from the shell of the outer container.

i) Consideration should be given to anti-vortex protection.

j) Where the inner tank has a fixed roof, the outlets should be designed such that under normal operating conditions sufficient liquid remains in the tank to provide pressure on the bottom plates to balance the interspace purge pressure.

6.9.4 *Nozzle welding details*

Weld details for nozzles shall be in accordance with **7.1.6.6** of BS 7777-2:1993, except that welds attaching the nozzles to the tank shell, bottom or roof shall be full penetration welds. Set-on nozzles shall not be used for nozzle to shell or nozzle to bottom connections.

6.9.5 *Inspection of mountings*

Mountings shall be inspected in accordance with **7.2.7.6** of BS 7777-2:1993.

6.9.6 *Flanges*

All flanges on nozzles or manholes shall be made and drilled in accordance with class 150 of BS 1560-3.1:1989.

COMMENTARY AND RECOMMENDATIONS ON **6.9.6**. *The design of the bolting system should take into account the low temperature conditions. Consideration should be given to differential contraction between bolts and flange, transient operating conditions and electrolytic corrosion (see **6.5**).*

*Alternative flange designs may be used subject to agreement between purchaser and contractor (see **5.2**).*

6.10 Permanent attachments other than manholes and nozzles

Permanent attachments other than manholes and nozzles shall be in accordance with **7.2.7.8** of BS 7777-2:1993.

6.11 Temporary attachments

Temporary attachments shall be in accordance with **7.2.7.9** of BS 7777-2:1993.

6.12 Interconnecting mountings (pipework)

Interconnecting mountings shall be in accordance with **7.2.8** of BS 7777-2:1993 with the following exceptions.

a) Unless otherwise agreed between the purchaser and contractors, connections with flexible loops shall be used (see **5.2**).

b) Flanges shall not be located in the annular space below the liquid level.

NOTE Flange joints may be situated above the liquid level, such as in the pressure relief valve lines, with prior approval by the purchaser (see **5.2**).

c) Piping of 200 mm nominal diameter or smaller which enters the tank below the liquid level shall be manufactured from seamless pipe.

d) The material for interconnecting pipework shall be selected in accordance with **6.2**.

6.13 Tank anchorage

Tank anchorage shall be in accordance with **7.2.9** of BS 7777-2:1993.

7 Outer container

7.1 Materials

Materials for the outer container shall be selected in accordance with **6.2.2** of BS 7777-2:1993.

7.2 Loadings

7.2.1 *General*

The outer container shall be designed to contain the insulation surrounding the inner tank and either the inert purge gas or, in the case of suspended roof designs, vaporized product.

The outer container shall not contain liquid.

The outer container shall be designed for the most severe possible combination of the loads specified in **7.2.2** to **7.2.5**.

COMMENTARY AND RECOMMENDATIONS ON **7.2.1**. *For the outer container it is important to consider all possible loads at the design stage, in view of the fact that the shell thickness may be less than that required for a similar tank designed to contain a liquid.*

7.2.2 *Bottom loads*

The outer container bottom shall be designed to withstand the total superimposed loads due to the product, the inner tank weight, the outer tank weight and the insulation weight that are transferred directly to the foundations where the bottom is acting as a fully supported membrane.

7.2.3 *Shell loads*

The shell shall be designed to withstand the following loads:

a) wind loads: the wind speed used in the calculations shall be the maximum gust estimated to be exceeded on the average only once in 50 years; in the United Kingdom this value shall be taken as design wind speed as defined in CP 3:Chapter V-2:1972;

b) the design pressure;

c) the design internal negative pressure;

d) the insulation weight;

e) the insulation pressure;

f) the weight of the shell above the point under consideration (temporary and/or permanent);

g) roof loads (see **7.2.4**);

h) loads or moments applied to the container shell by pipes, valves and other items connected to the outer container shell;

i) external impact loads (if applicable).

COMMENTARY AND RECOMMENDATIONS ON **7.2.3**. *With regard to windspeed, the value outside the United Kingdom should be obtained from the appropriate local authority.*

Where loads from pipes and valves on the outer container shell are unavoidable, the purchaser should advise the manufacturer of their nature and magnitude. The design should therefore be a matter for agreement between the purchaser and manufacturer. Settlement of the foundations should also be taken into consideration.

7.2.4 *Roof loads*

The design of the outer container roof shall take into account the worst possible combination of the following loads:

a) the weight of the roof and supporting structure;

b) the weight of accessories, e.g. pipes, valves, platforms, walkways and hand-rails;

c) the suspended deck weight (where applicable) including the weight of insulation and support structure;

d) the uniformly distributed load of 1.2 kN/m^2 over the projected fixed roof area; this includes snow load and internal negative pressure;

e) A concentrated load of 5 kN over a square area of 300 mm × 300 mm placed at any location; this shall not be combined with load d).

f) a uniformly distributed load of 2.4 kN/m^2 acting on the roof platforms and access ways;

g) a uniformly distributed load of 1 kN/m^2 on the suspended deck during erection and maintenance;

h) the design pressure;

i) the wind loads (see **7.2.3**);

j) the load imposed by external or internal connections.

COMMENTARY AND RECOMMENDATIONS ON **7.2.4**. *It should be noted that heavy asymmetric roof loads may have an influence on the choice of roof design. They should therefore be identified at an early stage.*

7.2.5 *Seismic loads*

Seismic loads shall be considered using the analysis method in accordance with Annex B of BS 7777-1:1993.

7.3 Design

7.3.1 *Bottom design*

The bottom design shall be in accordance with **7.1.3** of BS 7777-2:1993.

7.3.2 *Shell design*

The shell design shall be in accordance with **7.1.4** of BS 7777-2:1993.

Shell thickness shall be calculated in accordance with **7.1.4.2** of BS 7777-2:1993, using the loadings specified in **7.2.3**.

The shell stiffeners for wind and vacuum design shall be in accordance with **7.1.4.3** of BS 7777-2:1993.

The outer container shell plate arrangement shall be in accordance with **7.1.4.4** of BS 7777-2:1993.

The other container shell joints shall be in accordance with **7.1.4.5** of BS 7777-2:1993.

7.3.3 *Roof design*

The roof design shall be in accordance with **7.1.5** of BS 7777-2:1993, using the loadings specified in **7.2.4**.

7.4 Mountings

Mountings shall be in accordance with **7.1.6** of BS 7777-2:1993 with the following exceptions.

a) The radiography and crack detection requirements of **7.1.6.7** of BS 7777-2:1993 are not required provided that a visual inspection shall be undertaken and all joints are leak tested by the vacuum box method or soap solution during the pressure test.

b) In **7.1.6.2** of BS 7777-2:1993, t shall be taken as the calculated plate thickness.

c) When the inner tank has a fixed roof and the outer container is only subject to the purge gas pressure, radiography or crack detection is not required.

7.5 Stairways, gangways, platforms and ladders

Stairways, gangways, platforms and ladders shall be in accordance with **7.1.6.9** to **7.1.6.12** of BS 7777-2:1993.

NOTE Caged ladders are permitted for roof access.

Platforms shall be provided to all appliances above ground level to give access for operation and maintenance.

Ladders rising 2.5 m or more from the ground, and all other ladders in elevated positions, shall be provided with self-closing safety gates.

7.6 Anchorage

Anchorage shall be in accordance with **7.2.9** of BS 7777-2:1993.

8 Shop fabrication

Shop fabrication shall be in accordance with clause **10** of BS 7777-2:1993.

9 Site erection

Site erection shall be in accordance with clause **11** of BS 7777-2:1993.

10 Non-destructive testing

10.1 Radiography

Radiography shall be in accordance with **11.13.1** of BS 7777-2:1993, except as follows.

a) When the plate thickness does not exceed the nominal values given in Table 2, radiography of the horizontal seams of liquid nitrogen or liquid argon tanks shall be carried out on not less than the following:

100 % of all tee joints with the film hoizontal, plus 2 % of the remainder of the horizontal seam.

These radiographs shall be taken and sentenced before welding the next horizontal seam.

b) All butt welds in piping below the liquid level shall be 100 % radiographed. 30 % of butt welds in the remaining piping shall be 100 % radiographed.

c) When the inner tank has a fixed roof and the outer container is subject to purge gas pressure, there shall be no radiography on the outer container.

10.2 Crack detection

Crack detection shall be in accordance with **11.13.2** of BS 7777-2:1993.

When the inner tank has a fixed roof and the outer container is subject to purge gas pressure, there shall be no crack detection on the outer container.

10.3 Leak testing

Leak testing shall be in accordance with **11.13.3** of BS 7777-2:1993.

For oxygen tanks with a lap welded inner roof, the inside fillet weld for any joint shall have a 100 % vacuum box examination or 100 % dye penetrant crack detection before the outside fillet weld of the same joint is completed, to ensure that no product enters the trapped space (see Figure 1).

11 Testing

11.1 General

The hydrostatic and pneumatic testing of the inner tank and the pneumatic testing of the outer container shall be completed before installation of the shell insulation.

11.2 Hydrostatic testing

The inner tank shall be tested in accordance with **12.1.1** of BS 7777-2:1993.

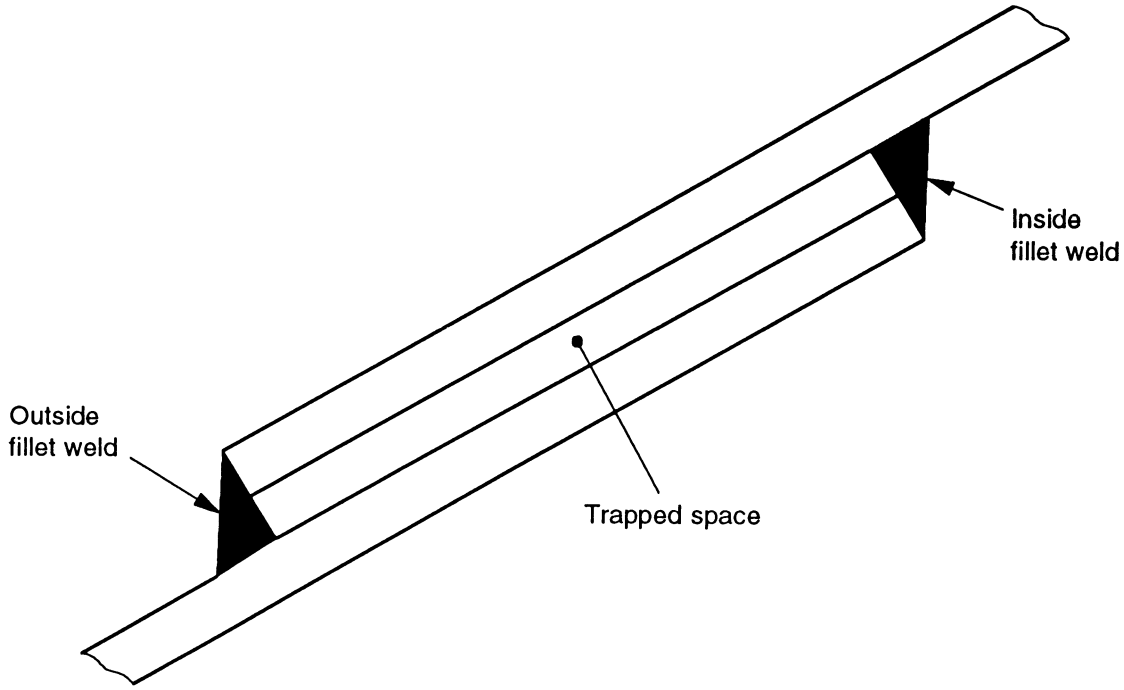

Figure 1 — Detail of lap welded inner roof

11.3 Pneumatic testing

11.3.1 ***Testing of inner tanks with integral roofs***

Inner tanks with integral roofs shall be tested in accordance with **12.2.1** of BS 7777-2:1993.

11.3.2 ***Testing of outer containers***

Outer containers shall be tested in accordance with **12.2.2** of BS 7777-2:1993.

11.4 Test procedures

The test procedures shall be agreed between the purchaser and the contractor (see **5.2**).

12 Cleanliness

Equipment surfaces that come into contact with an oxygen enriched environment shall be dry and free from materials that are incompatible with oxygen, such as the following:

a) loose foreign matter such as slag, adhered slag, weld splatter, blasting material or fibrous material;

b) flux residues from brazing, welding or soldering;

c) cleaning agents;

d) organic material such as oil, grease, paint, etc.;

e) adhesives or sealants not compatible with or not approved for oxygen service.

Equipment for nitrogen or argon service shall conform to the requirements for cleanliness as specified by the purchaser (see **5.1**).

13 Insulation

Insulation shall be in accordance with **6.6**, clause **10** and clause **14** of BS 7777-3:1993.

Materials used for the insulation system of oxygen storage tanks shall be free of organic material.

NOTE 1 Corrosion protection is not required on the inside of outer containers.

NOTE 2 The allowable compressive stress in cellular glass base insulation at the design condition should be 0.33 times the guaranteed average compressive strength of the material

COMMENTARY AND RECOMMENDATIONS ON CLAUSE **13**. *The allowable loads on cellular glass base insulation systems should take into account the effect of the material used between the layers of cellular glass on the strength of the system.*

14 Foundation

Foundations shall be in accordance with clause **7** of BS 7777-3:1993.

NOTE 1 Permanent instrumentation to monitor tank settlement is not required.

NOTE 2 Gas detection equipment under elevated slab foundations is not required.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE **14**. *Tanks for liquid nitrogen, liquid oxygen or liquid argon service are generally supported on elevated slab foundations. This eliminates the need for foundation heating and operating controls.*

15 Internal positive and internal negative pressure relief

Internal positive and internal negative pressure relief shall be in accordance with clause **8** of BS 7777-1:1993.

NOTE Consideration of conditions **8.5.1** c) and **8.5.1** d) of BS 7777-1:1993 is not required.

When additional relief capacity is fitted to the inner tank, the additional devices shall, under normal operating conditions, be available for operation.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE **15**. *Duplicate values are not required on the outer container when the inner tank has a fixed roof and the outer container is intended for insulation purposes only.*

16 Commissioning and decommissioning

Commissioning and decommissioning shall be in accordance with clause **9** of BS 7777-1:1993.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE **16**. *Decommissioning procedures need not be supplied by the tank contractor to the purchaser/operator.*

17 Name plate

A name plate shall be permanently attached to the outer tank giving the following information:

a) the name of the contractor;

b) the stored liquid;

c) the tank capacity;

d) the inner tank design pressure, positive and negative;

e) the inner tank design temperature, maximum and minimum;

f) the outer container design pressure, positive and negative;

g) the outer container design temperature, maximum and minimum;

h) the year of construction;

i) the number and date of this British Standard, i.e. BS 7777-4:1993.

List of references

Normative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 1501, *Steels for pressure purposes.*

BS 1501-2:1988, *Specification for alloy steels: plates.*

BS 1501-3:1990, *Specification for corrosion- and heat-resisting steels: plates, sheet and strip.*

BS 1503:1989, *Specification for steel forgings for pressure purposes.*

BS 1506:1990, *Specification for carbon, low alloy and stainless steel bars and billets for bolting material to be used in pressure retaining applications.*

BS 1560, *Circular flanges for pipes, valves and fittings (Class designated).*

BS 1560-3, *Steel, cast iron and copper alloy flanges.*

BS 1560-3.1:1989, *Specification for steel flanges.*

BS 3603:1991, *Specification for carbon and alloy steel pipes and tubes with specified low temperature properties for pressure purposes.*

BS 3605, *Austenitic stainless steel pipes and tubes for pressure purposes.*

BS 3605-1:1991, *Specification for seamless tubes.*

BS 3605-2:1992, *Specification for longitudinally welded tubes.*

BS 4360:1990, *Specification for weldable structural steels.*

BS 7777, *Flat-bottomed, vertical, cylindrical storage tanks for low temperature service.*

BS 7777-1:1993, *Guide to the general provisions applying for design, construction, installation and operation.*

BS 7777-2:1993, *Specification for the design and construction of single, double and full containment metal tanks for the storage of liquefied gas at temperatures down to – 165 °C.*

BS 7777-3:1993, *Recommendations for the design and construction of prestressed and reinforced concrete tanks and tank foundations, and the design and installation of tank insulation, tank liners and tank coatings.*

CP3, *Code of basic data for the design of buldings.*

CP 3:Chapter V, *Loading.*

CP 3:Chapter V-2:1972, *Wind loads.*

BS EN 10028, *Specification for flat products made of steels for pressure purposes.*

BS EN 10028-1:1993, *General requirements.*

BS EN 10045, *Charpy impact test on metallic materials.*

BS EN 10045-1:1990, *Test method (V- and U- notches).*

Informative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

PD 6501, *The preparation of British Standards for building and civil engineering.*

BS 6501-1:1982, *Guide to the types of British Standard, their aims, relationship, content and application*[2)].

[2)] Referred to in the foreword only.

Other references

[1] BRITISH COMPRESSED GASES ASSOCIATION (BCGA). *Code of practice for bulk liquid oxygen storage at production sites.* CP 20:1990.

[2] BRITISH COMPRESSED GASES ASSOCIATION (BCGA). *Code of practice for bulk liquid argon or nitrogen storage at production sites.* CP 22[3)].

[3)] In preparation.

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