BS 5045-2:
1989

Incorporating Amendments Nos. 1 and 2.

Transportable gas containers —

Part 2: Specification for steel containers of 0.5 L up to 450 L water capacity with welded seams

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/3, upon which the following bodies were represented:

Aluminium Federation
Associated Offices Technical Committee
Association of Manufacturers of Domestic Electrical Appliances
British Compressed Gases Association
British Fire Consortium
British Fire Protection Systems Association Ltd.
British Railways Board
British Soft Drinks Association Ltd.
Chief and Assistant Chief Fire Officers' Association
Department of Trade and Industry [Mechanical Engineering and Manufacturing Technology Division (Mmt)]
Department of Trade and Industry (National Engineering Laboratory)
Department of Trade and Industry (National Physical Laboratory)
Department of Transport (Marine Directorate)
Engineering Equipment and Materials Users' Association
Fire Extinguishing and Trades Association
Health and Safety Executive
Home Office
Industrial Safety (Protective Equipment) Manufacturers' Association
Institute of Refrigeration
Institution of Chemical Engineers
Liquefied Petroleum Gas Industry Technical Association (UK)
Metal Packaging Manufacturers' Association
Ministry of Defence
Society of Motor Manufacturers and Traders Limited
Coopted members

The following body was also represented in the drafting of the standard, through subcommittees and panels:

Welding Institute

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Contents

Foreword

This Part of BS 5045 has been prepared under the direction of the Pressure Vessel Standards Policy Committee and deals with materials, design, construction and testing of new containers intended for the conveyance by road of permanent, liquefiable and dissolved gases, under pressure.

This revision supersedes BS 5045-2:1978 which is withdrawn. This Part was originally published in 1974, covering steel containers having mechanized welded circumferential seams only. The 1978 revision was made to incorporate containers with both longitudinal and circumferential seams and to make it applicable to containers for dissolved acetylene. This revision incorporates a prototype test, clarifies the classification of containers and updates other requirements as dictated by experience.

The BS 5045 series is being prepared in a number of Parts to cover the various forms of manufacture. Those Parts published or in preparation are as follows:

— *Part 1: Specification for seamless steel gas containers above 0.5 litre water capacity;*

— *Part 3: Specification for seamless aluminium alloy gas containers above 0.5 litre water capacity and up to 300 bar charged pressure at 15 °C;*

— *Part 5: Specification for aluminium alloy containers above 0.5 litre up to 130 litres water capacity with welded seams;*

— *Part 6: Specification for seamless containers of less than 0.5 litre water capacity*.

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 40, 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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Section 1. General

1 Scope

This Part of BS 5045 specifies requirements for the materials, design, construction and testing of containers for the conveyance of permanent, liquefiable and dissolved gases under pressure; such containers are suitable also for storing gas under pressure. It applies to steel containers of water capacity of 0.5 L up to 450 L having longitudinal and/or circumferential main seams, made up mechanized arc welding.

It includes appendices giving examples of design calculations, a description of the methods for pressure testing of containers and a model form of test certificate.

It does not cover the design and manufacture of portable fire extinguishers where the developed pressure of the contents does not exceed 25 bar[1)] at the appropriate reference temperature; these are specified in BS 5423.

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

2 Manufacture and testing of containers

The manufacture, inspection and testing of containers shall be carried out to the satisfaction of an Independent Inspecting Authority to be approved by the Health and Safety Executive.

3 Classification of gases

For the purposes of the design and filling of the container, gases are classified as follows.

a) *Permanent gases*. Those gases that have a critical temperature below – 10 °C.

b) *Liquefiable gases*. Those gases that are liquefiable by pressure at – 10 °C but that are completely vaporized at 17.5 °C when at 1 013 mbar.

1) *High pressure liquefiable gases*. Those gases that have a critical temperature between – 10 °C and 70 °C inclusive.

2) *Low pressure liquefiable gases*. Those gases that have a critical temperature above 70 °C.

Any toxic substance that is liquid at 0 °C at 1 013 mbar pressure, but that is completely vaporized at or below 30 °C when at that pressure, is treated as a low pressure liquefiable gas.

c) *Dissolved gases*. Those gases that are dissolved under pressure in a solvent contained in a porous substance at ambient temperature and that are released from the solvent without the application of heat.

Gases that are currently conveyed in commercial quantities are classified in Table 1.

4 Information to be supplied by the purchaser and the manufacturer

4.1 Information to be supplied by the purchaser

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

a) name or classification of gas(es);

b) class of construction (e.g. BS 5045-2, class 1A);

c) volumetric capacity (minimum for liquefiable gases);

d) for permanent gases, the filling pressure at 15 °C;

e) for liquefiable gases, the mass of gas or filling ratio at the prescribed reference temperature or the required developed pressure in service;

f) material of construction;

g) preferred dimensions;

h) shape of base;

i) internal and/or external neck screwing dimensions;

j) fittings required, including set pressure and flow rate of any pressure relief devices;

k) external/internal finish required;

l) any special or adverse conditions under which the container will be required to operate, and any corrosion allowance required;

m) any requirements in addition to those specified in this Part of BS 5045;

n) name of the independent inspecting authority.

[1)] 1 bar = 10^5 N/m^2 = 100kPa.

4.2 Information to be supplied by the manufacturer

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

a) fully dimensioned sectional drawing of the container including:

1) name or classification of gas(es);

2) volumetric capacity (minimum for liquefiable gases);

3) filling pressure at 15 °C for permanent gas(es) or mass of liquefiable gas(es);

4) material of construction;

5) test pressure;

6) minimum and maximum masses of container;

7) statement that the container will be constructed to the requirements of this standard;

8) design approval reference (see clause **13**);

9) corrosion allowance (if any);

10) large scale dimensional details of weld preparation for all seams and details of the joints;

b) fittings to be supplied including set pressure and flow rate of any pressure relief device;

c) drawing showing layout of container marking, including set pressure and flow rate of any pressure relief device;

d) a statement which permits access at all reasonable times by the independent inspecting authority to that part of the manufacturer's works engaged upon the order, for the purpose of inspecting the fabrication of the containers at any stage;

e) a statement that the manufacturer shall supply labour and appliances for the inspection and tests required;

f) an undertaking to give an agreed period of notice to the independent inspecting authority of when the containers will reach a stage at which the inspection and/or test is required;

g) certificate of compliance for materials and container (see Appendix D).

Table 1 — Classification of gases

Permanent gases	Liquefiable gases		Dissolved gases
	High pressure	Low pressure	
($T_c < -10$ °C)	(-10 °C $\leq T_c \leq 70$ °C)	($T_c > 70$ °C)	
Air	Bromotrifluoromethane (R.13B1)	Allene[b]	Acetylene[b]
Argon	Carbon dioxide	*Ammonia*[a]	
Boron trifluoride[a]	Chlorotrifluoromethane (R.13)	Arsine[ab]	
Carbon monoxide[ab]	Diborane[a]	Boron trichloride[a]	
Carbon tetrafluoride (R.14)	1, 1-Difluoroethylene (R.1132a)	Bromochlorodifluoromethane (R.12B1)	
Coal gas (including coke oven gas)[a]	Ethane[b]	Butadiene[b]	
Deuterium[b]	Ethylene[b]	Butane[b]	
Fluorine[ab]	Hexafluoroethane (R.116)	1-Butene[b]	
Helium	Hydrogen chloride[ac]	2-Butene[b]	
Hydrogen[b]	Nitric oxide	Carbonyl chloride[ac]	
Krypton	Nitrous oxide	Carbonyl sulphide[ac]	
Methane (natural gas)[b]	Phosphine[a]	*Chlorine*[ac]	
Neon	Silane[a]	Chlorine trifluoride[ac]	
Nitrogen	Sulphur hexafluoride	1-Chloro-1, 1-difluoroethane (R.142b)[b]	
Oxygen	Trifluoromethane (R.23)	Chlorodifluoromethane (R.22)	
Town gas (excluding coal gas)[ab]		Chloropentafluoroethane (R.115)	
Xenon		2-Chloro-1,1,1-trifluoroethane (R.133a)	
		Cyanogen[ab]	
		Cyanogen chloride[a]	
		Cyclopropane[b]	
		Dichlorodifluoromethane (R.12)	
		Dichlorofluoromethane (R.21)	
		1,2-Dichlorotetrafluoroethane (R.114)	
		1,1-Difluoroethane (R.152a)[b]	
		Dimethylamine[b]	
		Dimethyl ether[b]	
		2,2-Dimethyl propane[b]	
		Ethylacetylene[b]	
		Ethylamine[b]	
		Ethyl chloride[b]	
		Ethylene oxide[ab]	
		Hexafluoropropene	
		Hydrogen cyanide[ab]	
		Hydrogen fluoride[ac]	
		Hydrogen selenide	
		Hydrogen sulphide[ac]	
		Isobutane[b]	
		Isobutylene[b]	
		Methyl acetylene[b]	
		Methylamine[b]	
		Methyl bromide[ab]	
		3-Methyl-1-butene[b]	
		Methyl chloride[ab]	
		Methyl mercaptan[ab]	
		Monomethylamine[b]	

Table 1 — Classification of gases

Permanent gases (T_c < – 10 °C)	Liquefiable gases		Dissolved gases
	High pressure (– 10 °C ≤ T_c ≤ 70 °C)	Low pressure (T_c > 70 °C)	
		Nitrogen dioxide[a] Nitrogen tetroxide[a] Nitrogen trioxide[a] *Nitrosyl chloride*[ac] Octafluorocyclobutane (R.C318) Perfluoropropane Propane[b] Propylene[b] *Sulphur dioxide*[ac] Trimethylamine[b] Vinyl bromide[a] Vinyl chloride[b] Vinyl fluoride[b] Vinyl methyl ether[b] Gas mixtures: Azeotrope R.500 (73.8 % R.12 and 26.2 % R.152a) Azeotrope R.502 (48.8 % R.22 and 51.2 % R.115) *Ethylene oxide*[a] 12 % and R.12 88 %	

[a] These gases are poisonous and are the ones referred to in this standard as toxic gases requiring special treatment. Other gases not so marked may have poisonous properties in a lesser degree or be suffocating in heavy concentrations.

[b] For the purposes of transport these gases are considered to be flammable.

[c] These gases are considered corrosive for the purpose of **9.2**.

NOTE 1 T_c is the critical temperature.

NOTE 2 Reference to refrigerants by number designation (e.g. R.12) is in accordance with international agreements (see BS 4580).

NOTE 3 Those gases italicized may, in accordance with **9.2.2**, be conveyed in class IA or class IB or class I containers.

NOTE 4 The list is not intended to be comprehensive as other gases may be transported.

NOTE 5 Halogenated hydrocarbon gases used for fire-fighting purposes are referred to by the halon numbering system. Under this system the two most commonly used gases for fire-fighting purposes, bromochlorodifluoromethane (CF_2ClBr) and bromotrifluoromethane (CF_3 Br), are designated Halon 1 211 and Halon 1 301, respectively. Halon 1 211 is also known as BCF and Halon 1 301 is also known as BTM. Both substances are also refrigerant gases, and are designated R.12B1 and R.13B1 respectively when used for refrigeration purposes.

5 Certificate of compliance

The manufacturer shall certify that the manufacture, inspection and testing of the container were carried out in compliance with this standard.

The independent inspecting authority shall certify acceptance of the above certification.

NOTE A model form of certificate is shown in Appendix D.

Section 2. Permissible materials

6 Materials for pressure parts

6.1 The materials shall be supplied in such a condition that the specified mechanical properties are obtained in the finished container after heat treatment.

6.2 The materials shall be suitable for use at the lowest permissible operating temperature in transport which shall be atmospheric temperature.

6.3 Sheet and plate material used for containers shall be balanced or killed steel in accordance with Table 2 or, subject to the agreement of the independent inspecting authority, steel as specified in Euronorm 120.

The mechanical properties of the finished containers shall be in accordance with Table 2. The yield stress shall be the lower yield stress, except that where a distinct yield is not apparent, the value shall be the 0.2 % proof stress.

6.4 Steels used for bungs and other pressure parts of containers shall be balanced or killed and shall be suitable for welding to the steels given in Table 2.

6.5 Each bundle or coil shall be identified for use in containers manufactured in accordance with BS 5045-2 and shall be marked with the type letter (see Table 2) or other identification mark by which it can be traced to the ladle of steel from which it was made. If the plate or sheet is not supplied directly by the steelmaker to the container manufacturer, then the material shall also be marked to identify the steelmaker.

6.6 The container manufacturer shall ensure that the steel supplier has provided an appropriate manufacturer's certificate with each batch of steel giving details of ladle analysis and mechanical properties.

6.7 The ladle analysis of materials shall be within the specified composition limits. In the event of one melt being divided between more than one ladle, samples shall be analysed from each ladle and a separate analysis provided for each ladle. The permitted deviations of any ladle analysis of the product from those specified compositions shall be as given in Table 3. These deviations, other than when maxima only are specified, shall apply either above or below the specified limits of the range, but not both above and below for the same element from different samples from the same ladle. When maxima only are specified the deviations shall be positive only.

Each ladle shall subsequently be regarded as a specified cast and identified accordingly.

Samples for product analysis shall be taken in accordance with BS 1837.

7 Material for attachments

The independent inspecting authority shall be satisfied that the material used in attachments is suitable in all respects, including weldability where relevant.

Table 2 — Permissible materials

Chemical and physical properties	Type A	Type B	Type C	Type D	Type E	Type F	Type G
Carbon % max.	0.20	0.18	0.20	0.20	0.15	0.18	0.25
Silicon % max.	0.30	0.25	—	0.30	0.30	0.40	0.35
Manganese							
% min.	—	0.40	0.70	—	—	0.50	0.60
% max.	0.60	1.20	1.50	0.60	1.20	1.40	1.40
Phosphorus % max.	0.05	0.04	0.05	0.05	0.025	0.04	0.03
Sulphur % max.	0.05	0.04	0.05	0.05	0.030	0.04	0.045
Grain refining elements % max	—	—	—[a]	—	0.30[a]	—	0.70
Yield stress (N/mm^2) min	215	275	310	200	350	285	250
Tensile strength (N/mm^2) min.	340	400	430	320	430	430	430
Tensile strength (N/mm^2) max.	430	490	585	420	650	510	550
Elongation % min.[b]							
L_o = 50 mm	28	24	21	29	21	—	21
$L_o = 5.65 \sqrt{S_o}$	33	29	20	35	25	20	25

[a] Grain refining elements are limited to: niobium 0.08 %, titanium 0.20 %, vanadium 0.20 %, niobium plus vanadium 0.20 %.
[b] Where any other non-proportional gauge lengths are used, conversions are in accordance with BS 3894-1.

NOTE 1 L_o is the original gauge length.
S_o is the original cross-sectional area.

NOTE 2 Type A and type C are equivalent to grades of BS 1449:1962 (withdrawn); type E is equivalent to grade 43/35 of BS 1449-1; type D is similar to Euronorm 120; type G is equivalent to type 151 grade 430 of BS 1501-1.

Table 3 — Permissible deviations on product analysis

Element	Specified range	Permissible deviation[a] on product analysis
	%	%
Carbon	≤ 0.25	0.02
	> 0.25	0.03
Silicon	≤ 0.60	0.05
Manganese	≤ 1.0	0.08
	> 1.0	0.10
Phosphorus	≤ 0.050	0.010
Sulphur	≤ 0.050	0.010
Niobium	≤ 0.10	0.02

[a] Maximum and minimum values do not apply simultaneously for individual elements (see **6.7**).

Section 3. Design

8 Service conditions for design

8.1 Where gases are to be conveyed in the UK in uninsulated containers, it shall be assumed that the most severe conditions of exposure to the climate will cause the contents to reach the developed pressure at the reference temperature specified in Table 4, the values of which vary with the type of gas contained.

The maximum permissible pressure in service, to which the test pressure of the container is related (see **10.2**), shall be the pressure developed by the contents at the pressure reference temperature, taking into account the filling ratio for high pressure liquefiable gases, and the intended charged pressure at 15 °C for permanent gases.

NOTE The necessary data on the relationship between charged pressure (and on filling ratio) and developed pressure at the reference temperature are given in BS 5355.

The reference temperature for filling ratios of low pressure liquefiable gases in uninsulated containers shall be 45 °C.

Table 4 — Reference temperatures for developed pressure for conveyance in the UK in uninsulated containers

Type of contents	Reference temperature
	°C
Low pressure liquefiable gas	55
High pressure liquefiable gas	52.5[a]
Permanent gas	60

[a] When safety devices are fitted to carbon dioxide containers, this reference temperature may be reduced to 50 °C.

8.2 The water capacity of a container for a liquefiable gas shall be not less than the intended maximum mass of contents divided by the filling ratio.

NOTE The necessary data on the physical properties of the liquefiable gases are given in BS 5355.

8.3 The internal volume of a container for a permanent gas shall be such as to provide a nominal gas content which at 15 °C will have a developed pressure of 1 013 mbar.

The charged pressure shall be specified to ensure that the maximum developed pressure at the pressure reference temperature does not exceed the requirements specified in this standard.

8.4 when gases are to be conveyed in insulated containers the operational criteria for design shall be sought from the independent inspecting authority.

NOTE The temperature which can be reached by their contents, the corresponding developed pressure required for design and the allowable mass of liquefiable gas are all conditional upon the intended degree of insulation proposed with or without the assistance of some form of refrigeration and upon the journey duration.

8.5 For containers used for fire-fighting purposes filled with halons and dry nitrogen the developed pressure requirements shall conform to the appropriate Part of BS 5306.

Containers intended to contain carbon dioxide as the fire extinguishant shall conform to the developed pressure and filling ratio requirements of BS 5355 and BS 5423.

9 Classification of containers

9.1 Classification by construction

9.1.1 *General.* Containers shall be constructed to one of the following classes, depending on their intended application (see **9.2** and Table 5):

a) class I

b) class IA, IB, IAC

c) class IIA, IIB

The different construction criteria for each class (i.e. batch size for testing, degree of radiography, stress reduction factor) shall be as specified in **18.1.1**, clause **25** and Table 6 respectively.

9.1.2 *Class II containers.* Containers shall be eligible for construction to class IIA only if the container does not possess a longitudinal seam, has outwardly domed ends and the distance (in millimetres), between the nearest edge of any welded seam and the geometrical transition between the cylindrical portion and the domed ends is not less than $2\sqrt{(D_i\ t_e)}$ where D_i is the internal diameter of the container (in millimetres) and t_e is the actual thickness of the dished end (in millimetres).

Class II containers not eligible for class IIA construction shall be made to class IIB.

9.2 Relationship of classification to contents

NOTE Class II containers constructed to class IIA or class IIB may be used whenever construction to classes I, IA, IB or IAC is not prescribed by **9.2.1**, **9.2.2** or **9.2.3**.

9.2.1 ***Permanent gases and high pressure liquefiable gases***

9.2.1.1 When the gas(es) is (are) not toxic, flammable or corrosive, and the developed pressure at 55 °C is less than 75 bar but more than 25 bar they shall be carried in class IA, class IB or class I containers; when the developed pressure is less than 25 bar, class II containers shall be allowable.

9.2.1.2 In all other cases the gases shall be carried in class I containers.

9.2.2 ***Toxic gases***

NOTE See Table 1.

9.2.2.1 The non-corrosive toxic gases italicized in Table 1 (i.e. those gases which are of moderate toxicity or which give sensory warning of a slight escape) shall be carried in class IA, class IB or class I containers.

9.2.2.2 The corrosive toxic gases italicized in Table 1 shall be carried in class IB or class I containers.

9.2.2.3 All other toxic gases or their mixtures shall be carried in class I containers.

9.2.3 *Acetylene.* Class IAC containers shall be used exclusively for dissolved acetylene (see **13.2**).

Table 5 — Classification and construction criteria

Classification by content	**Classification of container** (see note 1)					
	I	**IA**	**IB**	**IAC**	**IIA**	**IIB**
Toxic gases (see **9.2.2.3**)	X					
Corrosive toxic gas: moderate toxicity (see **9.2.2.2**)	X		X			
Non-corrosive toxic gas: moderate toxicity (see **9.2.2.1**)	X	X	X			
Permanent and liquefiable gas having a developed pressure greater than 75 bar at 55 °C: including mixtures (see **9.2.1.2**)	X					
Permanent and liquefiable gas and having a developed pressure between 75 bar and 25 bar at 55 °C. Including mixtures (see **9.2.1.1**)	X	X (see note 2)	X			
Acetylene (see **9.2.3**)				X		
Non-toxic non-corrosive gases having a developed pressure lower than 25 bar at 55 °C (see note to **9.2**)					X (see **9.1.2**)	X

Construction criteria		I	IA	IB	IAC	IIA	IIB
Radiographic examination of welds at manufacture	Full	X					
	Sample		X	X (see note 3)	X		
	None					X (see note 4)	X
Radiographic examination of weld repairs (see note 5)	Full	X	X	X	X		
	None					X (see note 6)	X

NOTE 1 Classifications shown are minimum. Gases can be conveyed in containers of higher class than specified.
NOTE 2 Applicable only to gases which are non-toxic, non-corrosive and non-flammable.
NOTE 3 Class IB containers should either have all pressure containing welds made with a double run; or all pressure containing welds made in a single run should be radiographed.
NOTE 4 Sample radiography is only required for weld thicknesses 6 mm or above.
NOTE 5 All repairs are to be approved by the independent inspecting authority.
NOTE 6 All repairs of weld thicknesses 6 mm or above are to be radiographed.

Table 6 — Stress reduction factors for walls of cylindrical or spherical containers

Class of container	Stress reduction factor
I	0.95
IA, IB and IC	0.90
IIA	0.85
IIB	0.80

NOTE The stress reduction factors are not valid for containers to be subjected to a large number of fluctuations of pressure. It is recommended that prototype tests, see clause **24**, should prove the design of a container which is expected to be charged more than 10 000 times in the course of its life.

10 Design of container shell

10.1 Nomenclature for the cylindrical part of the shell

t is the minimum wall thickness (in mm) to resist internal pressure and external forces due to handling, but excluding any additional thickness for corrosion and other influences;

P_1 is the test pressure (in bar) applicable to design governed by equations (1) and (4);

P_2 is the test pressure (in bar) applicable to design governed by equation (3);

p is the pressure (in bar) developed by the contents of a container at the pressure reference temperature;

D_o is the external diameter of the container (in mm);

D_i is the internal diameter of the container (in mm);

f_e is the maximum permissible equivalent stress (in N/mm^2) at test pressure (= 0.75 × minimum specified yield stress Y of the material of construction × appropriate stress reduction factor as given in the Table 6);

T is the minimum specified tensile strength (in N/mm^2) of the material of construction;

Y is the minimum specified yield stress (in N/mm^2) of the material of construction.

10.2 Derivation of test pressure

Test pressure is defined as the pressure used to calculate minimum wall thickness (t), and the pressure at which hydraulic testing is carried out.

Test pressure P_1 is deduced in terms of the container's contents and the material of construction. Test pressure P_2 is applicable only to those containers whose minimum wall thickness is governed by equation (3).

Test pressure P_1 is derived from a consideration of:

a) the maximum pressure (p) developed in service by the gaseous contents at the nominated reference temperature as given by BS 5355;

b) the yield and tensile (Y and T) properties of the container material as given in Table 2.

Table 7 specifies formulae to be used for deriving minimum values of test pressure P_1 applicable to the various gas classifications.

For containers for use with dissolved acetylene the test pressure P_1 shall be 52 bar in all circumstances.

10.3 Thickness of cylindrical wall

The thickness of the cylindrical wall of a container shall be not less than the values given by equation (1):

$$t = \frac{0.3P_1 D_i}{7f_e - P_1} \quad \text{or} \quad t = \frac{0.3P_1 D_o}{7f_e - 0.4P_1} \qquad (1)$$

except that the thickness of the cylindrical wall determined by equation (1) shall be not less than the value given by equation (2):

$$t = 2.48 \sqrt{\left(\frac{D_i}{T}\right)} \qquad (2)$$

Equation (2) will override equation (1) for comparatively low values of P_1, in which case the test pressure P_2 shall be derived from equation (3):

$$P_2 = \frac{7f_e}{1 + 0.12\sqrt{(D_i T)}} \qquad (3)$$

NOTE In these circumstances it is permissible to reassess the pressure duty of the container within the maximum limitation obtained, by substitution of the values of P_2 for P_1 in Table 7.

10.4 Wall thickness of a spherical container

The thickness of the wall of a spherical container shall be not less than the value given by equation (4):

$$t = \frac{P_1 D_i}{40f_e - 4.5P_1} \quad \text{or} \quad t = \frac{P_1 D_o}{40f_e - 2.5P_1} \qquad (4)$$

except that the thickness of the wall determined by equation (4) shall be not less than the value given by equation (2).

Equation (2) will override equation (4) for comparatively low values of P_1, in which case the test pressure P_2 shall be derived from equation (3).

NOTE In these circumstances it is permissible to reassess the pressure duty of the container, within the maximum limitation obtained, by substitution of the value of P_2 for P_1 in Table 7.

10.5 Domed ends

10.5.1 ***Nomenclature for ends***

t is the minimum thickness of the cylindrical wall (in mm) to resist internal pressure and external forces due to handling, but excluding any additional thickness for corrosion and other influences (see **10.6**);

t_e is the minimum thickness of ends (in mm) to resist internal pressure and external forces due to handling, but excluding any additional thickness for corrosion and other influences;

D_o is the external diameter (in mm) of the domed end;

D_i is the internal diameter (in mm) of the domed end;

K is the shape factor obtained according to the values h_e/D_o and t_e/D_o (with interpolation where necessary from Figure 1);

R_o is the external crown radius (in mm) of dishing of torispherical end;

R_i is the internal crown radius (in mm) of dishing of torispherical end;

r_o is the external knuckle radius (in mm) of torispherical end;

r_i is the internal knuckle radius (in mm) of torispherical end;

h_o is the external height (in mm) of domed end (see note);

h_i is the internal height (in mm) of domed end;

h_e $= h_o$ for a semi-ellipsoidal end, or the least of h_o, $D_o^2/4R_o$, or $\sqrt{(D_o\, r_o/2)}$ for a torispherical end;

S_f is the straight flange length (in mm) (see Figure 2 for diagrammatic representation).

NOTE The external height of a domed end h_o, for a torispherical end, may be determined from:

$$h_o = R_o - \sqrt{\left\{\left(R_o - \frac{D_o}{2}\right)\left(R_o + \frac{D_o}{2} - 2r_o\right)\right\}} \qquad (5)$$

10.5.2 *Wall thickness of domed ends.* When the material of the ends is the same as that used for the cylindrical part of the shell, the wall thickness of the domed ends shall be the greater of:

a) the thickness of cylindrical wall (see **10.3**); or

b) the valve calculated from equation (6):

$$t_e = tK \qquad (6)$$

When the material of the ends has different mechanical properties from that used for the cylindrical part of the shell (see **10.7**) t shall be calculated using the mechanical properties of the material of the cylindrical part of the shell and the thickness of the domed ends shall be the greater of a) or b).

Table 7 — Formulae for deriving minimum values of test pressure

Gas classification	Test pressure P_1	
	$Y/T \leq 0.7$	$Y/T > 0.7$
Permanent gases in uninsulated containers, the charged pressure not exceeding 300 bar	$P_1 = \frac{p}{0.9}$	P_1 shall be the greater of: a) $\frac{p}{0.85}$; or b) 1.5 × charged pressure at 15 °C except that P_1 shall not exceed $\frac{pY}{0.63T}$
Permanent gases in uninsulated containers and liquefiable gases in insulated containers	$P_1 = \frac{p}{0.9}$ except that P_1 shall be not less than 200 bar for carbon dioxide or nitrous oxide	$P_1 = \frac{pY}{0.63T}$ except that P_1 shall be not less than 200 bar for carbon dioxide or nitrous oxide
Low and high pressure liquefiable gases in uninsulated containers	$P_1 = p$ except that P_1 shall be not less than 200 bar for carbon dioxide or nitrous oxide	P_1 shall be the lower of: a) $\frac{pY}{0.7T}$; or b) $\frac{p}{0.85}$ except that P_1 shall be not less than 200 bar for carbon dioxide or nitrous oxide
Dissolved-acetylene containers	P_1 = 52 bar	P_1 = 52 bar

10.5.3 *Limitations of shape* (see Figure 2). The shape of the ends shall be subject to the following limitations.

a) In a torispherical end R_i shall not be greater than D_o.

b) In a torispherical end r_i shall be not less than 0.1 D_i nor less than three times the actual wall thickness of the dished end as manufactured.

c) In a semi-ellipsoidal end the ratio h_o/D_o shall be not less than 0.192.

d) S_f shall be not less than 0.3 $\sqrt{(D_o t_e)}$.

10.6 Additional thickness

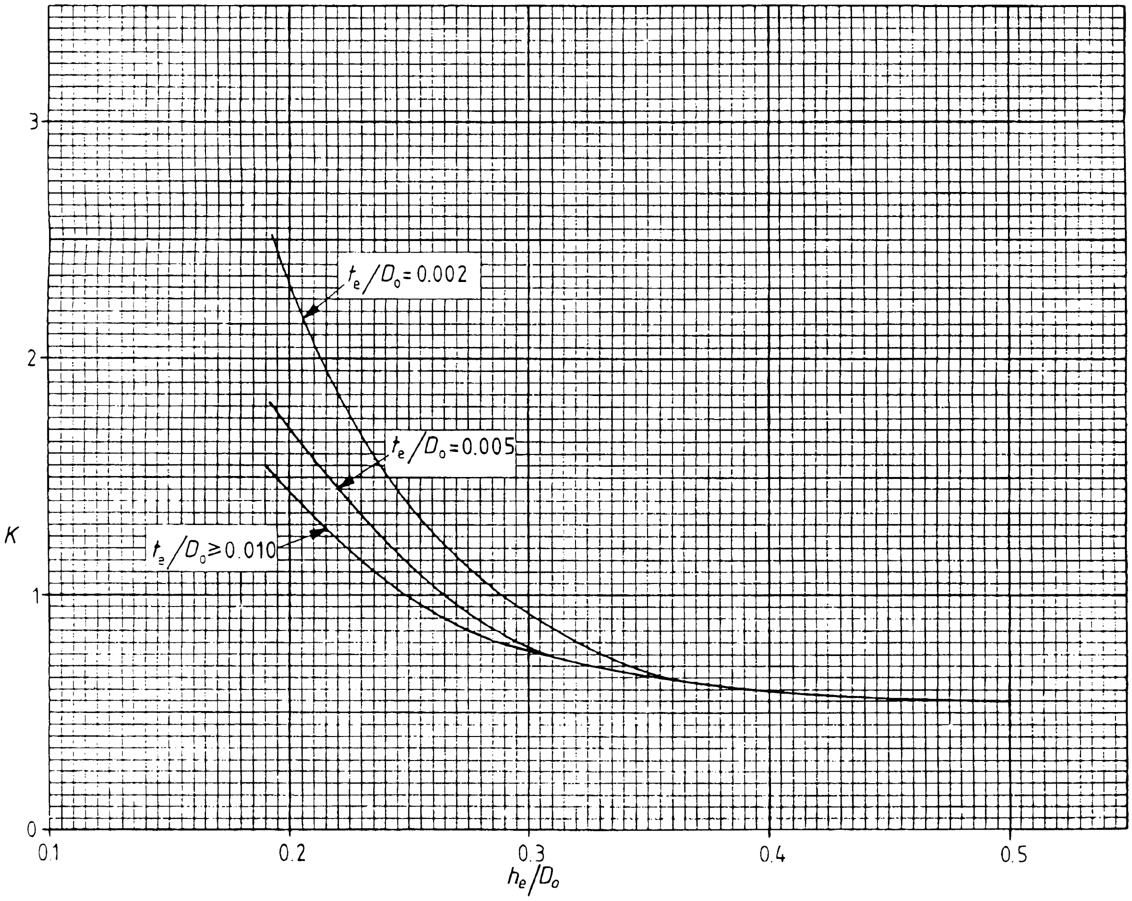
NOTE Influences other than those of internal pressure and of external forces due to ordinary handling may require the provision of additional thickness above the calculated values. Additional thickness may be necessary to allow for corrosion during service; additional thickness may also be necessary, on containers for liquefied gases, so that the container can withstand stresses due to horizontal acceleration and retardation in road transportation.

The variety of conditions occurring in practice makes it impracticable to give a general specification of the necessary allowances; they shall be carefully considered and agreed upon in each particular case by the manufacturer and user of the container. If a pronounced departure from normal practice is proposed or if other unusual features arise, the independent inspecting authority shall be consulted.

10.7 Three-piece containers

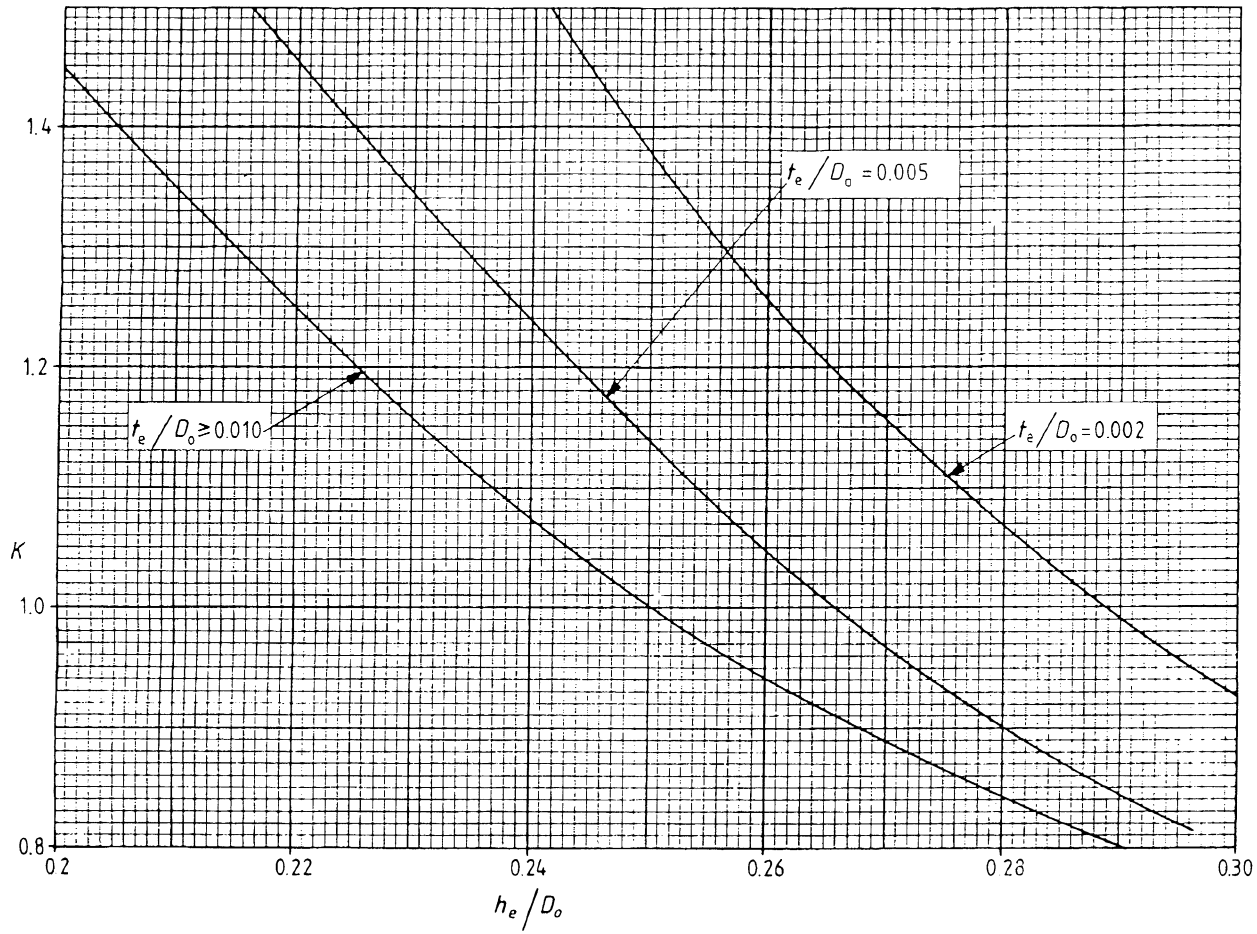
It is permissible for three-piece containers to be designed such that the cylindrical part of the shell is made from material with different mechanical properties from that of the ends, provided that the minimum burst test requirements are met for the material with the higher mechanical properties. The thickness of the wall shall be calculated using the properties of the material of the cylindrical section

If this method of design is followed it shall be stated on the test certificate and marked on the container (see clause **29**).



(a) Normal size

Figure 1 — Shape factor *K*



(b) Enlargement of figure 1(a)

Figure 1 — Shape factor *K (concluded)*

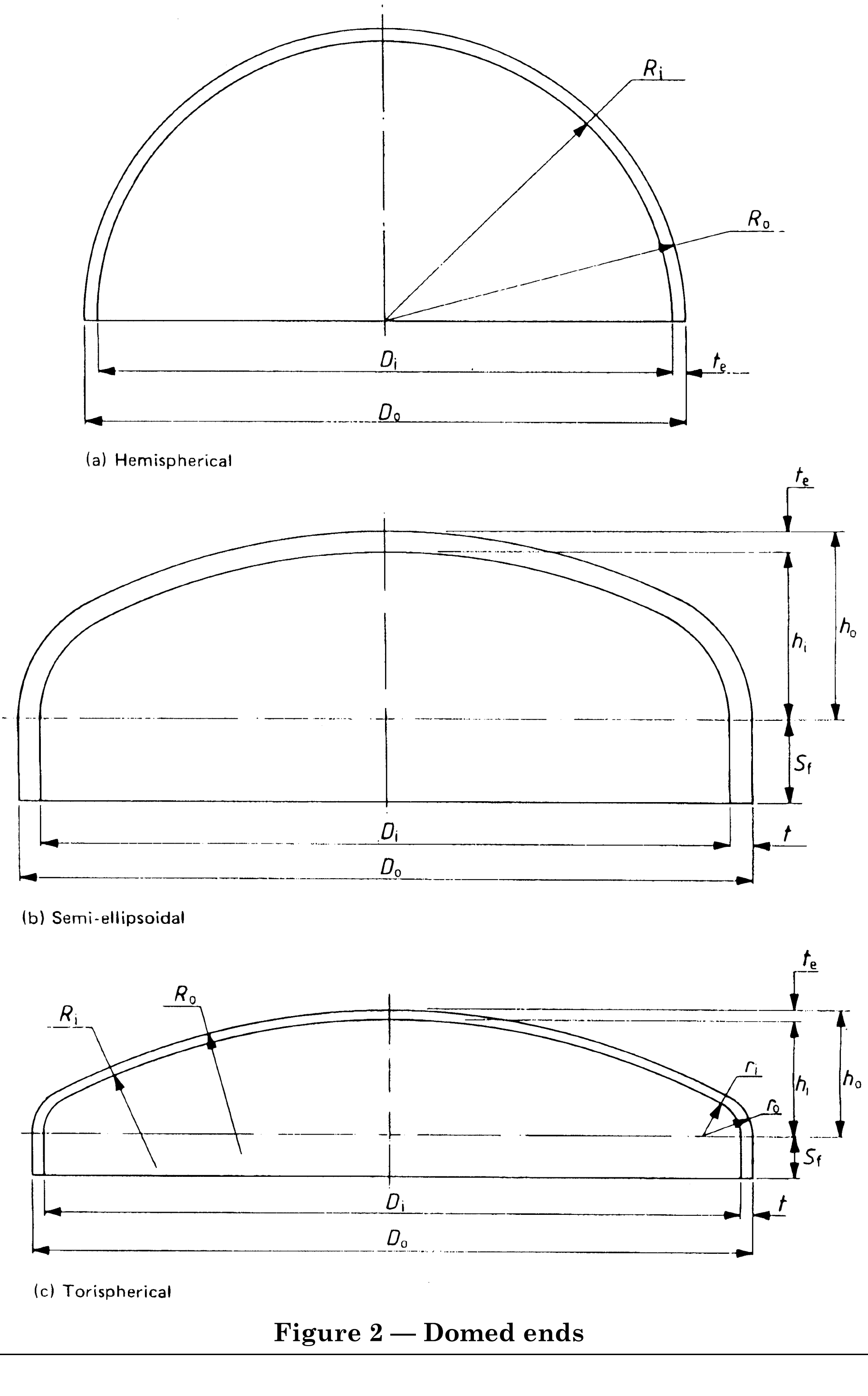


Figure 2 — Domed ends

11 Openings and branch connections

11.1 The design and methods of attachment to the container of bungs and bosses shall be approved by the independent inspecting authority. In the case of class I construction the only permissible method of attachment of such pressure parts shall be full penetration butt welding.

11.2 Each container shall be provided with one or more openings sufficient to enable complete visual internal inspection.

NOTE Normally the valve opening satisfies this requirement.

11.3 Where special openings such as inspection openings or branch connections are required, they shall comply with BS 5500.

12 Fittings

12.1 Valve fittings

Valve fittings shall comply with BS 341-1 or BS 341-2 or BS 1319, as appropriate. The design of spindle-operated valves shall be such that when fitted to the container it shall not be possible to withdraw the spindle under normal operating conditions.

Only lubricants compatible with the contents shall be used on valves or other fittings.

12.2 Valve protection

12.2.1 Containers intended for the transport of toxic and/or flammable gases shall have their valves protected against damage, either by the design of the container, the design of the valve or by the provision of a cap or shroud securely attached to the body of the container, except in the following cases:

a) containers intended for the transport of non-toxic flammable gases and carbon monoxide and mixtures thereof where direct consignments are made between filler/supplier and user;

b) a container or group of containers securely attached to a cradle (see **12.2.2**).

The construction of the cap or shroud shall be such that it is nowhere in contact with any part of the valve or valve body.

The valve cap or shroud shall be provided with a side vent or vents of such size as to prevent any gas pressure accumulating inside the cap or shroud, unless the cap, collar and its fixing are designed to withstand the pressure that could be developed in the container by the contents at the reference temperature.

If the container is used for highly toxic[2)] gases, additional protection shall be provided, such as a valve locking device and/or by the removal of the valve hand wheel. A suitably designed gastight plug or cap shall be fitted to the valve outlet to minimize the risk of valve leakage in transit.

NOTE The additional protection can also be provided by means of a non-vented gastight valve cap designed to withstand the pressure that can be developed in the container by the contents at the reference temperature.

In the case of non-vented valve protection the cap shall be provided with a device that will allow any pressure that has accumulated inside the valve cap to be slowly relieved before removal of the cap.

The protective device shall be so designed to prevent damage to the valve, that would result in the escape of the product, if a filled container is dropped from a height of 1.2 m so that the protective device strikes a hard flat surface.

12.2.2 In the case of a container or group of containers securely attached to a cradle, the valves shall be protected as required by **12.2.1** or, alternatively, the valves shall be protected either by the design of the cradle or by a stout guard. If the containers are connected to a common manifold, the manifold as well as the valves shall be protected by a stout guard. The guard shall be either hinged or removable and it shall be provided with a lock to enable it to be kept in a locked position during conveyance.

12.3 Dip pipes

When a dip pipe is fitted to the service outlet connection of a container its presence shall be indicated. It shall be stated whether the container is intended for vapour or liquid off-take and, where necessary, the correct operating position of the container shall be shown.

NOTE This requirement may be fulfilled either by a metal disc betwee the valve and the neck of the container or by a 25 mm wide black or white stripe painted along the longitudinal axis of the container, with the disc or line indicating whether the dip pipe is short or long and straight or curved.

12.4 Pressure relief devices

12.4.1 *General.* No pressure relief device shall be fitted to a container intended for the conveyance of toxic gases (see Table 1) in the UK.

NOTE 1 A pressure relief device may be fitted to a container intended for the conveyance of non-toxic gases.

NOTE 2 Where a container has a duty which includes a sea journey an appropriate pressure relief device may be fitted.

The materials of construction for all pressure relief devices shall be compatible with the gas to be conveyed and other service conditions.

[2)] For the purpose of **12.2.1** the following gases listed in Table 1 are classified as highly toxic: arsine, boron trifluoride, fluorine, carbonyl chloride, chlorine trifluoride, cyanogen chloride, hydrogen cyanide, hydrogen sulphide, phosphine.

All pressure relief devices shall be so designed and fitted as to ensure that the cooling effect of the contents of the container during discharge shall not prevent the effective operation of the devices.

The outlets from all pressure relief devices shall be so sited that free discharge from the devices is not impaired.

The outlets from all pressure relief devices shall be so designed and constructed as to prevent the collection of moisture or other foreign matter that could adversely affect the performance of the devices.

If a pressure relief device is to be fitted to dissolved-acetylene containers, this shall be either by means of one or more fusible plugs, set to operate at 100 ± 2 °C or by means of other such pressure relief devices as may be approved by the Health and Safety Executive.

12.4.2 *Pressure relief valve.* If a pressure relief valve is fitted to a container, it shall be of the spring-loaded type. Where practicable the pressure at which the relief valve is designed to start lifting shall be marked on the relief valve or the outlet valve body where the relief valve forms part of the outlet valve.

Discharge from the pressure relief valve shall be obtained at a pressure not greater than the test pressure of the container, except in the case of liquefiable petroleum gas containers for service in the UK.

Where liquefiable petroleum gas containers for service in the UK are fitted with pressure relief valves they shall be set as follows:

a) propane: 26 bar;

b) butane: 21 bar.

12.4.3 *Bursting discs.* Bursting discs, if fitted, shall be constructed in accordance with BS 2915 and shall be so designed as to ensure that rupture occurs at a pressure not greater than the test pressure of the container except in the case of containers for halons and nitrogen.

Container assemblies filled with mixtures of halons and dry nitrogen for fire protection purposes shall be fitted with a bursting disc that will rupture at not more than 1.26 × test pressure of the container.

NOTE A bursting disc may be fitted to any container intended for the conveyance of non-toxic and non-flammable gases.

The pressure at which the bursting disc is designed to rupture shall, where practicable, be stamped on the bursting disc holder.

If a container is liable to be subjected to vacuum conditions during service, the bursting disc shall be resistant to vacuum or be fitted with a vacuum support.

12.4.4 *Fusible plugs.* When fusible plugs are used they shall, where practicable, be externally marked to indicate the temperature at which they are designed to relieve pressure.

NOTE The Health and Safety Executive should be consulted if it is proposed to fit containers, other than dissolved-acetylene containers, with one or more fusible plugs.

Section 4. Manufacture and workmanship

13 Approval of design and construction details

13.1 Before manufacture is commenced the manufacturer shall submit for approval by the purchaser and independent inspecting authority, dimensioned sectional drawing(s) showing in full detail the construction of the container and carrying the information listed in **4.2**.

NOTE Approval requirements relating to massed containers are specified in BS 6061.

13.2 *Text deleted.*

13.3 No modification shall be made to the design, after approval by the independent inspecting authority, without prior agreement between the purchaser, manufacturer and independent inspecting authority.

14 Tolerances

14.1 Cylindrical part of the shell

14.1.1 *Circularity.* The difference between the maximum and minimum external diameters measured at any cross section of the completed container shall not exceed 1 % of the specified internal diameter.

14.1.2 *Circumference.* The external circumference of the cylindrical shell of the completed container shall not depart by more than ± 0.25 % from the circumference calculated from the nominal outside diameter (equal to the nominal internal diameter plus twice the actual plate thickness).

14.1.3 *Straightness.* Unless otherwise shown on the drawing, the maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 0.3 % of the cylindrical length.

14.2 Domed ends

14.2.1 *Circularity.* The difference between the maximum and minimum outside diameters of the straight flange shall not exceed 1 % of the specified internal diameter.

14.2.2 *Circumference.* The external circumference of the dished ends shall not depart by more than ± 0.25 % from the circumference calculated from the nominal outside diameter (equal to the nominal internal diameter plus twice the actual plate thickness).

15 Welds

15.1 Prior to welding, components shall be examined in accordance with clause **17**.

15.2 The pressure parts of containers shall be welded by a mechanized arc welding process as defined in BS 499-1 unless an alternative process has been approved by the independent inspecting authority.

15.3 All filler metal shall be such as to ensure the required physical properties in the completed weld.

15.4 A circumferential seam shall consist of either a joggle joint such that the external surface of the container does not have any abrupt changes of diameter, or an edge-to-edge butt joint and shall have full penetration.

A longitudinal seam shall consist of a butt joint; backing material, where used, shall be temporary.

15.5 Prior to welding, all welding surfaces shall be cleaned by degreasing and dressed smooth. Surfaces and edge preparations shall be consistent with the welding procedure.

15.6 The surfaces of the plates at the seams shall not be out of alignment with each other at any point by more than 10 % of the plate thickness.

15.7 Welds, except the ends of longitudinal welds, shall not be dressed without the approval of the independent inspecting authority. The weld surface shall have a smooth contour and there shall be no undercutting.

15.8 All welding of the shell and attachments shall be completed before final heat treatment.

15.9 The manufacturer shall satisfy the independent inspecting authority that all welding procedures have been approved in accordance with BS 4870-1.

15.10 The manufacturer shall satisfy the independent inspecting authority that each welder has been approved in accordance with BS 4871-1.

NOTE The independent inspecting authority may require re-tests from an approved welder if it is not satisfied with the work of that welder or if there has been a lapse of time since the welder was last employed on the welding of containers manufactured in accordance with this standard.

16 Heat treatment

After the completion of all welding (including that of any attachments) and before hydraulic test, containers shall be either normalized at a temperature of between 890 °C and 930 °C, or stress relieved at a temperature of between 625 °C and 675 °C. The containers shall be heated for a sufficiently long period to ensure that they are all uniformly at the required temperature and then cooled in a controlled environment, or treated in an equivalent continuous process as approved by the independent inspecting authority.

Section 5. Inspection and tests

17 Inspection of components

17.1 All pressings and cylindrical shells shall be examined for surface defects before any seam is welded. If there are defects which, in the opinion of the independent inspecting authority, would be detrimental to the sound construction of the container, the pressing or shell shall be rejected.

17.2 At the discretion of the independent inspecting authority, 2 % or more of the pressings and of the cylindrical shells shall be selected at random to represent all batches of material used for the manufacture of the containers and these batches shall be examined for minimum thickness before any seam is welded.

NOTE For the purpose of this clause, "batch of material" means pressings or cylindrical shells manufactured in a continuous production run.

Should any pressing or shell be less than the minimum specified thickness, the whole of the output from the relevant batch of material shall be examined for minimum thickness and any pressing or shell which is less than the specified minimum thickness shall be rejected.

18 Test requirements

18.1 Normal batch production

18.1.1 For test purposes a batch shall consist of not more than:

classes I, IA, IB and IAC	202 containers
classes IIA and IIB	402 containers

made consecutively from the same size, design and material specification, on the same types of automatic welding machines and heat treated under the same conditions of temperature and time.

18.1.2 One container selected at random from every batch or part batch of containers shall be subjected to the mechanical tests as described in clause **19** and shall satisfy the requirements of clause **19** (see also **25.1.3**).

18.1.3 One container selected at random from every batch or part batch of containers shall be subjected to a volumetric expansion test, in accordance with **20.4** and then shall comply with clause **21** when hydraulically tested to destruction (see also **25.1.3**).

18.1.4 Radiographic examination of containers shall be carried out in accordance with clause **25**.

18.1.5 After heat treatment each container shall be pressure tested in accordance with **20.3** and clause **23**.

18.1.6 The water capacity of each container shall be checked in accordance with clause **22**.

18.2 Continuous mechanized production

18.2.1 Where production is organized on a flow line basis and the various processes are fully mechanized, and provided that the process achieves consistently reproducible results to the satisfaction of the manufacturer and is approved by the independent inspecting authority, the test requirements shall be in accordance with **18.2.2** to **18.2.9**.

18.2.2 For test purposes containers shall be divided into inspection lots not exceeding 1 000 in number.

18.2.3 The number of containers to be tested shall be as follows.

a) Quantity: ≤ 3 000 containers.

1) From the first 250 containers or less in each inspection lot, two containers shall be selected at random, one for a burst test and one for mechanical tests.

2) From each subsequent group of 250 containers or less in the inspection lot, one container shall be selected at random for either a burst test or mechanical tests.

b) Quantity: > 3 000 containers.

1) For ≤ 35 L capacity. From each 1 000 containers or less above 3 000, two containers shall be selected at random, one for a burst test and one for mechanical tests.

2) For > 35 L capacity.

i) From the first 500 containers or less in each inspection lot above 3 000, two containers shall be selected at random, one for a burst test and one for mechanical tests.

ii) From the remaining 500 containers or less in such inspection lots above 3 000, one container shall be selected at random for either a burst test or mechanical tests.

18.2.4 The criteria for testing as given in **18.2.3** shall apply after:

a) material cast change;

b) break in production, e.g. a weekend, overnight.

All containers shall be identified so that if a container fails the mechanical or volumetric tests all containers since the last successful test shall be isolated and submitted to further tests in accordance with clause **27** in which case all the isolated containers shall be treated as a batch.

18.2.5 Containers selected at random shall be subjected to the mechanical tests as described in clause **19** and shall satisfy the requirements of clause **19** (see also **25.1.3**).The number of containers to be tested shall be in accordance with **18.2.3**.

18.2.6 Containers selected at random shall be subjected to a volumetric expansion test in accordance with **20.4** and then shall comply with clause **21** when hydraulically tested to destruction (see also **25.1.3**). The number of containers to be tested shall be in accordance with **18.2.3**

18.2.7 Radiographic examination of containers shall be carried out in accordance with clause **25**.

18.2.8 After heat treatment each container shall be pressure tested in accordance with **20.3** and clause **23**.

18.2.9 The water capacity of each container shall be checked in accordance with clause **22**.

18.3 Small batch production

18.3.1 Small batch production test requirements shall apply only to three-piece containers and only to a maximum of 30 containers.

The containers shall be considered to be of the same batch providing that the longest shell length is not more than 50 % longer than the smallest and all are of an approved design length (see item g) of **24.1**).

The manufacturer shall use only material for which he has adequate burst test data and recorded data relating to its mechanical properties in the formed shape and in its normalized or heat-treated condition.

18.3.2 The tests shall consist of either:

a) mechanical tests on coupon plates, radiography of the T junction welds and internal inspection of the weld seams of each container; or

b) mechanical tests on coupon plates, and a bursting test on a selected container.

18.3.3 Where there are three or more containers in a batch a production coupon plate shall be attached to three containers. One coupon plate shall be subjected to the mechanical tests of **19.4**, **19.5** and **19.6**. If the plate fails any test the other two coupon plates shall both comply with clause **27**.

When less than three containers are made, a production coupon plate shall be attached to one container. The coupon plate shall be subjected to the mechanical tests of **19.4**,**19.5** and **19.6**. The failure of any test shall result in that container(s) being rendered unserviceable (see **27.6**).

18.3.4 One container shall be subjected to a volumetric expansion test in accordance with **20.4**.

All containers shall be pressure tested and tightness tested in accordance with **20.3** and clause **23**.

18.3.5 Radiographic inspection of T junction welds shall be in accordance with **25.2** and **25.3**.

18.3.6 Hydraulic bursting tests shall be in accordance with clause **21**.

19 Mechanical tests

19.1 General

The mechanical tests shall be carried out on the parent material and the welds.

Test specimens shall be cut from locations on the container as indicated in Figure 3. The specimens for tests on the parent material shall be cut so that no part of the gauge length of the test specimen is within **4** t of the edge of the weld, where t is the minimum design thickness as specified on the drawing(s), see **13.1**, (including any corrosion allowance).

The mechanical tests carried out on each container shall be in accordance with **19.2** to **19.6**.

A test specimen of each type required under **19.2** and **19.3** shall be cut from the cylindrical shell and from one of the end pressings.

Test specimens of each type required under **19.4** to **19.6** shall be cut transversely across the longitudinal weld and alternately from the top and bottom circumferential welds on successive containers selected for test.

19.2 Tensile test on parent material

The tensile test specimens T1 and T2 (see Figure 3) shall be made from strips cut from a finished container with the axis of the strips, where possible, parallel to the axis of the container. Where necessary, test specimen T1 shall be cut transverse to the axis of the container as shown in Figure 3 b). The form and dimensions shall be as specified in **6.3** or **6.4** and Table 3 of BS 18:1987. The face and back of the test specimen shall not be machined, but shall represent the surface of the container as manufactured.

The tolerance on form (i.e. the difference between maximum and minimum values of a given dimension in any one test specimen) for the machined surfaces of a test specimen shall be in accordance with the tolerance grade IT 9 of BS 4500-1.

NOTE The test specimens may be carefully straightened cold as necessary to place them in the testing machine.

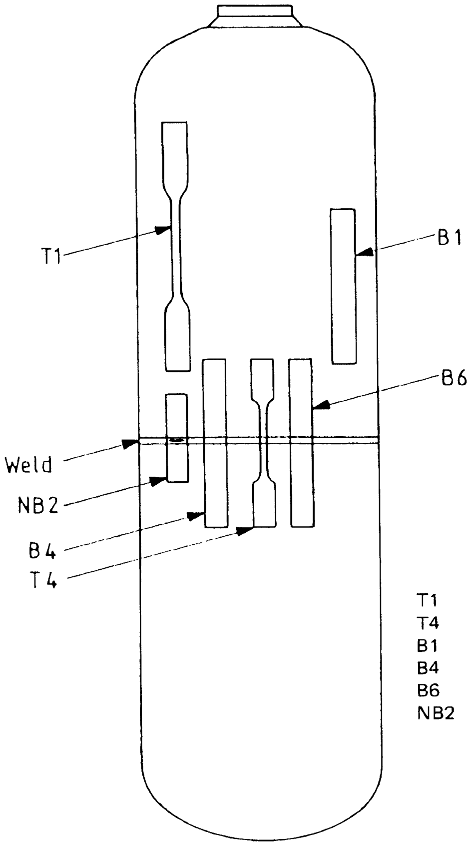
Tensile testing shall be carried out as specified in BS 18. The limit of error of measurement shall be not more than ± 0.5 % or 0.01 mm, whichever is the greater, as prescribed in **8.1** of BS 18:1987 and shall be interpreted as applying to each individual measurement. If individual measurements of the thickness of a test specimen, the two faces of which are formed by the surfaces of the container wall, differ from one another, the minimum value shall be taken for calculation.

When the parallel length is in excess of the gauge length a series of overlapping gauge lengths shall be marked, or alternatively gauge marks be applied every 5 mm, 10 mm or 20 mm along the parallel length so that the elongation on the prescribed gauge length can be determined by some suitable method of interpolation.

The tensile testing machine shall be maintained to grade 1.0 of BS 1610-1. The results obtained from the tensile test shall meet the requirements of Table 2 for the container material from which the specimens were taken.

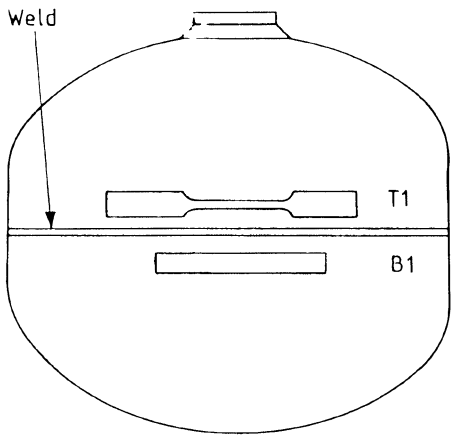
19.3 Bend test on parent material

The width of the test specimens B1 and B2 (see Figure 3) shall be not less than 25 mm or four times the minimum design thickness of the container as shown in the drawing(s), see **13.1**, (including any corrosion allowance), whichever is the greater. The face and back of the test specimen shall not be machined except that the edges may be rounded off. When bent at room temperature round a former, of diameter not greater than *n* times the thickness of the specimen, until the gap between the ends is not greater than the diameter of the former, the specimen shall remain uncracked. Values of *n* are given in Table 8.



T1 Tensile test on parent material
T4 Tensile test on welded joint
B1 Bend test on parent material
B4 Bend test on weld, outer surface in tension
B6 Bend test on weld, inner surface in tension
NB2 Nick-break test on weld

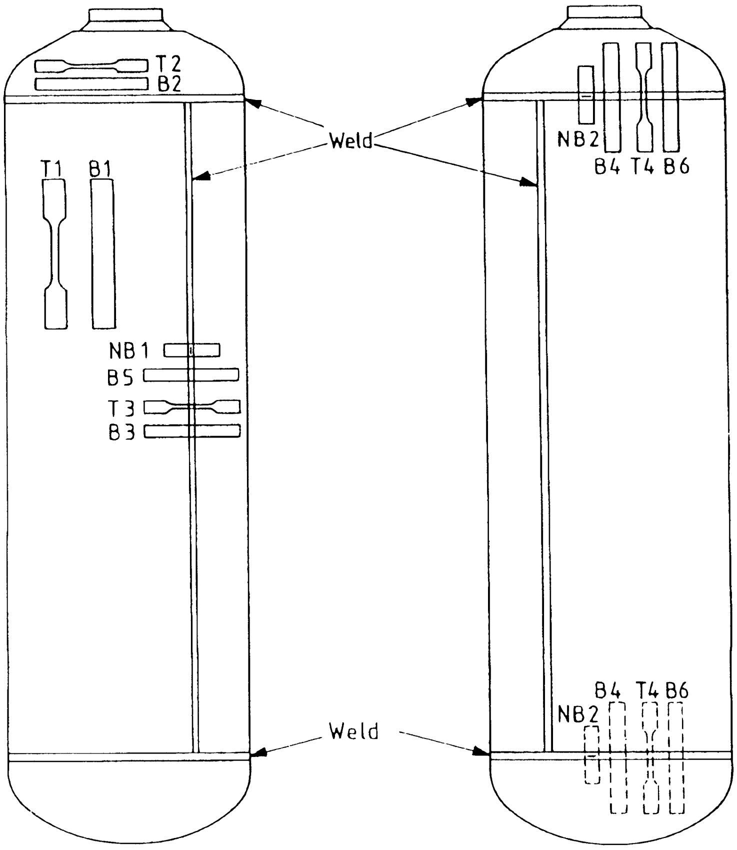
(a) Containers with circumferential seams only



(b) Containers with circumferential seams only. Alternative positions for T1 and B1

NOTE. The location of specimens around the circumference of the cylinder is not specified.

Figure 3 — Location of test specimens in a container



T1 Tensile test on parent material
T2 Tensile test on parent material
T3 Tensile test on weld
T4 Tensile test on weld (see **19.1** regarding alternate test specimens)
B1 Bend test on parent material
B2 Bend test on parent material
B3 Bend test on weld outer surface in tension
B4 Bend test on weld outer surface in tension (see **19.1** regarding alternate test specimens)
B5 Bend test on weld inner surface in tension
B6 Bend test on weld inner surface in tension (see **19.1** regarding alternate test specimens)
NB1 Nick-break test on weld
NB2 Nick-break test on weld (see **19.1** regarding alternate test specimens)

(c) Containers with longitudinal and circumferential seams

Figure 3 — Location of test specimens in a container *(concluded)*

Table 8 — Ratio *n* between the diameter of the former and the thickness of the bend test specimen

Actual tensile strength	Value of *n*
N/mm^2	
Up to 440 inclusive	2
above 440 to 520 inclusive	3
above 520 to 560 inclusive	4
above 560	5

19.4 Tensile test on the welds

The test specimens T3 and T4 (see Figure 3) shall be cut transversely to the weld and shall be the full thickness of the material at the welded joint. The shape and dimension of the test specimen shall be as shown in Figure 4.

In preparing the test specimens the face and back shall not be machined except to remove the backing strip or the tongue of a joggle joint. The face and back of the test piece shall each represent the surface of the parent material and the weld.

NOTE The test specimens may be carefully straightened cold as necessary in order to place them in the testing machine.

The tensile strength shall be not less than that specified for the parent material and where there are different parent materials joined by the weld it shall be not less than that specified for the parent material with the lowest tensile strength.

Tensile testing shall be carried out as specified in BS 18. The tolerance on form and limits of error measurement shall be as described in **19.2**. The tensile testing machine shall be maintained to grade 1.0 of BS 1610-1.

19.5 Bend test across the welds

The width of the test specimen shall be 25 mm or four times the design thickness of the container, whichever is the greater. In preparing the test specimen the corners shall be rounded off and the backing strip or the tongue of a joggle joint and any weld reinforcement shall be machined off before testing.

Specimens B3 and B4 (see Figure 3) shall be bent with the outer surface of the weld in tension, and specimens B5 and B6 (see Figure 3) with the inner surface of the weld in tension.

When bent at room temperature round a former, of diameter not greater than *n* times the thickness of the specimen, until the gap between the ends is not greater than the diameter of the former, the specimen shall remain uncracked. Values of *n* are given in Table 8.

In a joggle joint welding configuration defects in the exposed end grain of the material shall not be sufficient reason for rejection, providing all other material tests are passed.

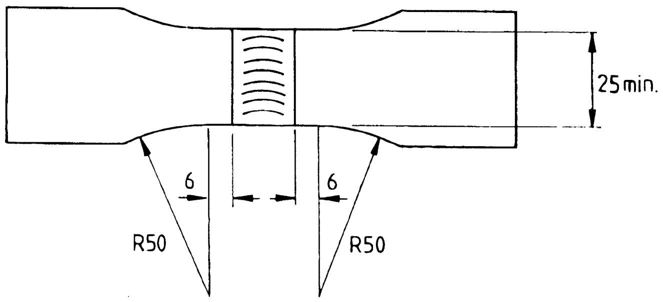
19.6 Nick-break test on the welds

Two nick-break test specimens shall be made, the specimens NB1 and NB2 (see Figure 3) being similar to those required for a bend test, except that a slot is cut along the weld on each side at the centre line. The slot shall be of a form shown in Figure 5. The specimen shall then be broken cold in the weld by pressure or blows applied to one of the slotted faces, and the fracture shall reveal a sound, homogeneous weld with complete penetration, free from oxide, slag inclusions or excessive porosity.

20 Hydraulic tests

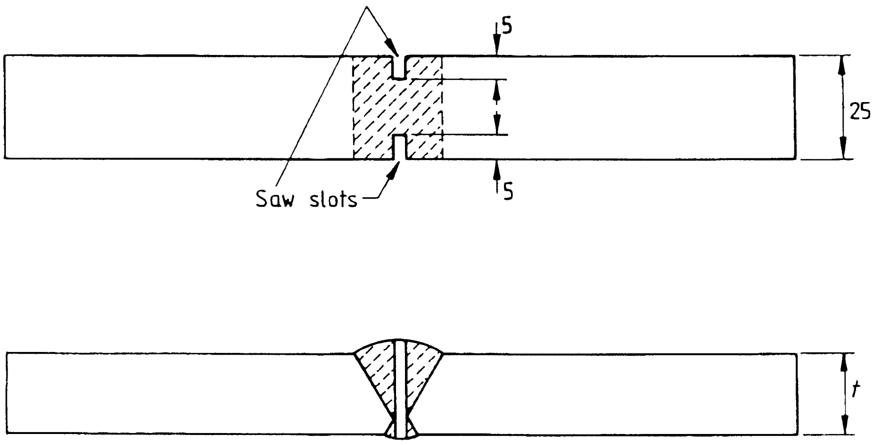
20.1 General

After heat treatment the container(s) selected in accordance with **18.2** and **18.3** shall be subjected to a proof pressure test (as described in Appendix A) or a volumetric expansion test.The preferred method for the volumetric expansion test is the “water jacket” method (see Appendix B).



All dimensions are in millimetres.

Figure 4 — Reduced section tensile test specimen



All dimensions are in millimetres.

Figure 5 — Nick-break test specimen

20.2 Test pressure

The test pressure shall be determined by the requirements of section 3.

No pressure greater than 80 % of the test pressure shall have been applied to any container before the test.

20.3 Proof pressure test

NOTE More than one container may be tested at a time provided that they all have the same test pressure and that each individual container is capable of being isolated so that a faulty container may be identified.

20.3.1 When subjected to a proof pressure test as described in Appendix A the container shall show no sign of leakage or visible deformation other than the normal volumetric expansion that is experienced at test pressure.

20.3.2 Any container that fails to comply with **20.3.1** shall be rendered unserviceable for further use in accordance with **27.6**.

20.4 Volumetric expansion test

When tested using the water jacket volumetric expansion test described in Appendix B the permanent volumetric expansion shall not exceed 10 % of the total expansion under the test pressure.

If the test is made by the "non-water jacket method" (see **B.4**) the container shall be examined for signs of leakage when subjected to the test pressure.

Should the permanent volumetric expansion of a container, selected as specified in **18.1.3**, **18.2.6** or **18.3.4**, exceed 10 % of the total expansion under the test pressure, the procedure laid down in **27.5** shall be followed.

20.5 Drying of containers

Unless the testing medium is compatible with the gas to be used the container(s) shall be thoroughly purged following testing. When water has been used as the test medium the interior of each container shall be thoroughly dried.

21 Hydraulic bursting test

Containers selected as specified in **18.1.3**, **18.2.6** or **18.3.2** shall be hydraulically tested to destruction. The nominal hoop stress corresponding to the pressure at which destruction occurs shall be calculated from the formula:

$$f_b = \frac{P_b D_i}{20t} \quad (7)$$

where

- f_b is the nominal hoop stress (in N/mm^2) at which destruction occurs;
- P_b is the internal pressure (in bar) at which destruction occurs;
- D_i is the nominal original internal diameter (in mm), of the container;
- t is the minimum design thickness (in mm) as specified on the drawing(s) (including any corrosion allowance) of the wall of the container.

The value of f_b shall be not less than 95 % of the minimum specified tensile strength of the material of the container (see Table 2). The container shall burst without fragmentation.

22 Checking of water capacity

The water capacity of each container shall be checked. This shall be done by weighing the empty container, and then by filling the container with a calibrated volume of liquid or by other means approved by the independent inspecting authority in order to ensure compliance with the required minimum specified water capacity (see **4.1**).

For dissolved acetylene containers the water capacity shall be recorded, see BS 6061.

23 Tightness test

After each container has complied with **20.3** it shall show no signs of leakage when subjected to an internal pneumatic pressure of 7 bar. Any leakage shall be detected either by immersing the container in water, by applying a soap solution to the welds or any other test of equivalent sensitivity. If any leakage occurs the container shall be regarded as having failed the test.

24 Prototype fatigue tests

24.1 New designs

NOTE For new designs the independent inspecting authority may consider that the prototype test may be waived in the light of tests that have been carried out on containers of similar design.

For the purpose of this standard a container shall be considered to be of a new design, compared to an existing approved design, when one of the following applies:

a) it is manufactured in a different factory;

b) it is manufactured by a different process;

c) it is manufactured from a different material;

d) it is given a different heat treatment;

e) the base profile and the base thickness have changed relative to the container diameter and calculated wall thickness;

f) the specified minimum yield stress has changed by more than 50 N/mm^2;

g) the length of the container has increased by more than 50 %;

h) the diameter has changed by more than 5 %;

i) a change in hydraulic test pressure has caused a change in wall thickness (a container used for a duty requiring a lower test pressure than that for which the design approval has been given shall not be deemed to be of a new design).

24.2 Pressure cycling test

24.2.1 Where the duty is such that in the opinion of the independent inspecting authority a fatigue test is necessary, three containers from the first batch or production run made to a new design shall be submitted to the pressure cycling test. The containers shall be certified by the manufacturer to be representative of his design and manufacturing procedure.

24.2.2 The test shall be carried out using a non-corrosive fluid with a range of pressure equivalent to either the test pressure or the charging pressure of the container. The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure. The frequency of reversals shall not exceed 15 cycles/min. The temperature measured on the outside surface of the container shall not exceed 50 °C during the test.

24.2.3 The containers shall be considered to have passed the test if they satisfactorily complete, without any sign of leakage, either:

a) 12 000 cycles over a range equivalent to 0.9 × test pressure; or

b) 80 000 cycles over a range equivalent to 0.6 × test pressure.

Containers designed to convey acetylene shall be considered to have passed if they satisfactorily complete 80 000 cycles over a range equivalent to 0.3 × test pressure without any sign of leakage.

25 Radiographic examination of welds

25.1 Number of containers to be radiographed

25.1.1 *Class I containers.* The entire length of all pressure containing welds on every container shall be radiographed.

25.1.2 *Class IA and IB containers.* Upon the introduction, or reintroduction after stoppages exceeding three days, of a discrete design of container to a production line, the first container welded, or more, from each welding machine, at the discretion of the independent inspecting authority, shall be radiographed over the full length of the circumferential and longitudinal welds and of bung or boss butt-welds in order to establish satisfactory machine settings. The radiographs shall be assessed in accordance with **25.3** and bulk production shall not commence unless they are found to be satisfactory.

Thereafter during production of that design of container, in order to demonstrate that satisfactory welds are being produced consistently, one container shall be selected at random from each welding machine at the beginning and end of each working shift's production or at intervals not exceeding 12 h, whichever is the shorter, and radiographed. For three-piece containers the radiography shall be carried out at the intersection of the welds for a distance of 100 mm beyond the intersection in the case of the longitudinal weld and 50 mm (25 mm on each side) in the case of circumferential welds. The last container produced from each welding machine in any production run shall be fully radiographed. If the radiographs show no unacceptable defects, the whole of the production of the relevant working shift shall be accepted subject to further tests as specified in clause **18**.

Should any of the radiographs show an unacceptable defect, production shall be stopped and the whole of the relevant shift's production shall be quarantined until it is demonstrated that the containers are satisfactory, either by radiography or by other appropriate means approved by the independent inspecting authority.

Production shall not be started until the cause of the defect has been established and rectified, and the starting up test procedure, as specified above, has been repeated.

Class IB containers shall either have all pressure containing welds made with a double run; or all pressure containing welds made in a single run shall be fully radiographed.

Any weld repairs agreed by the independent inspecting authority shall be carried out in accordance with clause **26**.

NOTE Containers selected for radiography may be those containers which are to be used for destructive mechanical testing.

25.1.3 *Class IAC.* The two containers selected in accordance with **18.1** and **18.2** shall be radiographed over the pressure containing welds, before being subjected to the tests specified in clauses **19** and **20**.

25.1.4 *Classes IIA and IIB containers.* Containers having a minimum design thickness, as specified on the drawing (s), of 6 mm or greater, selected for the hydraulic bursting test, shall be radiographed over the pressure containing welds.

NOTE No radiography is required for containers to classes IIA or IIB construction having a minimum specified design thickness less than 6 mm.

25.2 Radiographic techniques

25.2.1 Radiographic examination of the circumferential and longitudinal welds in containers shall be carried out by the double wall, single image (or where practicable, double image) method using a radiographic technique which is sufficiently sensitive to reveal a defect having a thickness equal to 2 % of the combined thickness of the weld and the backing material.

NOTE Reference should be made to BS 2910.

25.2.2 Radiographic examination of bung and boss butt welds in containers shall be carried out using, where possible, a direct film technique. The sensitivity of the technique shall be as given in **25.2.1**.

Radiographic examination of bung and boss fillet welds shall be augmented with a macro-examination of the weld taken from a container selected for mechanical tests.

25.3 Assessment of radiograph

The radiograph shall show that the pressure containing welds have complete penetration and are free from significant defects especially those likely to be of a repetitive character. Particular attention shall be given to the radiograph of the initial test or tests as specified in **25.1.2**. In judging what constitute unacceptable defects the provisions of Table 5 of BS 4870-1:1981 shall be followed as far as they are relevant.

26 Repair of welds

26.1 If during the hydraulic or tightness tests minor leaks are found, or if minor but unacceptable defects are found by radiography the weld shall, at the discretion of the independent inspecting authority, either be repaired by rewelding by mechanized or manual means or the container shall be rendered unserviceable in accordance with **27.6**.

26.2 All weld repairs shall be radiographed except repairs to containers of less than 6 mm wall thickness of class IIA or IIB. After rewelding and where necessary re-radiography all containers shall be re-heat treated as part of a batch or production run in accordance with clause **16**, and then shall be retested in accordance with clauses **19** to **25**.

27 Results of mechanical and pressure tests

27.1 If any of the mechanical tests required under **19.1**, except the nick-break test, results in failure then, at the manufacturer's discretion, the procedures in either **27.2** or **27.3** shall be followed.

27.2 The mechanical tests in which the failure occurred shall be repeated on a test specimen cut from the same container and all the mechanical tests required under **19.1** shall be carried out on another container from the same batch or production run. If both containers then comply with **19.2** to **19.6**, the batch or production run, if otherwise complying with this standard, shall be accepted.

27.3 Alternatively the batch or production run shall be re-heat treated in accordance with clause **16** and the tests required under **19.1** shall be carried out on two further containers from the batch or production run. If both containers then comply with **19.2** to **19.6**, the batch or production run, if otherwise complying with this standard, shall be accepted.

27.4 If any of the mechanical tests specified in **27.2**, results in failure, the batch or production run shall either be rejected or if applicable re-heat treated and retested in accordance with **27.3** and be accepted if it then complies with **19.2** to **19.6** and otherwise complies with this standard.

27.5 If the containers selected for test under clause **18** fail because of any of the following reasons:

a) excessive expansion when subjected to the hydraulic volumetric expansion test;

b) the container pressure at destruction was below that specified;

c) the container burst with fragmentation;

d) an unacceptable weld in the nick-break test, or if a batch of containers, having been re-heat treated and tested as given in **27.3** is rejected, no further containers shall be accepted from the production line concerned until it has been demonstrated to the satisfaction of the independent inspecting authority that the cause of the failure has been identified and corrected.

No container from the batch that failed shall be accepted by the independent inspecting authority unless it has been demonstrated to that authority that each of such containers is free from the defect which caused the failure.

27.6 Any container not accepted by the independent inspecting authority shall be rendered permanently unserviceable for holding gas under pressure. The procedure used for the destruction of such containers shall be acceptable to the independent inspecting authority.

28 Final internal inspection

28.1 All moisture and other foreign matter shall be completely removed from the interior of each container and its cleanliness checked with the use of an inspecting lamp.

28.2 The cleaning operation specified in **28.1** shall be carried out immediately prior to assembly of valves, fittings or sealing plugs as appropriate.

Section 6. Marking of containers

29 Information to be marked

Each container shall be permanently and legibly marked with the following information:

a) the manufacturer's mark and container serial number;

b) the date of test (indicated by the month and year, or by the year followed by a number within a circle to denote the quarter of the year) and the identification mark of the person or firm who made the test;

c) the identification mark(s) of the independent inspecting authority;

d) the number of this British Standard, i.e. BS 5045-2[3], followed by the class of construction, e.g. BS 5045/2/1A. Where construction to this standard is called for in another British Standard, that British Standard number only shall be marked, e.g. for dissolvedacetylene containers reference should be made to BS 6061 and markings made accordingly;

e) the test pressure (in bar);

f) the charged pressure (in bar) at 15 °C if the container is intended to be used for permanent gases;

g) the minimum designed water capacity (in litres) of the container as fitted with dip tube, valve, etc., if it is intended to be used for liquefiable gases;

h) the mass (in kg) of the empty container only, if it is intended to be used for permanent gases;

i) the tare (in kg), i.e. the mass of the container, valve and dip tube where applicable (excluding the valve loose cap or cover), if it is intended to be used for liquefiable gases;

j) the type letter of the steel used in the construction of the container;

k) in the case of containers made from different materials with different mechanical properties, the type letter of the steel used for the cylindrical part of the shell followed by that used for the ends.

30 Method of marking

Where possible the characters in the marking shall be at least 6 mm in height. In no case shall the characters be less than 3 mm in height. They shall be permanently and legibly marked on:

a) a label which is securely attached to the container; or

b) the foot ring if this is permanently welded to the container; or

c) a valve shroud securely attached to the container; or

d) the valve boss.

If welding is not used as the method of attachment in the case of a) or c) there shall be other permanent means of identifying the container.

[3] Marking BS 5045-2 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Appendix A Hydraulic proof pressure test

A.1 General

This appendix describes an example of a method for carrying out the hydraulic proof pressure test.

Containers if tested in batches shall be of the same test pressure, established as described in section 3, which shall not be exceeded by 3 % or 10 bar, whichever is the lower.

A.2 Equipment

A.2.1 All rigid pipework, flexible tubing, valves, fittings and components forming the pressure test equipment should be capable of withstanding a pressure 1.5 times the maximum test pressure of any container that may be tested. Flexible tubing should have sufficient wall thickness to prevent kinking.

A.2.2 Pressure gauges should comply with the requirements of the industrial class of BS 1780 and have a scale range appropriate to the container test pressure.

They should be tested and recalibrated as necessary, at regular intervals and in any case not less frequently than once per month against a dead weight tester.

A.2.3 A device should be fitted to the test equipment to ensure that no container is subjected to a pressure in excess of its test pressure by more than the tolerances in **A.1**.

A.2.4 All joints shall be leaktight.

A.2.5 The design and installation of the equipment and of the containers connected to it should be such as to avoid trapping air in the system.

NOTE An example of the equipment required is shown in Figure 6.

A.3 Procedure

Carry out the following procedure.

a) Completely fill all container(s) with water.

b) Connect the container(s) to the test equipment as shown in Figure 6, leaving all valves open.

c) Fill the pump and pipework system with water and close the air bleed valve when water appears. Close the bypass valve.

d) Remove any excess water from the outside of the container(s).

e) Operate the pump until the test pressure is reached. Stop the pump and close the hydraulic line valve.

f) Check that the test pressure remains constant for a minimum period of 1 min.

g) Inspect the container(s) visually. The presence of water is an indication of either:

1) a leaking connection to a container; or

2) a leak in a test container.

In case 1) the system is depressurized, the connection made good and the test repeated on the batch.

In case 2) the faulty container(s) is isolated and the test continued on the remainder of the batch.

h) If at the end of the test period the pressure in the system has fallen, this may indicate that one or more of the containers has failed under pressure.

In this event the whole test batch is retested, individually if necessary, to identify the faulty container(s).

Appendix B Hydraulic volumetric expansion test

B.1 General

This appendix gives details of two methods for determining the volumetric expansion of welded steel gas containers:

a) the water jacket method (preferred method);

b) the non-water jacket method.

The water jacket volumetric expansion test may be carried out using equipment with a levelling burette or with a fixed burette.

B.2 Equipment

NOTE **B.2.1** to **B.2.7** are general to both methods of test.

B.2.1 Hydraulic test pressure pipelines should be capable of withstanding a pressure twice the maximum test pressure of any container that may be tested.

B.2.2 Glass burettes should be of sufficient length to receive water equivalent to the full volumetric expansion of the container and capable of being read to an accuracy of 1 mL.

B.2.3 Pressure gauges should comply with the requirements of the industrial class of BS 1780. They should be tested at regular intervals and in any case not less frequently than once per month.

B.2.4 A device should be fitted to ensure that no container is subjected to a pressure in excess of its test pressure.

B.2.5 Pipework should use long bends in preference to elbow fittings, and pressure pipes should be as short as possible. Flexible tubing should be capable of withstanding twice the maximum test pressure in the equipment and have sufficient wall thickness to prevent kinking.

B.2.6 All joints shall be leaktight.

B.2.7 The installation of the equipment should be such as to avoid trapping air in the system.

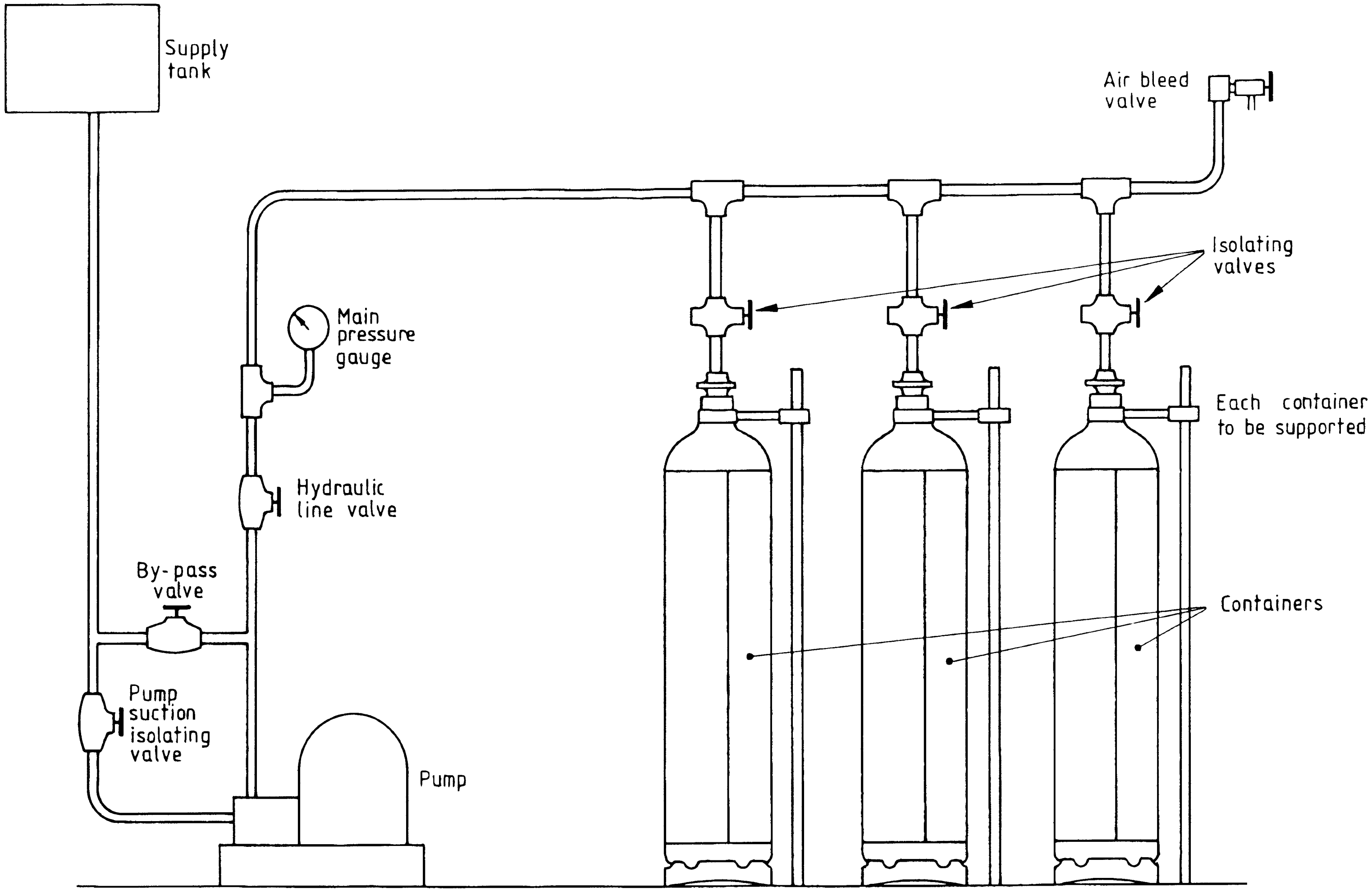


Figure 6 — Example of hydraulic proof pressure test equipment

B.3 Water jacket volumetric expansion test

B.3.1 ***Principle***

This method of test necessitates enclosing the water-filled container in a jacket also filled with water. The total volumetric expansion of the container is measured by the amount of water displaced from the jacket when the container has been pressurized. The permanent volumetric expansion of the container is measured by the amount of water which continues to be displaced from the jacket when the pressure has been released.

B.3.2 ***Additional equipment***

The water jacket should be fitted with a safety device capable of releasing the energy from any container that may burst at the test pressure.

An air bleed valve should be fitted to the highest point of the jacket.

B.3.3 ***Procedure***

B.3.3.1 *General.* Two methods of performing this test are described in **B.3.3.2** and **B.3.3.3**. Other methods are acceptable provided that they are capable of measuring the total and, if any, the permanent volumetric expansions of the container.

B.3.3.2 *Water jacket volumetric expansion test: levelling burette method.* An example of the equipment required is shown in Figure 7, but other types of installation may be acceptable.

Carry out the following procedure.

a) Fill the container with water and attach the water jacket cover to it.

b) Seal the container in the jacket and attach the pressure line to the container.

c) Fill the jacket with water, allowing air to bleed off through the air bleed valve. Close the air bleed valve when water issues freely from it.

d) Adjust the zero level on the burette to the datum mark on the burette support stand. Adjust the height of the water to the burette zero level by manipulation of the jacket filling valve and the drain valve.

e) Raise the pressure in the container to two-thirds of the test pressure. Close the hydraulic line valve and check that the burette reading remains constant.

NOTE A rising water level indicates a leaking joint between the container and the jacket. A falling water level indicates a leaking joint between the water jacket and the atmosphere.

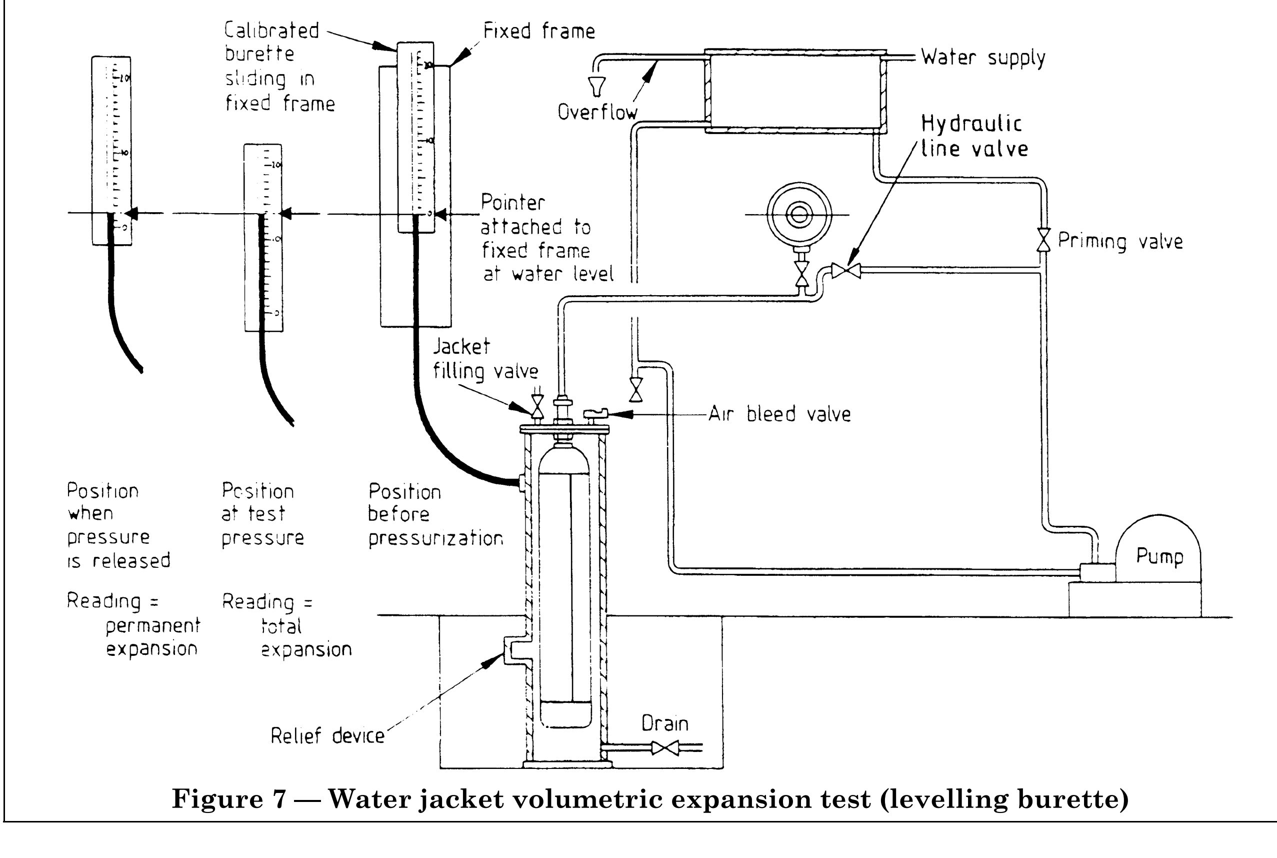


Figure 7 — Water jacket volumetric expansion test (levelling burette)

f) Open the hydraulic line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic line valve.

g) Lower the burette until the water level is at the datum mark on the burette support stand. Take the reading of the water level in the burette. Record this reading, the total expansion, on the test certificate.

h) Open the hydraulic line drain valve to release pressure from the container. Raise the burette until the water level is again at the datum line on the burette support stand. Check that the pressure is at zero and that the water level is constant.

i) Read the water level in the burette. Record this reading, the permanent expansion, if any, on the test certificate.

j) Check that the permanent expansion does not exceed 10 % of the total expansion as determined by the following equation.

$$\frac{\text{Permanent expansion} \times 100}{\text{Total expansion}} = \%$$

B.3.3.3 *Water jacket volumetric expansion test: fixed burette method.* An example of the equipment required is shown in Figure 8, but other types of installation may be acceptable.

Carry out the following procedure.

a) Fill the container with water and attach the water jacket cover to it.

b) Seal the container in the jacket and attach the pressure line to the container.

c) Fill the jacket with water, allowing air to bleed off through the air bleed valve. Close the air bleed valve when water issues freely from it.

d) Adjust the water level to the zero mark on the burette by manipulation of the jacket filling valve and the drain valve.

e) Raise the pressure in the container to two-thirds of the test pressure. Close the hydraulic line valve and check that the burette reading remains constant.

NOTE A rising water level indicates a leaking joint between the container and the jacket. A falling water level indicates a leaking joint between the water jacket and the atmosphere.

f) Open the hydraulic line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic line valve.

g) Read the level of the water in the burette. Record this reading, the total expansion, on the test certificate.

h) Open the hydraulic line drain valve to release pressure from the container. Check that the pressure is at zero and that the water level is constant.

i) Read the level of the water in the burette. Record this reading, the permanent expansion, if any, on the test certificate.

j) Check that the permanent expansion does not exceed 10 % of the total expansion as determined by the following equation.

$$\frac{\text{Permanent expansion} \times 100}{\text{Total expansion}} = \%$$

B.4 Non-water jacket volumetric expansion test

B.4.1 ***Principle***

This method consists of measuring the amount of water passed into the container under proof pressure and, on release of this pressure, measuring the water returned to the manometer. It is necessary to allow for the compressibility of water, and the volume of the container under test to obtain true volumetric expansion. No fall in pressure under this test is permitted.

B.4.2 ***Additional equipment***

The equipment should be arranged such that all air can be removed. The glass tube reservoir should be calibrated in millilitres and be accurate to 1 % of the reading. It should be so arranged that accurate readings can be determined of the volume of water required to pressurize the filled container, and of the volume expelled from the container when depressurized. In the case of larger containers, it may be necessary to augment the glass tube with metal tubes arranged in a manifold.

The pressure gauge should be calibrated as given in BS 1780.

If a single-acting hydraulic pump is used, care should be taken to ensure that the piston is in the "back" position when water levels are noted.

The water used should be free of air. Any leakage from the system or the presence of free or dissolved air will result in false readings.

Every care should be taken to maintain steady temperature conditions and sufficient time should be allowed to permit the apparatus, the containers and the water to attain a uniform constant temperature.

The equipment should be installed as shown in Figure 9. The water supply pipe should be connected to an overhead tank C as shown, or to some other supply giving a sufficient head of water.

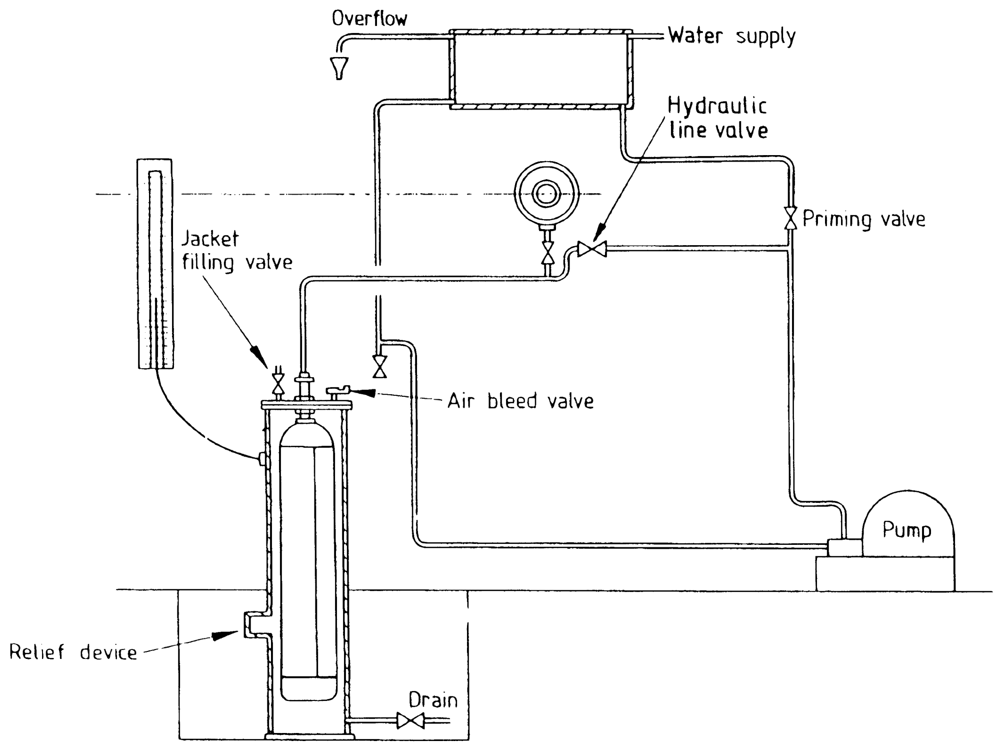


Figure 8 — Water jacket volumetric expansion test (fixed burette)

B.4.3 ***Procedure***

Carry out the following procedure.

a) Completely fill the container with water and determine the mass of water in it.

b) Connect the container to the hydraulic test pump through coil A and check that all valves are closed.

c) Fill the pump and system with water from tank C by opening valves D, E and H.

d) To ensure expulsion of air from the system, close valve H and raise the system pressure to approximately one-third of the test pressure. Open bleed valve G to release trapped air by reducing the system pressure to zero, and reclose valve G. Repeat if necessary.

e) Continue to fill the system until the level in glass tube M is approximately 300 mm from the top of this tube. Close valve D and mark the water level by pointer P, leaving valves E and H open. Record the level.

f) Close valve H. Raise the pressure in the system until the check pressure gauge K indicates the required test pressure. Stop the pump. After approximately 30 s there should be no change in either water level or pressure.

NOTE A change in level indicates leakage. A falling pressure, if there is no leakage, indicates that the cylinder is still expanding under pressure.

g) Record the fall of water level in the glass tube. Providing there has been no leakage, the water drained from the glass tube will have been pumped into the container to achieve the test pressure. This difference in water level is the total volumetric expansion of the container plus an amount attributable to the compressibility of water.

h) Open valve H slowly to release the pressure in the container and allow water so released to return to the glass tube. If the water level returns to a point below pointer P, this difference in level will denote the amount of permanent volumetric expansion in the container which is recorded on the test certificate.

i) Before disconnecting the container from the test rig, close valve E. This will leave the pump and system full of water for the next test, however, stage d) is repeated at each subsequent test.

j) If permanent volumetric expansion has occurred, record the temperature of water in the container.

k) Calculate the percentage ratio of permanent expansion to total expansion using the method illustrated in **B.4.6**.

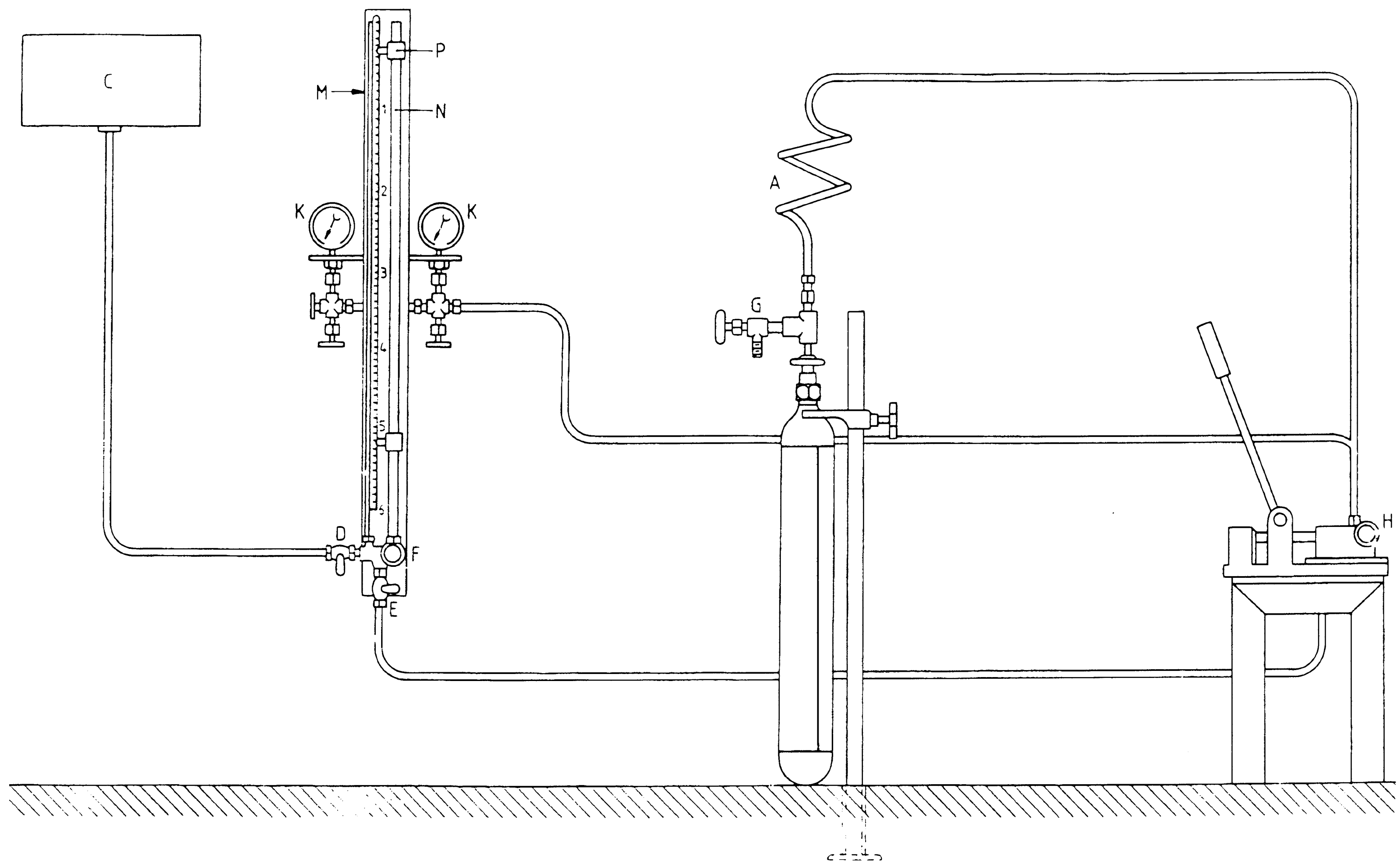


Figure 9 — Non-water jacket volumetric expansion test

B.4.4 ***Test results***

The tests determine the volume of water in millilitres required to pressurize the filled container to test pressure.

The total mass and temperature of water in the container are known, enabling the change in volume of the water in the container due to its compressibility to be calculated (see **B.4.5**). The volume of water expelled from the container when depressurized is known. Thus total volumetric expansion and permanent volumetric expansion can be determined.

The permanent volumetric expansion shall not exceed 10 % of the total volumetric expansion.

B.4.5 ***Calculation of compressibility of water***

The compressibility of water is calculated using the following formula.

$$C = mP\left(K - \frac{0.68P}{10^5}\right) \quad (8)$$

where

- C is the volume of water forced into the container due to the compressibility of water (in mL);
- m is the mass of water in the container at test pressure (in kg);
- P is the test pressure (in bar);
- K is a factor, dependent upon temperature.

Values of K are given in Table 9.

B.4.6 ***Example calculation***

In the following calculation, allowance for pipe stretch has been ignored.

Given that 1 kg of water occupies 1 L, a typical example is as follows.

Test pressure P	= 232 bar gauge
Mass of water in container at zero gauge pressure	= 113.8 kg
Temperature of water	= 15 °C
Volume of water forced into container to raise pressure to 232 bar	= 1 745 mL or 1.745 kg
Total mass of water m in container at 232 bar = 113.8 + 1.745	= 115.545 kg
Volume of water expelled from container to depressurize	= 1 742 mL
Permanent expansion (PE) = 1 745 – 1 742	= 3 mL
From Table 9, K factor for 15 °C water temperature	= 0.047 25
Using equation (8) the volume of water C forced into the container due to the compressibility of water at 232 bar and 15 °C = 115.5 × 232 (0.047 25 – 0.001 50)	= 1 224 mL
Total volumetric expansion (TE) = 1 745 – 1 224	= 521 mL
$\frac{PE \times 100}{TE} = \frac{3 \times 100}{521}$	= 0.58 %

Table 9 — *K* factors for the compressibility of water

Temperature	*K*	Temperature	*K*	Temperature	*K*
°C		°C		°C	
6	0.049 15	13	0.047 59	20	0.046 54
7	0.048 86	14	0.047 42	21	0.046 43
8	0.048 60	15	0.047 25	22	0.046 33
9	0.048 34	16	0.047 10	23	0.046 23
10	0.048 12	17	0.046 95	24	0.046 13
11	0.047 92	18	0.046 80	25	0.046 04
12	0.047 75	19	0.046 60	26	0.045 95

Appendix C Example of design procedure

C.1 Contents

The container is to be charged with 13 kg of commercial propane to BS 4250-1. A minimum liquid density should be determined and for the purpose of this example it will be assumed to be 0.505 g/mL at 15 °C and to contain more than 2 mol % of unsaturated C_2 hydro-carbons.

From clause **8** the reference temperature for the filling ratio is 45 °C and from BS 5355 the required filling ratio is therefore 0.433.

Thus the required minimum water capacity in terms of mass is 13/0.433 = 30.02 kg of water.

Since the density of water is 1 kg/L the capacity of the container is 30.02 L.

In this example no account has been taken of the allowance required for filling tolerances, etc. required by BS 5355.

C.2 Dimensions

Assuming that the container in **C.1** is required to have an internal diameter of 314 mm; then the effective internal length is not to be less than 388 mm. The actual length is determined taking into account the volume enclosed by the ends.

C.3 Material

Type B steel (see Table 2), with:

a) yield stress of 275 N/mm^2 [4)];

b) tensile strength of 400 N/mm^2.

C.4 Construction

The conditions do not make class I construction obligatory. Assume that class II is selected and that the container is made from two deep pressings with a central circumferential weld and with one of the domed ends having a bung, secured by welding, to accommodate the container valve. This form of construction will allow the container to be designed as class IIA provided that the requirements of **9.1.2** are met.

C.5 Calculation of minimum test pressure

From Table 4 the reference temperature for developed pressure is 55 °C and from BS 5355 the developed pressure p at 55 °C for commercial propane is 22.13 bar.

The ratio of $\dfrac{\text{yield stress } Y}{\text{tensile strength } T}$ for type B steel is 0.69.

Hence, from Table 7, test pressure $P_1 = p = 22.13$ bar.

C.6 Thickness of cylindrical wall

NOTE See **10.3**.

Equation (1) of 10.3 gives $t = \dfrac{0.3 P_1 D_i}{7 f_e - P_1}$

where

$P_1 = 22.13$ bar;

$D_i = 314$ mm;

$f_e = 0.75 \times 275 \times 0.85 = 175.3$ N/mm^2;

thus, $t = \dfrac{0.3 \times 22.13 \times 314}{7 \times 175.3 - 22.13} = 1.73$ mm.

However, the thickness (in mm) of the cylindrical wall shall not be less than the value given by equation (2) of **10.3**; thus

$$t = 2.48 \sqrt{\left(\frac{D_i}{T}\right)} = 2.2$$

Hence, the required minimum wall thickness is 2.2 mm and as this is determined from equation (2) the test pressure (in bar) has now to be calculated from equation (3) of **10.3**.

$$P_2 = \frac{7 f_e}{1 + 0.12\sqrt{(D_i T)}} = \frac{7 \times 175.3}{1 + 0.12\sqrt{(314 \times 400)}}$$

$= 28.19$

C.7 Thickness of domed end

NOTE See **10.6**.

Assume that the domed end is torispherical with an internal crown radius R_i of 251 mm, an internal knuckle radius r_i of 63.5 mm and a straight flange of not less than 8 mm. Thus the shape of the domed end complies with **10.5.3**.

For the calculation it is necessary to establish the shape factor K which depends on the values h_e/D_o and t_e/D_o.

Since the value of t_e is not highly critical in establishing the value of K, the calculated shell thickness t of 2.2 mm may be used. Hence the values to be used in the calculation of K are as follows:

$D_o = D_i + 2t = 318$ mm;

$R_o = R_i + t = 253$ mm;

$r_o = r_i + t = 66$ mm;

4) 1 N/mm^2 = 1 MPa.

h_e is the least of:

$$h_o = R_o - \sqrt{\left\{\left(R_o - \frac{D_o}{2}\right)\left(R_o + \frac{D_o}{2} - 2r_o\right)\right\}}$$

= 91 mm;

$D_o^2/4R_o$ = 100 mm;

$$\sqrt{\left(\frac{D_o r_o}{2}\right)} = 102 \text{ mm.}$$

Therefore

$h_e = h_o$ = 91 mm,

giving values of:

h_e/D_o = 0.286; and

t_e/D_o = 0.007.

Hence, from Figure 1 factor K = 0.84.

The thickness of the domed end (see **10.5.2**) shall be the greater of the values given by $t_e = tK$, i.e. 1.85 mm, or the wall thickness calculated in **C.6**, i.e. 2.2 mm.

Therefore, the thickness of the domed end shall be 2.2 mm.

C.8 Minimum bursting pressure

NOTE See clause **21**.

The nominal hoop stress corresponding to the pressure at which destruction occurs is calculated from equation (7):

$$f_b = \frac{P_b D_i}{20t}$$

Hence, the required minimum bursting pressure is

$$P_b = \frac{f_b 20t}{D_i}$$

Where

f_b = 0.95 T = 380 N/mm^2;

D_i = 314 mm;

t = 2.2 mm.

Thus

$$P_b = \frac{380 \times 20 \times 2.2}{314} = 53.25 \text{ bar}$$

C.9 Summary

Minimum wall thickness (shell and ends)	= 2.2 mm
Test pressure (see clause **20**)	= 28.19 bar
Minimum bursting pressure (see clause **21**)	= 53.25 bar

Appendix D Specimen certificate of compliance for welded steel gas containers

Certificate number ....

Date ....

Concerning the manufacture and testing of (quantity) steel containers for (designation or type of gas) according to BS 5045-2 for class ...... construction

Manufacturer:	**Name** **Address**		**Symbol**
Purchaser:	**Name** **Address**		

To purchaser's order no .... and container reference ....

Manufacturer's nos .... to ....

Purchaser's nos .... to ....

Technical data

Containers

The above containers are manufactured in accordance with BS 5045-2 and as detailed on approved drawing nos ....

Container test pressure = ... bar.

Container max. attainable pressure = ...bar.

Materials

Steel manufacturer: Name **Address** **Ref. no.**		**Steel specification** ....

Cast no.	Chemical composition																	
	C	Si	Mn	P	S	Nb												
Heat treatment	N ... normalized S ... stress relieved																	

Container heat treatment

Each of the above containers has been heat treated at a temperature between ....°C and ....°C for .... min.

Water capacity

The water capacity of each of the above containers has been checked and found to be not less than ......L.

Pressure test

Each of the above containers has been hydraulically tested at ..... bar and subsequently air tested at......bar.

Mechanical tests on representative container(s)

Test container serial no.	Containers represented by test	Tensile tests					180° bend test			Nick-break test		Minimum thickness	
		Symbol[a]	Cross-sectional area	Yield stress	Tensile strength	% Elongation on .... mm gauge	Symbol[a]	Former radius	Result	Symbol[a]	Result	Wall	End
			mm	N/m^2	N/m^2			mm				mm	mm
		T1					B1			NB1			
		T2					B2			NB2			
		T3					B3						
		T4					B4						
							B5						
							B6						
		T1					B1			NB1			
		T2					B2			NB2			
		T3					B3						
		T4					B4						
							B5						
							B6						
		T1					B1			NB1			
		T2					B2			NB2			
		T3					B3						
		T4					B4						
							B5						
							B6						

[a] Symbols refer to Figure 3.

Radiographic examination of welds

The welds of ....containers representing a batch of .... containers were radiographically examined and found to be satisfactory.

Hydraulic volumetric expansion and bursting tests

Test container number	Containers represented by test	Permanent/total expansion ratio ...... % at ...... bar	Bursting pressure		Nature of failure
			Calculated minimum	Actual	
			bar	bar	

Certified by .... Date ....
(for manufacturer)

On behalf of .... Date ....
(Independent inspecting authority)

Accepted by .... Date ....

blank

Publications referred to

BS 18, *Method for tensile testing of metals (including aerospace materials).*

BS 341, *Specification for valve fittings for compressed gas cylinders.*

BS 341-1, *Valves with taper stems (excluding valves used for breathing and medical purposes).*

BS 341-2, *Valves with taper stems for use with breathing apparatus (excluding medical gas cylinders to BS 1319).*

BS 499, *Welding terms and symbols.*

BS 499-1, *Glossary for welding, brazing and thermal cutting.*

BS 1319, *Specification for medical gas cylinders, valves and yoke connections.*

BS 1449, *Steel plate, sheet and strip.*

BS 1449-1, *Specification for carbon and carbon-manganese plate, sheet and strip.*

BS 1501, *Steels for pressure purposes: plates.*

BS 1501-1, *Specification for carbon and carbon manganese steels.*

BS 1610, *Materials testing machines and force vertification equipment.*

BS 1610-1, *Specification for grading of the forces applied by materials testing machines.*

BS 1780, *Specification for bourdon tube pressure and vacuum gauges.*

BS 1837, *Methods for the sampling of iron, steel, permanent magnet alloys and ferro-alloys.*

BS 2910, *Methods for radiographic examination of fusion welded circumferential butt joints in steel pipes.*

BS 2915, *Specification for bursting discs and bursting disc devices.*

BS 3894, *Method for converting elongation values for steel.*

BS 3894-1, *Carbon and low alloy steels.*

BS 4250, *Liquefied petroleum gas.*

BS 4250-1, *Specification for commercial butane and propane.*

BS 4500, *ISO limits and fits.*

BS 4500-1, *General, tolerances and deviations.*

BS 4580, *Specification for number designation of organic refrigerants.*

BS 4870, *Specification for approval testing of welding procedures.*

BS 4870-1, *Fusion welding of steel.*

BS 4871, *Specification for approval testing of welders working to approved welding procedures.*

BS 4871-1, *Fusion welding of steel.*

BS 5045, *Transportable gas containers.*

BS 5045-1, *Specification for seamless steel gas containers above 0.5 litre water capacity*[5)].

BS 5045-3, *Specification for seamless aluminium alloy gas containers above 0.5 litre water capacity and up to 300 bar charged pressure at 15 °C*[5)].

BS 5045-5, *Specification for aluminium alloy containers above 0.5 litre up to 130 litres water capacity with welded seams*[5)].

BS 5045-6, *Specification for seamless containers of less than 0.5 litre water capacity*[5)].

BS 5306, *Fire extinguishing installations and equipment on premises.*

BS 5355, *Specification for filling ratios and developed pressures for liquefiable and permanent gases.*

BS 5423, *Specification for portable fire extinguishers.*

BS 5500, *Specification for unfired fusion welded pressure vessels.*

BS 6061, *Specification for transportable acetylene containers.*

Euronorm 120 Steel sheet and strip for welded gas cylinder.

[5)] Referred to in the foreword only.

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