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British Standard

# Transportable gas containers

## Part 5. Specification for aluminium alloy containers above 0.5 litre up to 130 litres water capacity with welded seams

Bouteilles à gaz transportables
Partie 5. Bouteilles en alliages d'aluminium, à joints soudés, de capacité en eau comprise entre 0,5 litre (exclu) et 130 litres – Spécifications

Transportable Gasbehälter
Teil 5. Behälter aus Aluminiumlegierungen mit mehr als 0,5 Liter bis 130 Liter Volumen mit Schweißnähten

British Standards Institution

# Foreword

This British Standard prepared under the direction of the Pressure Vessel Standards Committee, is one of the series based on the recommendations of the report, published 1969, of the Home Office Gas Cylinders and Containers Committee for materials, design, construction, testing, filling and maintenance of new containers intended for the conveyance by road of permanent, liquefiable and dissolved gases under pressure.

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

Part 1 Specification for seamless steel gas containers above 0.5 litre water capacity

Part 2 Steel containers up to 130 litres water capacity with welded seams

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

Part 4 Specification for steel containers of over 450 litres water capacity with circumferential and longitudinal welded seams*

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 up to and including 0.5 litre water capacity

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

*In preparation.

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# Section one. General

## 1 Scope

This Part of BS 5045 specifies requirements for the materials, design, construction and testing of containers for the conveyance of gases under pressure; such containers are suitable also for storing gas under pressure. It applies to aluminium alloy containers of water capacity above 0.5 litre up to 130 litres having longitudinal and/or circumferential seams, made by mechanized TIG or MIG 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* 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.

## 3 Classification of gases

### 3.1 General

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

(a) *Permanent gas.* A gas that has a critical temperature below -10 °C.

(b) *Liquefiable gas.* A gas that is liquefiable by pressure at -10 °C but which is completely vapourized below 17.5 °C when at 1013 mbar*.

(1) *High pressure liquefiable gas.* A gas that has a critical temperature from -10 °C to 70 °C inclusive.

(2) *Low pressure liquefiable gas.* A gas that has a critical temperature above 70 °C.

Any toxic substance that is liquid at 1013 mbar pressure at 0 °C, but that boils at or below 30 °C at that pressure, shall be treated as a low pressure liquefiable gas.

Gases that may be contained in aluminium alloy containers are classified in table 1.

### 3.2 Gases that shall not be contained in aluminium alloy containers

Subject to the exception stated, the following gases shall not be contained in aluminium alloy containers. Certain of these gases may however be contained in aluminium alloy containers in small quantities as components of gas mixtures. Approval for such use shall be sought from the Health and Safety Executive.

acetylene
boron trifluoride
bromotrifluoroethylene
carbonyl chloride
chlorine
chlorine trifluoride
cyanogen chloride
fluorine
hydrogen bromide
hydrogen chloride
hydrogen fluoride
methyl bromide
methyl chloride
nitrosyl chloride

### 3.3 Unlisted gases

For conditions pertaining to the carriage in aluminium alloy containers of a gas not listed in table 1 or 3.2, reference shall be made to the Health and Safety Executive.

## 4 Information to be supplied by the purchaser and the manufacturer

### 4.1 Information to be supplied by the purchaser

It is essential that the purchaser supplies the manufacturer with the following information as appropriate:

(a) name or classification of gas(es);

(b) class of construction (e.g. BS 5045 : Part 5, class IA);

(c) volumetric capacity (minimum for liquefiable gases);

(d) for permanent gases, the charged 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) materials of construction;

(g) preferred dimensions;

(h) type of base;

(i) internal and/or external neck screwing dimensions;

(j) fittings required;

(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) whether any addition is required to the requirements of this standard;

(n) the name of the Independent Inspecting Authority.

*1 bar = $10^5$ N/m$^2$ = $10^5$ Pa.

**Table 1. Classification of gases suitable for conveyance in welded aluminium alloy containers**

| **Permanent gases** ($T_c < -10\,^\circ C$) | **Liquefiable gases** | |
|---|---|---|
| | **High pressure** ($-10\,^\circ C \leq T_c \leq 70\,^\circ C$) | **Low pressure** ($T_c > 70\,^\circ C$) |
| Air | Bromotrifluoromethane (R13B1) | Allene* |
| Argon | Carbon dioxide | *Ammonia*† |
| Carbon monoxide*† | Chlorotrifluoromethane (R13) | Arsine*† |
| Carbon tetrafluoride (R14) | Diborane†‡ | Bromochlorodifluoromethane (R12B1) |
| Coal gas*† | 1,1-Difluoroethylene (R1132a)* | Butadiene* |
| Deuterium* | Ethane* | Butane* |
| Helium | Ethylene* | 1 Butene* |
| Hydrogen* | Hexafluoroethane (R116) | 2 Butene* |
| Krypton | Nitric oxide | Carbonyl sulphide*† |
| Methane (natural gas)* | Nitrous oxide | 1-Chloro-1,1-difluoroethane* (R142b) |
| Neon | Phosphine† | Chloropentafluoroethane (R115) |
| Nitrogen | Silane | 2-Chloro-1,1,1-trifluoroethane (R133a) |
| Oxygen | Sulphur hexafluoride | Cyanogen*† |
| Town gas (excluding coal gas)*† | Trifluoromethane (R23) | Cyclopropane* |
| Xenon | | Dichlorodifluoromethane (R12) |
| | | Dichlorofluoromethane (R21) |
| | | 1,2-Dichlorotetrafluoroethane (R114) |
| | | 1,1-Difluoroethane* (R152a) |
| | | Dimethylamine* § |
| | | Dimethyl ether* |
| | | 2,2 Dimethyl propane* |
| | | Ethyl acetylene* |
| | | Ethylamine* § |
| | | Hexafluoropropene |
| | | Hydrogen cyanide*† |
| | | Hydrogen selenide |
| | | Hydrogen sulphide*† |
| | | Isobutane* |
| | | Isobutylene* |
| | | Methyl acetylene*† § |
| | | Methylamine* |
| | | 3 Methyl-I-butene* |
| | | Methyl mercaptan*† |
| | | Nitrogen dioxide† |
| | | Nitrogen tetroxide† |
| | | Nitrogen trioxide† |
| | | Octafluorocyclobutane (RC318) |
| | | Perfluoro-2-butene† |
| | | Perfluoro propane |
| | | Propane* |
| | | Propylene* |
| | | *Sulphur dioxide*† |
| | | Trimethylamine* § |
| | | Vinyl bromide†‖ |
| | | Vinyl chloride*‖ |
| | | Vinyl fluoride*‖ |
| | | Vinyl methyl ether* |
| | | Gas mixtures: |
| | | Azeotrope R500 (73.8 % R12 and 26.2 % R152a) |
| | | Azeotrope R502 (48.8 % R22 and 51.2 % R115) |

*For the purpose of transport, these gases are considered to be flammable.

†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.

‡Normally only available as a component of a mixture.

§Special care is necessary to ensure that these gases are dry to less than 20 vpm of moisture.

‖As a mixture component only up to 1 % by volume of total cylinder contents.

NOTE 1. $T_c$ in the column headings is the critical temperature.

NOTE 2. Gas mixtures may contain small fractions of other gases, and/or liquid components. The filler should ascertain that these mixtures are compatible with aluminium alloys under all normal conditions of use.

NOTE 3. All gases contained in aluminium containers are to be free from reactive halogens.

NOTE 4. Those gases italicized may in accordance with **9.3** be contained in class IA containers.

**4.2 Information to be supplied by the manufacturer**

The manufacturer shall supply the purchaser and the Independent Inspecting Authority with the following information:

(a) fully dimensioned sectional drawing of the container including:

(1) name or classification of gas(es);

(2) volumetric capacity (minimum for liquefiable gases);

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

(4) materials 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) amount of corrosion allowance (if any);

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

(b) fittings to be supplied;

(c) marking arrangement drawing;

(d) certificate of compliance for materials and container.

## 5 Certificate of compliance

**5.1** The Independent Inspecting Authority to be approved by the Health and Safety Executive shall certify that the manufacture of the container was carried out in accordance with the requirements of this standard. ⚠1

NOTE. A suitable form of certificate is shown in appendix C.

**5.2** The Independent Inspecting Authority shall indicate on the certificate that inspection and testing has been carried out in accordance with the requirements of this standard and, when applicable, with the procedures for testing for limited production (see **18.4**).

**5.3** When a batch consists of containers of various lengths (see **18.4.1**), certificates shall be issued for each size of container within the batch.

# Section two. Materials

## 6 General

**6.1** The materials used for the container 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 marked and records shall be kept so as to enable the cast(s) from which a container is made to be identified.

**6.3** The container manufacturer shall obtain from the aluminium alloy producer a certificate giving details of cast analysis and mechanical properties in the as supplied condition.

**6.4** The cast shall be considered to be:

(a) the product of one furnace melt; or

(b) the product of one crucible melt; or

(c) the product of a number of crucible or furnace melts mixed prior to casting; or

(d) the amount of metal having been made (when a continuous melting process is employed); or

(e) as may be otherwise defined by the Independent Inspecting Authority.

**6.5** The product analysis and the cast analysis shall be within the composition limits given in table 2.

## 7 Permissible materials for container

### 7.1 Cylindrical shells and dished ends

Containers shall be made from either of types A and B materials given in table 2. Mechanical properties of finished containers shall be in accordance with the values given in table 3.

NOTE. Type A is equivalent to material 6082 in the BS 1470 series and the following may be used:

BS 1470 6082
BS 1471 6082
BS 1474 6082

### 7.2 Valve plates, bungs and bosses

The material used shall be either of types A and B given in tables 2 and 3.

NOTE. For type A the following British Standard alloys may be used:

BS 1470 6082
BS 1472 6082
BS 1474 6082

### 7.3 Materials for welded integral non-pressure parts

The material used shall be selected from one of the types A, B or C given in tables 2 and 3.

NOTE. BS 1474 6063 meets the requirements of type C, and for type A the following British Standard alloys may be used:

BS 1470 6082
BS 1474 6082

### 7.4 Materials for attachments (including non-aluminium alloy)

The Independent Inspecting Authority shall be satisfied that the material used in attachments is suitable in all respects including weldability where relevant.

**Table 2. Cast analysis**

| Element | Chemical composition | | |
|---|---|---|---|
| | Type A (6082)* | Type B | Type C (6063* complies) |
| Silicon % | 0.7 to 1.3 | 1.2 to 1.6 | 0.2 to 0.7 |
| Iron % | 0.50 max. | 0.5 max. | 0.5 max. |
| Copper % | 0.10 max. | 0.1 max. | 0.1 max. |
| Manganese % | 0.40 to 1.0 | 0.8 to 1.0 | 0.3 max. |
| Magnesium % | 0.6 to 1.2 | 1.0 to 1.4 | 0.4 to 0.9 |
| Chromium % | 0.25 max. | 0.1 max. | 0.1 max. |
| Zinc % | 0.20 max. | 0.2 max. | 0.2 max. |
| Titanium % | 0.10 max. | 0.2 max. | 0.2 max. |
| Others % | 0.05 each total 0.15 | | |
| Aluminium | Remainder | Remainder | Remainder |

*See clause 7.

NOTE. The rounding off rule given in BS 1957 applies to the limits given in table 2.

**Table 3. Mechanical properties**

| Mechanical properties | Type A | | Type B | Type C |
|---|---|---|---|---|
| | TF | Alternative | | |
| Tensile strength (N/mm$^2$) | 295 min.* | 275 min.* | 275 min. | To be agreed with purchaser |
| 0.2 % proof stress (N/mm$^2$) | 255 min.* | 195 min.* | 195 min. | |
| Elongation % | | | | |
| $L_o = 50$ mm | 8 min. | — | — | |
| $L_o = 5.65\sqrt{S_o}$ | — | 14 min. | 14 min. | |
| Bend test former radius (parent metal) | $3t_a$ | $3t_a$ | $3t_a$ | |

*The manufacturer is to specify the selected value.

NOTE. $t_a$ is the actual thickness of the specimen.

# Section three. Design

## 8 Service conditions for design

**8.1** Where gases are to be conveyed in the United Kingdom 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.

**Table 4. Reference temperatures for developed pressure for conveyance in the United Kingdom in uninsulated containers**

| Type of contents | Reference temperature |
|---|---|
| | °C |
| Low pressure liquefiable gas | 55 |
| High pressure liquefiable gas | 52.5* |
| Permanent gas | 60 |

*When safety devices are fitted to carbon dioxide containers this reference temperature may be reduced to 50 °C.

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 filled pressure at 15 °C for permanent gases.

NOTE. The necessary data on the relationship between filled pressure or filling ratio and developed pressure at the reference temperatures are given in BS 5355.

The reference temperature for filling ratios of low pressure liquefiable gases in uninsulated containers shall be 45 °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 nominated gas content at 15 °C and 1013 mbar.

The charged pressure shall 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 being conveyed in insulated containers the reference temperatures quoted in table 4 shall not apply. In such cases the operational criteria for design shall be sought from the Independent Inspecting Authority.

NOTE. The temperature which can be reached by the contents of an insulated container, 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 with halons and dry nitrogen the developed pressure requirements shall conform to the appropriate Part of BS 5306.

## 9 Classification of containers

**9.1 General**

Containers shall be constructed to one of the classes in **9.2**, **9.3** or **9.4** depending on the intended application.

Construction criteria and other factors for each class shall be in accordance with table 5.

**9.2 Class I**

Containers shall be constructed to class I if either of the following criteria apply:

(a) they are to be used to contain permanent or high pressure liquefiable gas or gas mixture (see table 1);

(b) they are to be used for the transport of a toxic gas (see table 1).

**9.3 Class IA**

Construction to class IA is subject to the approval of the Independent Inspecting Authority and requires that the longitudinal and/or circumferential seams shall be made by a mechanized MIG or TIG welding process which has been shown to produce welds free from unacceptable defects.

Containers shall be constructed to class IA if they are to be used for the transport of the gases italicized in table 1 (i.e. those gases which are of moderate toxicity or which give a sensory warning of a slight escape) subject to the Health and Safety Executive indicating that they have no objection to the proposal.

NOTE. No objection will be raised if evidence is produced to show that the design concerned is satisfactory in all respects for the proposed service. Additional tests may be required in support of this evidence.

**9.4 Class II**

**9.4.1** *General.* Containers for which construction to classes I, or IA, is not prescribed by **9.2** or **9.3** may be constructed to class IIA, IIB or IIC.

**9.4.2** *Class IIA.* Containers shall only be constructed to class IIA if they do not possess a longitudinal seam, have outwardly dished ends and the distance (in mm) between the nearest edge of any welded seam and the geometrical transition between the cylindrical portion and the dished ends is not less than $2\sqrt{(D_i t_e)}$ where $D_i$ is the internal diameter of the container (in mm) and $t_e$ is the actual thickness of dished end (in mm).

**9.4.3** *Class IIB.* Containers for which construction to classes I or IA is not prescribed by **9.2** or **9.3** and which do not comply with the requirements of **9.4.2** or **9.4.4** shall be constructed to class IIB.

**9.4.4** *Class IIC.* Containers shall only be constructed to class IIC where there is only a bung/boss seam not occurring in the cylindrical part of the container and where there is no longitudinal seam (see figure 3(c)).

**Table 5. Classification and construction criteria**

| Classification by content | | Classification of container (see note 4) | | | | |
|---|---|---|---|---|---|---|
| | | I | IA | IIA | IIB | IIC |
| Toxic gases (see 9.2) | | x | | | | |
| Toxic gas: moderate toxicity (see 9.3) | | | x (see 9.3) | | | |
| Permanent and liquefiable gases having a developed pressure greater than 75 bar at 55 °C, including mixtures (see 9.2) | | x | | | | |
| Permanent and liquefiable gases having a developed pressure between 75 bar and 25 bar at 55 °C, including mixtures (see 9.3) (Non toxic, non flammable) | | | x | | | |
| Gases having a developed pressure lower than 25 bar at 55 °C (see 9.4 (Non toxic)) | | | | x | x (see 9.4) | x |
| **Construction criteria** | | | | | | |
| Radiographic examination of welds at manufacture | Full | x | | | | |
| | Sample | | x | | | |
| | None | | | x (see note 2) | x | x |
| Radiographic examination of weld repairs (see note 1) | Full | x | x | | | |
| | None | | | x (see note 3) | x | x |
| **Other factors** | | | | | | |
| Stress reduction factor | | 0.95 | 0.90 | 0.85 | 0.80 | 0.80 |
| Batch number | | 202 | 202 | 402 | 402 | 402 |
| Mechanical tests per batch | | 1 | 1 | 1 | 1 | 1 |

NOTE 1. All repairs are to be approved by an Independent Inspection Authority.
NOTE 2. Sample radiography is required for weld thicknesses 6 mm or above, otherwise none.
NOTE 3. All repairs of weld thicknesses 6 mm or above are to be radiographed.
NOTE 4. Classifications shown are minimum. Gases can be conveyed in containers of higher class than specified.

## 10 Design of container shell

### 10.1 Nomenclature for the cylindrical part of the shell

- $t$ is the minimum thickness of the cylindrical wall (in mm), to resist internal pressure and external forces due to normal 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) and calculated in accordance with table 6;
- $P_2$ is the test pressure (in bar) applicable to design governed by equations (3) and (6);
- $p$ is the pressure (in bar) developed by the contents of a container at the pressure reference temperature;
- $D_o$ is the external diameter of container (in mm);
- $D_i$ is the internal diameter of container (in mm);
- $f_e$ is the maximum permissible equivalent stress (in $N/mm^2$) at test pressure (= 0.75 × minimum specified 0.2 % proof stress $Y$ (in $N/mm^2$) of the material of construction × appropriate stress reduction factor as given in table 7);
- $T$ is the minimum specified tensile strength (in $N/mm^2$) of the material of construction;
- $Y$ is the minimum specified 0.2 % proof stress (in $N/mm^2$) of the material of construction.

NOTE. Values of $Y$, $T$ and $f_e$ for the permissible materials are given in table 8.

### 10.2 Permissible pressure

**10.2.1** *Permanent gas.* The maximum pressure attainable in service shall not exceed the ratio of the minimum specified tensile strength to the minimum specified yield stress of the material of construction times 0.63 of the test pressure.

**10.2.2** *Liquefiable gas.* The maximum pressure attainable in service is dependent upon the type of container used. It shall not exceed the ratio of the minimum specified tensile strength to the minimum specified yield stress of the material of construction times:

(a) 0.63 of the test pressure for an insulated container; or

(b) 0.7 of the test pressure for an uninsulated container.

Carbon dioxide containers shall be designed for a test pressure of not less than 200 bar.

### 10.3 Thickness of cylindrical wall

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

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

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

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

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):

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

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 6.

### 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):

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

except that the thickness of the wall shall be not less than the values given by equation (5):

$$t = 2.48\sqrt{\left(\frac{D_i}{T}\right)} \quad (5)$$

Equation (5) will override equation (4) for comparatively low values of $P_1$, in which case the test pressure $P_2$ shall be derived from equation (6):

$$P_2 = \frac{7f_e}{1 + 0.12\sqrt{(D_i T)}} \quad (6)$$

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 6.

**Table 6. Relationship between test pressure, pressure developed at the reference temperature and gas classification**

| Gas classification | Relationship between $P_1$ and $p$ |
|---|---|
| Permanent gases in uninsulated containers, and liquefiable gases in insulated containers | $P_1 = \frac{p}{0.9} \times \frac{Y}{0.7T}$ <br> $= p \times \frac{Y}{0.63T}$ |
| Low pressure and high pressure liquefiable gases in uninsulated containers | $P_1 = p \times \frac{Y}{0.7T}$ |

**Table 7. Stress reduction factors for walls of cylindrical or spherical containers**

| Class of container | Stress reduction factor |
|---|---|
| I | 0.95 |
| IA | 0.90 |
| IIA | 0.85 |
| IIB and IIC | 0.80 |

NOTE. The stress reduction factors in tables 5 and 7 are not valid for containers to be subjected to a large number of fluctuations of pressure. It is recommended that prototype tests, see clause 25, should prove the design for a container which is expected to be charged more than 10 000 times in the course of its life.

### 10.5 Domed ends

**10.5.1** *Nomenclature for ends*

$t$ is the minimum wall thickness of the cylindrical wall (in mm) to resist internal pressure and external forces due to normal handling, but excluding any additional thickness for corrosion and other influences (see note to **10.5.3**);

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

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

$D_i$ is the internal diameter (in mm) of 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 radius (in mm) of dishing of torispherical end;

$R_i$ is the internal 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

$h_o$, $\frac{D_o^2}{4R_o}$ or $\sqrt{\left(\frac{D_o r_o}{2}\right)}$ 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:

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

**10.5.2** *Thickness of domed ends.* The minimum thickness of a domed end shall be the greater of:

(a) the thickness of the cylindrical wall (see **10.2**), or

(b) the value calculated from equation (7):

$$t_e = tK \quad (7)$$

**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 $0.1D_i$ nor less than three times the actual thickness of the 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 $0.3\sqrt{(D_o t_e)}$.

NOTE. *Additional thickness.* 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 should be carefully considered and agreed upon in each particular case by the manufacturer and user of the containers. If a pronounced departure from normal practice is proposed or if other unusual features arise, the Independent Inspecting Authority should be consulted.

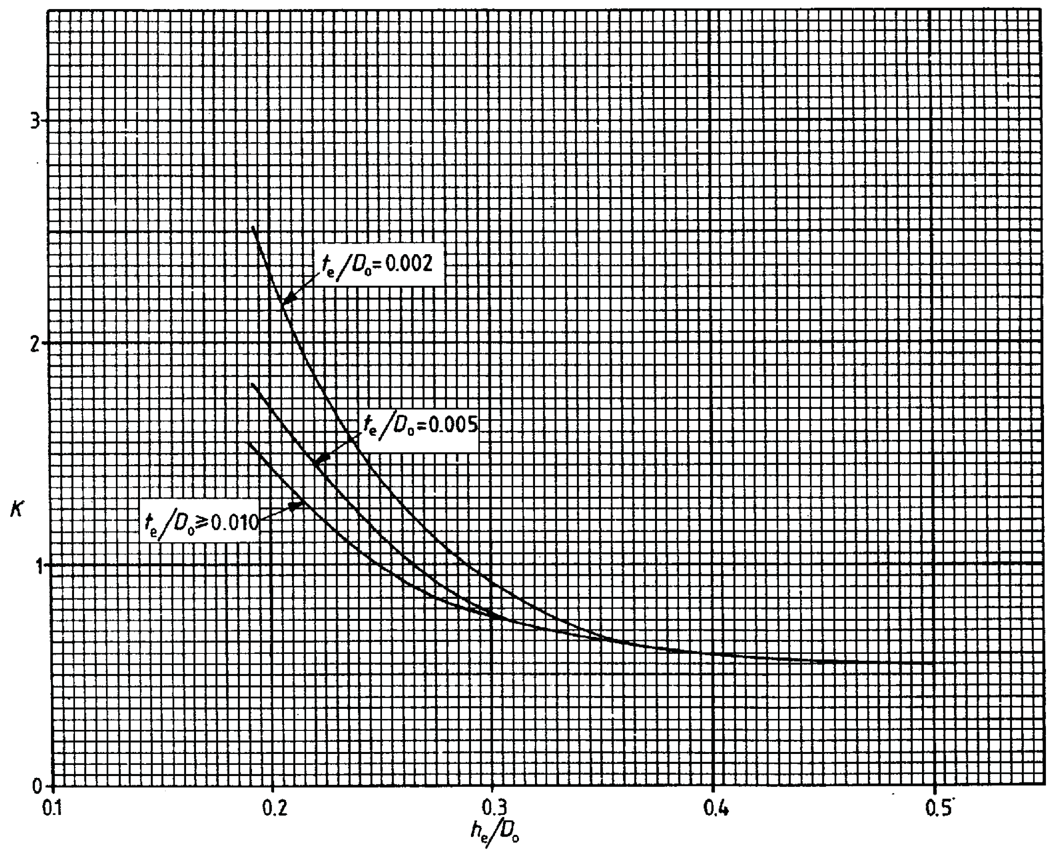



**Figure 1(a). Shape factor *K***

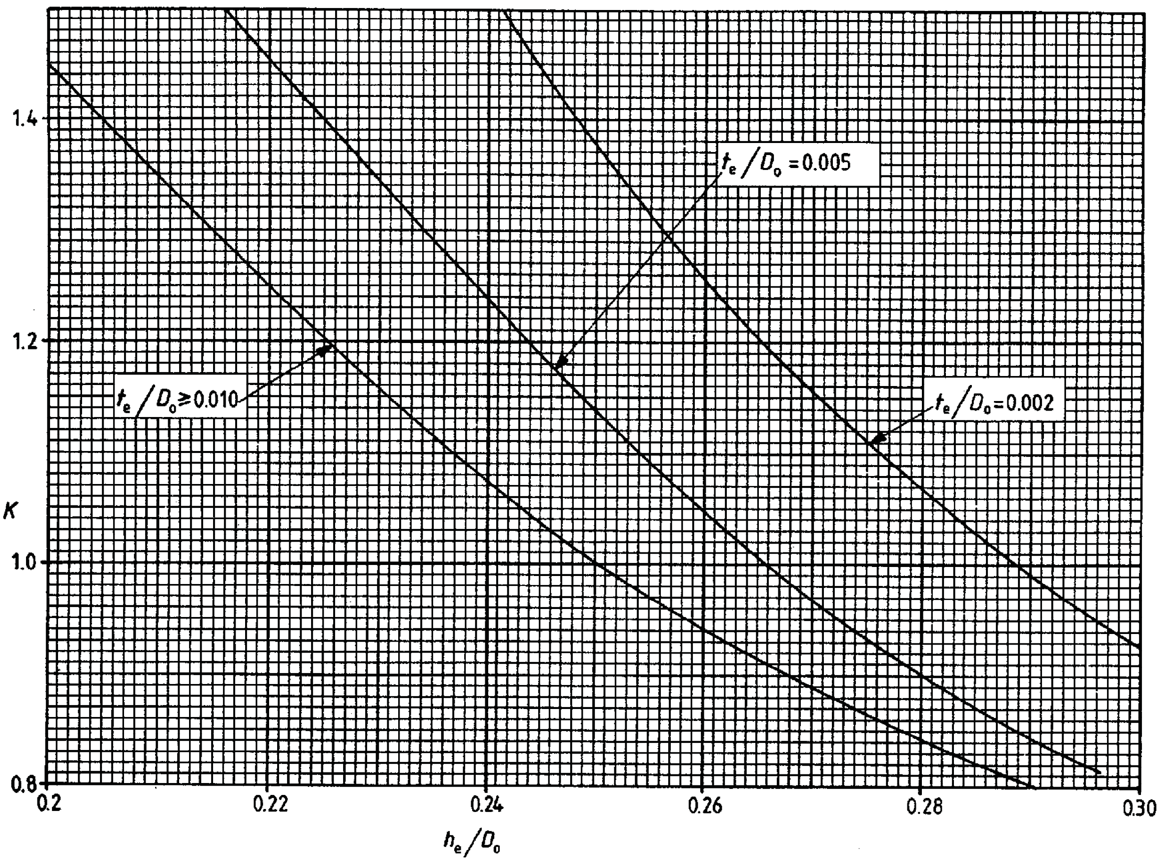
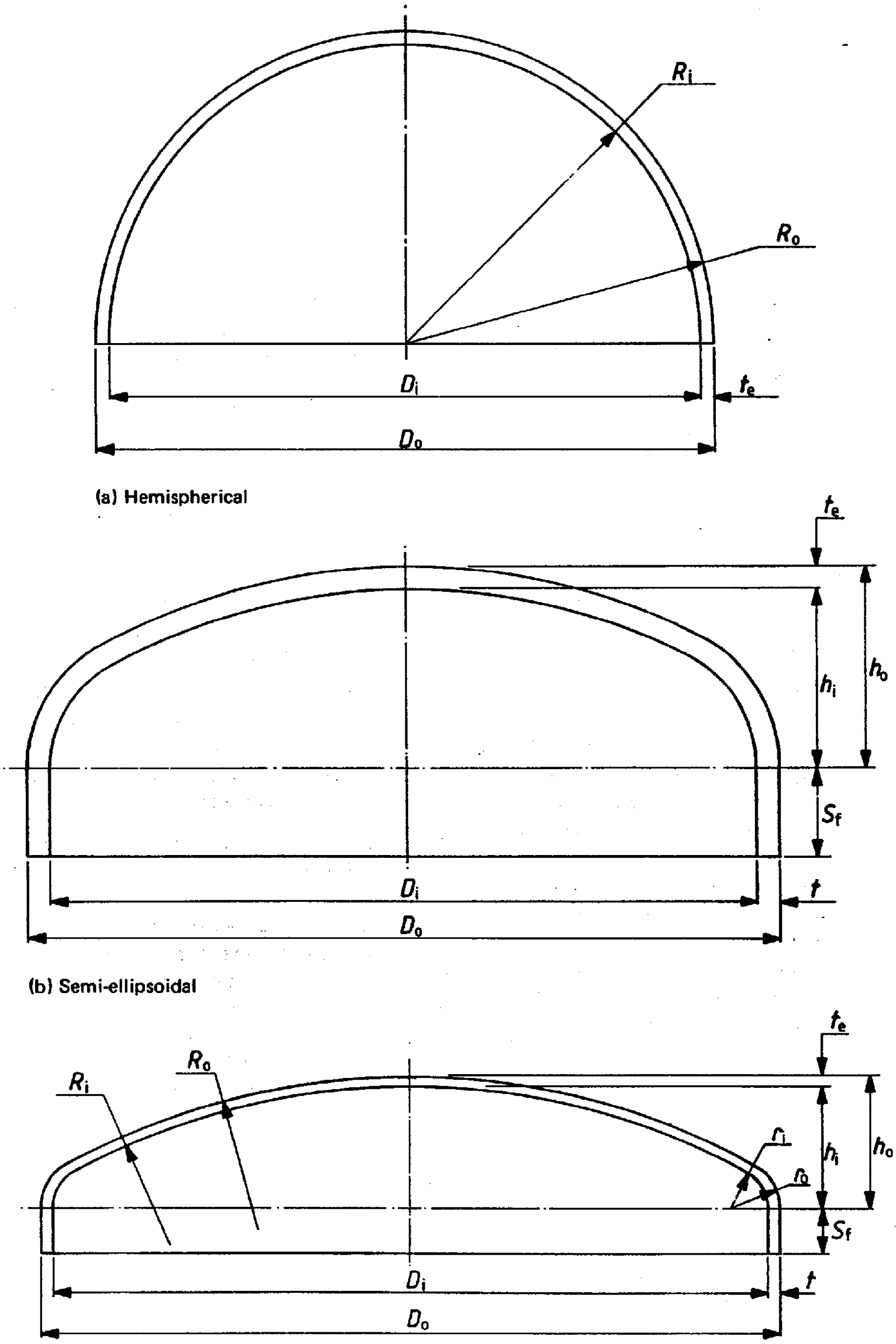



**Figure 1(b). Shape factor $K$ (enlargement of figure 1(a))**

**Table 8. Maximum permissible equivalent stress at test pressure for the cylindrical part of the shell**

| Material | Minimum specified 0.2 % proof stress $Y$ | Minimum specified tensile strength $T$ | Ratio of 0.2 % proof stress to tensile strength $Y/T$ | $f_e$ value | | | |
|---|---|---|---|---|---|---|---|
| | | | | Class 1 | Class IA | Class IIA | Classes IIB and IIC |
| | N/mm$^2$ | N/mm$^2$ | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| Type A | 195* or 255* | 275* or 295* | 0.86 max. | 138.9 or 181.7 | 131.6 or 171.1 | 124.3 or 162.6 | 117.0 or 153.0 |
| Type B | 195 | 275 | 0.71 | 138.9 | 131.6 | 124.3 | 117.0 |

*Manufacturers are to specify the chosen value.




(a) Hemispherical

(b) Semi-ellipsoidal

(c) Torispherical

**Figure 2. Domed ends**

## 11 Openings and branch connections

**11.1** The design and methods of attachment to the container of valve plates, 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 branch connections are required, they shall comply with the requirements of Part 4 of this standard (in preparation).

## 12 Fittings

### 12.1 Valve fittings

Valve fittings shall comply with BS 341 : Part 1 or Part 2 or BS 1319, as appropriate, and shall be constructed of a material compatible with aluminium alloys and gas conveyed in the container. Where material compatibility requires components to be protected by a suitable coating or plating, this shall be provided to the satisfaction of an Independent Inspecting Authority.

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. Screw-threaded valve outlet connections shall be right-hand on containers used for non-flammable gases and left-hand on containers used for flammable gases, except for containers not exceeding 10 L water capacity that are fitted with self-sealing valves that can only be connected to matching appliances. If banks of containers are permanently connected to a common manifold, this requirement shall apply to the manifold outlet only.

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

The maximum valving torque recommended by the container manufacturer shall not be exceeded.

### 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 or by the provision of a suitable 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 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 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 pressure reference temperature.

If the container is used for a highly toxic* gas suitable additional protection shall be provided, such as a valve locking device and/or by the removal of the valve handwheel. 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 may 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 suitable device that will allow any pressure that has accumulated inside the valve cap to be slowly released before removal of the cap.

The protective device shall be of adequate construction to prevent causing damage to the valve that results 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 the secure attachment to the cradle of a stout guard. If the containers are connected to a common manifold, the manifold as well as the valves shall be so protected. The guard shall be hinged or removable and if so it shall be provided with a lock to enable it to be kept in the locked position during conveyance.

### 12.3 Dip pipes

When a dip pipe is fitted to a container, other than a fire extinguisher, its presence shall be indicated.

NOTE. This requirement may be fulfilled either by a metal disc placed between 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).

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

*For the purpose of **12.2.1** the following gases listed in table 1 are classified as highly toxic: arsine, cyanogen, hydrogen cyanide, hydrogen sulphide, phosphine.

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

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.

**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.

The full discharge rate from the pressure relief valve shall be attained at a pressure not greater than the test pressure of the container.

The pressure relief valve shall be so constructed as to prevent unauthorized interference with the relief pressure setting during service.

**12.4.3** *Bursting discs.* Bursting discs, if fitted, shall comply 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.

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 discs shall be fitted with vacuum supports.

### 12.5 Fusible plugs

The Health and Safety Executive shall be consulted where it is proposed to fit containers with one or more fusible plugs. △1

Where practicable, fusible plugs shall be externally marked to indicate the temperature at which they are designed to relieve pressure.

# Section four. 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.

**13.2** No modification shall be made to the design, after approval by the Independent Inspecting Authority, except with 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 cylindrical part 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 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 MIG or TIG process as defined in BS 499 : Part 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 in the parallel part of the container shall consist of either a joggle joint such that the external surface of the containers does not have any abrupt change of diameter, or a butt joint used in conjunction with a permanent backing ring.

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 followed by abrading with a scraper or brushing with a stainless steel wire brush. Surface and edge preparations shall be consistent with the welding procedure.

NOTE. BS 3019 : Part 1 and BS 3571 : Part 1 give recommended procedures.

**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 the welding procedures comply with BS 4870 : Part 2. All completed internal welds shall be 100 % visually inspected by the manufacturer to ensure satisfactory welds.

**15.10** Where manual welding is employed for the attachment of non-pressure parts or for weld repairs in accordance with 27.1, the manufacturer shall satisfy the Independent Inspecting Authority that the welder has met the requirements of BS 4871 : Part 2.

## 16 Heat treatment

**16.1** After the completion of all welding (including that of the attachments) and before hydraulic test each container shall be solution heat treated uniformly at a selected temperature within the range 520 °C to 540 °C followed by water quenching, and then artificially aged at a selected temperature within the range 150 °C to 200 °C. Temperature shall be controlled to ± 5 °C of the selected temperature.

**16.2** The manufacturer shall satisfy the Independent Inspecting Authority that the temperatures and times adopted are appropriate for the materials of construction and the size and profile of the container.

# Section five. Inspection and tests

NOTE. See appendix D for recommendations concerning the availability of inspection and testing facilities.

## 17 Inspection of components

**17.1** All components forming part of the pressure containing envelope 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 components shall be rejected.

**17.2** 2 % or more of the pressings and of the cylindrical shells shall be selected at random by the Independent Inspecting Authority, 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.

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.

For the purpose of this clause, 'batch of material' is defined as meaning pressings or cylindrical shells manufactured in a continuous production run.

## 18 Test requirements

### 18.1 General

All tests specified in this clause shall be carried out on containers which have been heat treated.

### 18.2 Normal production

**18.2.1** One container selected at random from every batch of containers shall be subjected to the mechanical test requirements of clause **19** and shall satisfy those requirements.

**18.2.2** One container selected at random from every batch of containers shall be subjected to a volumetric expansion test in accordance with clause **20** and then shall be hydraulically tested to destruction and shall satisfy the requirements of clause **23**.

**18.2.3** A batch shall consist of not more than:

| | |
|---|---|
| classes I and IA | 202 containers |
| classes IIA, IIB and IIC | 402 containers |

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

**18.2.4** Radiographic examination shall be in accordance with clause **26**.

**18.2.5** Each container shall be pressure tested in accordance with clauses **22** and **24**.

**18.2.6** The water capacity of each container shall be checked in accordance with clause **23**.

### 18.3 Continuous mechanized production

**18.3.1** Where the production is organized on a flow line basis and the various processes are fully mechanized, and provided that the process achieves consistent reproducible results to the satisfaction of the manufacturer and is approved by the Independent Inspecting Authority, the test requirements shall be in accordance with **18.3.2** to **18.3.7**.

**18.3.2** Containers selected at random shall be subjected to the mechanical test requirements of clause **19** and shall satisfy those requirements. The number of containers to be tested shall be in accordance with **18.3.4**.

**18.3.3** Containers selected at random shall be subjected to a volumetric expansion test in accordance with clause **20** and shall then be hydraulically tested to destruction and shall satisfy the requirements of clause **21**. The number of containers to be tested shall be in accordance with **18.3.4**.

**18.3.4** The number of containers to be tested shall be as follows:

| Size of production run | No. of containers for test |
|---|---|
| Up to 3200 | 8 containers |
| Over 3200 up to 4000 | 10 containers |

For every 1000 containers over 4000 an additional two containers shall be required for test.

The size of production run as given above shall apply after any:

(a) material cast change;

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

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 **28**.

**18.3.5** Radiographic examination shall be in accordance with clause **26**.

**18.3.6** Each container shall be pressure tested in accordance with clauses **22** and **24**.

**18.3.7** The water capacity of each container shall be checked in accordance with clause **23**.

### 18.4 Limited production

**18.4.1** Limited production test requirements shall apply only to three-piece containers and only to a maximum of 30 containers made consecutively from the same size*, design and material specification on the same types of mechanized arc-welding machines and heat-treated under the same conditions of temperature and time.

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

*The size may vary only in the length of the containers.

**18.4.2** 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 burst test of a selected cylinder.

**18.4.3** 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** and if any test fails the other two coupon plates shall both meet the requirements of clause **28**.

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 **28.6**).

**18.4.4** One container shall be subjected to a volumetric expansion test in accordance with clause **20**.

All containers shall be pressure tested and tightness tested in accordance with clauses **22** and **24**.

**18.4.5** Radiographic inspection of T junction welds shall be in accordance with **26.2** and **26.3**.

**18.4.6** Burst tests shall be in accordance with clause **21**.

## 19 Mechanical tests

### 19.1 General

The mechanical tests shall consist of tests on the parent material and the welds.

Test specimens shall be obtained from locations on the container 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 $4t$ of the edge of the weld, where $t$ is the minimum manufacturing thickness as specified on the drawing (including corrosion allowance if any).

The mechanical tests carried out on each container shall be in accordance with the following:

**19.2** Tensile test on parent material
**19.3** Bend test on parent material
**19.4** Tensile test on the welds (not for class IIC containers)
**19.5** Bend test across the welds (not for class IIC containers)
**19.6** Nick-break test on the welds

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** inclusive 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 in accordance with figure 3(b). The form and dimensions shall be as specified in 2.1 and table 2 of BS 18 : Part 1 : 1970. The face and back of the test specimen shall not be machined, but shall represent the surfaces 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 to tolerance grade IT 9 of BS 4500.

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 : Part 1. If individual measurements of the thickness of a test specimen whose two faces are formed by the surface of the container wall differ somewhat from one another then the minimum 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 shall 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 results obtained shall meet the requirements of table 3. The tensile testing machine shall be maintained to grade A of BS 1610.

### 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 manufacturing thickness of the container as shown in the drawing (including corrosion allowance *if any*), 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 radius not greater than $3t_a$ where $t_a$ is the actual thickness of the specimen, until the gap between the ends is not greater than twice the radius of the former, the specimen shall remain uncracked. This test shall be carried out in accordance with clause **14** of BS 1639 : 1964 using a bending machine.

### 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 BS 3451.

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.

The tensile testing machine shall be maintained to grade A of BS 1610. This test shall be carried out in accordance with 3.2 of BS 3451 : 1973.

**19.5 Bend test across the welds**

The width of the test specimen shall be in accordance with BS 3451. 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. This test shall be carried out in accordance with 3.5 of BS 3451 : 1973.

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 round a former of radius not greater than $8t_a$, where $t_a$ is the thickness of the specimen, until the gap between the ends is not greater than twice the radius of the former, each test specimen shall remain uncracked.

**19.6 Nick-break test on the welds**

Nick-break tests shall be made, the specimens NB1, NB2, NB3 and NB4 (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 BS 3451 except that for NB3 and NB4 the dimensions and the form shall be modified as necessary to suit the design of the container. The specimen shall then be broken cold in the weld and the fracture shall reveal a sound, homogeneous weld with complete penetration, free from oxide or other inclusions or excessive porosity.

## 20 Hydraulic volumetric expansion test

**20.1** After heat treatment the container(s) selected in accordance with the requirements of **18.3** shall be subjected to a volumetric expansion test preferably by the 'water jacket' method (see appendix A).

**20.2** The test pressure shall be determined by the requirements of section three. No pressure greater than 80 % of the test pressure shall have been applied to any container before the test.

**20.3** The permanent volumetric expansion shall not exceed 10 % of the total expansion under the test pressure.

Should the permanent volumetric expansion of a container, selected as specified in **18.3**, exceed this value the procedure laid down in **28.5** shall be followed.

## 21 Hydraulic bursting test

The container selected as specified in **18.3** shall be hydraulically tested to destruction. The nominal hoop stress corresponding to the pressure at which destruction occurs shall be calculated from the formula:

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

where

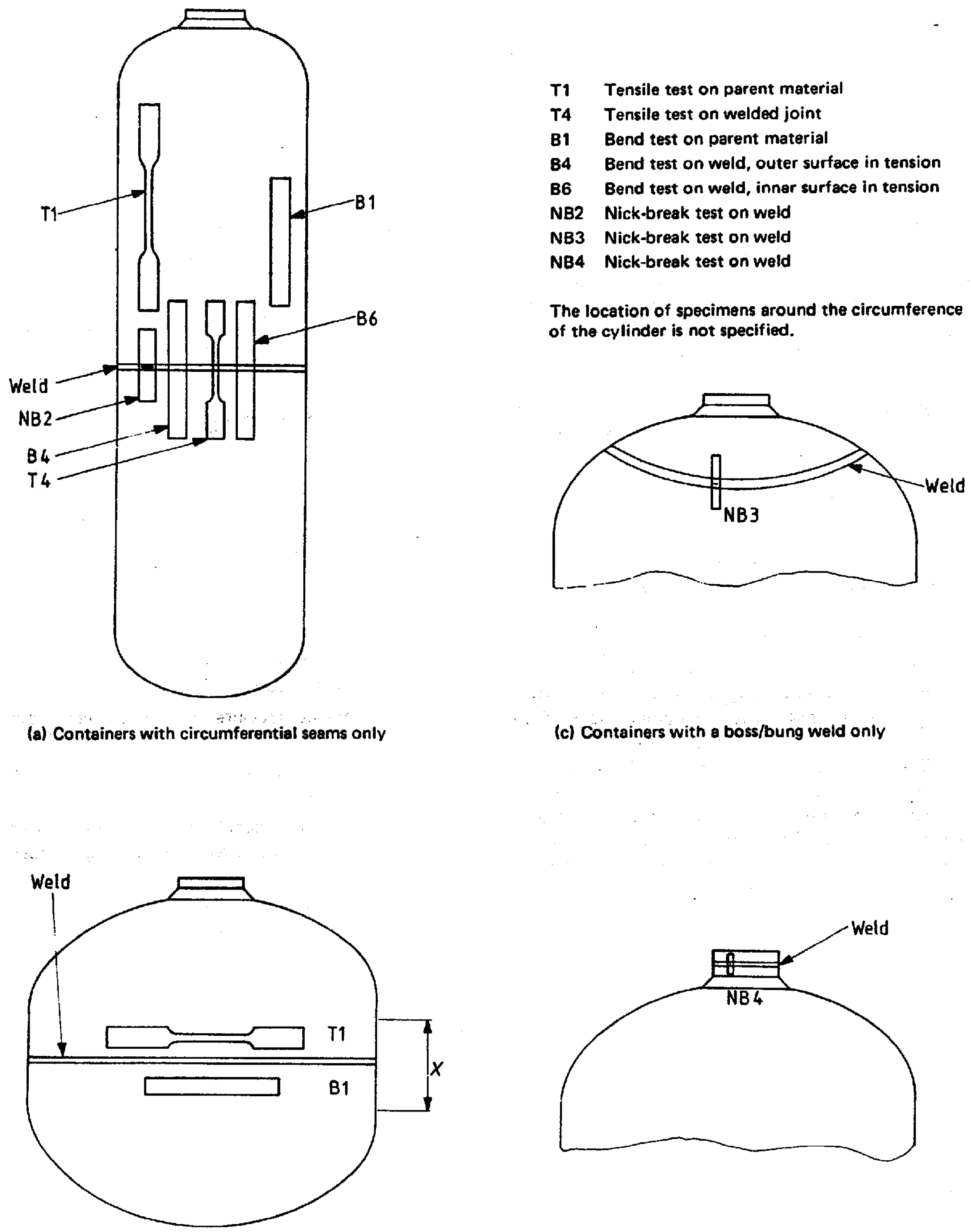
$f_b$ is the nominal hoop stress (in N/mm$^2$) at which destruction occurs;

$P_b$ is the internal pressure (in bar) at which destruction occurs;

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

$t_m$ is the minimum manufacturing thickness (in mm), as specified on the drawing (including corrosion allowance, if any) of the wall of the container.

The value of $f_b$ shall be not less than 0.95 of the minimum specified tensile strength of the material of the container. The container shall burst without fragmentation.



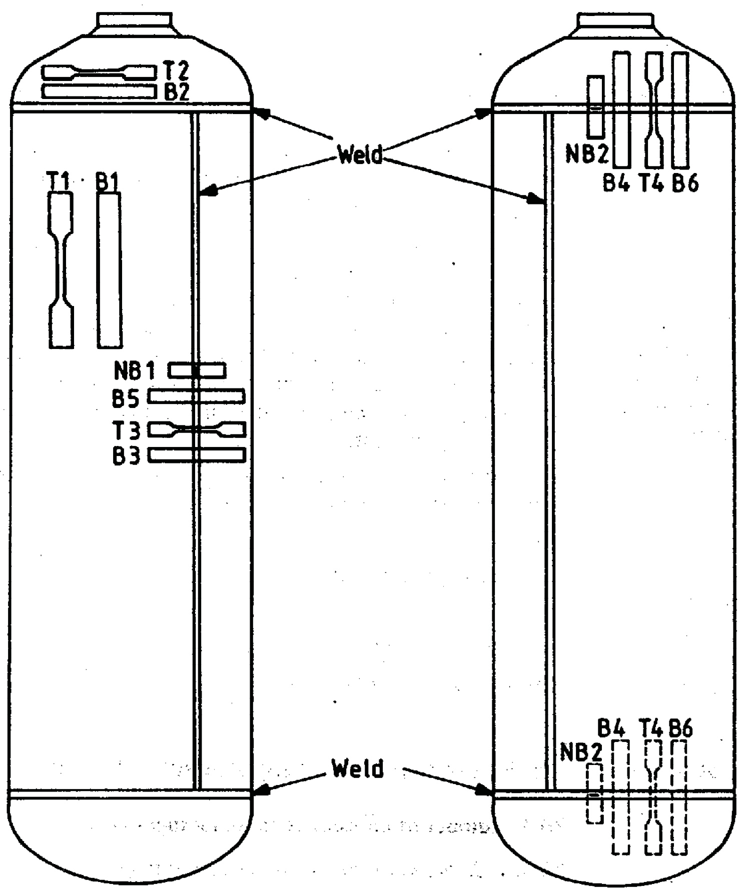

(a) Containers with circumferential seams only

(c) Containers with a boss/bung weld only

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

(d) Enlargement of neck of (a) or (b)

**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 **20.1** regarding alternate test pieces) |
| 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 **20.1** regarding alternate test pieces) |
| B5 | Bend test on weld inner surface in tension |
| B6 | Bend test on weld inner surface in tension (see **20.1** regarding alternate test pieces) |
| NB1 | Nick-break test on weld |
| NB2 | Nick-break test on weld |
| NB4 | Nick-break test on weld (see **20.1** regarding alternate test pieces) |

**(e) Containers with longitudinal and circumferential seams**

**Figure 3.** ***(concluded)***

## 22 Proof pressure test

After all heat treatment each container shall be subjected to a hydraulic proof test in which the test pressure shall be determined by the requirements of section three. The test pressure shall be held for at least 1 min. Under these conditions of test the container shall not show any sign of pressure loss, leakage, visible deformation or defect.

## 23 Checking of water capacity

The water capacity of each container shall be checked. This shall be done by weighing, 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.

## 24 Tightness test

After each container has passed the hydraulic test specified in clause **22**, it shall be subjected to an internal pneumatic pressure equal to half the hydraulic test pressure or 7 bar, whichever is the less. If any leakage occurs the container shall be regarded as having failed the test. 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.

## 25 Design qualification tests of prototype containers

### 25.1 New design

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

(a) it is manufactured in a different factory; or

(b) it is manufactured by a different process; or

(c) it is manufactured from a material of different nominal chemical composition; or

(d) it is given a different heat treatment; or

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

(f) the certified minimum yield stress has changed by more than 50 $N/mm^2$; or

(g) the length of the container has increased by more than 50 % (container with an *L/D* ratio less than 3 shall not be used as reference container for any new design with an *L/D* ratio greater than 3); or

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

(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.)

### 25.2 Pressure cycling test

In addition to the tests specified in clauses **19**, **20**, **21**, **22** and **24**, three containers from the first batch made to a new design shall be submitted to the following pressure cycling test. The containers shall be certified by the manufacturer to be representative of his design and manufacturing procedure. In the case of large containers, or of small batches where this test may be impracticable, the Health and Safety Executive shall be consulted.

The test shall be carried out using a non-corrosive fluid with a range of pressure equivalent to either 0.9 times the test pressure or 0.6 times the test 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.

The containers shall be considered to have passed the test if they satisfactorily complete:

either:

10 000 cycles at 0.9 × test pressure

or

75 000 cycles at 0.6 × test pressure

without any sign of leakage.

## 26 Radiographic examination of welds

### 26.1 Number of containers to be radiographed

**26.1.1** *Class I containers.* On every container the entire length of all pressure containing welds shall be radiographed.

**26.1.2** *Class IA and IIC 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, 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 **26.3** 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 at the beginning and end of each working shift's production or at intervals not exceeding 12 h, whichever is the shorter, and radiographed as above. 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.

Any weld repairs agreed by the Independent Inspecting Authority shall be carried out in accordance with clause **27**.

**26.1.3** *Classes IIA and IIB containers.* No radiography is required for containers to classes IIA or IIB construction.

**26.2 Radiographic techniques**

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 3451.

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 indicated above.

**26.3 Assessment of radiograph**

The radiograph shall show that the pressure containing welds have complete penetration and freedom 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 **26.1.2**. In judging what constitute unacceptable defects the provisions of table 5A.7 of BS 5500 : 1985 shall be followed as far as they are relevant.

## 27 Repair of welds

**27.1** If, during the hydraulic or tightness tests, minor leaks are found, or if minor but unacceptable defects are found by radiography the weld shall only be repaired by rewelding either by mechanized or by manual means when approved by the Independent Inspecting Authority.

**27.2** All weld repairs shall be radiographed except repairs to containers of classes IIA or IIB. After rewelding and where necessary re-radiography, all containers shall be reheat-treated as part of a new batch or production run in accordance with clause **16**, and shall be retested accordingly.

## 28 Results of mechanical and pressure tests

**28.1** If any of the mechanical tests required under **19.1**, except the nick-break test, results in a failure then, at the manufacturer's discretion, the procedures in either **28.2** or **28.3** shall be followed.

**28.2** 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 the requirements of **19.2** to **19.5** inclusive, the batch or production run, if otherwise complying with the requirements of this standard, shall be accepted.

**28.3** Alternatively, the batch or production run shall be reheat-treated and the heat treatment shall be as specified in clause **16** and all 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 **19.5** inclusive, the batch or production run, if otherwise complying with the requirements of this standard, shall be accepted.

**28.4** If any of the mechanical tests specified in **28.2** results in a failure, the batch or production run may be reheat-treated and retested in accordance with **28.3** and be accepted if it complies with **19.2** to **19.5** inclusive and otherwise complies with the requirements of this standard.

**28.5** If either of the containers selected for test under clause **18** fails 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 reheat-treated and tested as specified in **28.3** 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 failures.

**28.6** 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 cylinders shall be to the satisfaction of the Independent Inspecting Authority.

## 29 Final internal inspection

**29.1** 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 inspection lamp.

**29.2** The cleaning operation specified in **29.1** shall be carried out immediately prior to the assembly of valves, fittings or sealing plugs, as appropriate.

# Section six. Marking of containers

## 30 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 (which date may be 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 standard, class of construction and material type reference (e.g. BS 5045/5/1A/A);

(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 the conveyance liquefiable gases;

(h) the tare (in kg), i.e. the mass of the container and valve (excluding the valve cover) if it is intended to be used for liquefiable gases;

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

All the above markings shall be made by the container manufacturer.

## 31 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.

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

NOTE. The marks required by clause 30 may be marked on the valve boss if desired.

# Appendix A. Volumetric expansion testing of welded containers

## A.1 General

This appendix gives details of two methods for determining the volumetric expansion of welded aluminium alloy gas containers as required by clause 20:

(a) the water jacket method (preferred method);

(b) the non-water jacket method.

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

## A.2 Test equipment

NOTE. The requirements specified in **A.2.1** to **A.2.7** are general to both methods of test.

**A.2.1** Hydraulic test pressure pipelines shall be capable of withstanding a pressure twice the maximum test pressure of any container that may be tested.

**A.2.2** Glass burettes shall 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.

**A.2.3** Pressure gauges shall comply with the requirements for industrial gauges in BS 1780 : 1985. They shall be tested at regular intervals and in any case not less frequently than once per month.

**A.2.4** A suitable device shall be employed to ensure that no container is subjected to a pressure in excess of its test pressure.

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

**A.2.6** All joints shall be leaktight.

**A.2.7** When installing equipment care shall be taken to avoid trapping air in the system.

## A.3 Water jacket volumetric expansion test

### A.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.

### A.3.2 Apparatus

The water jacket shall 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 shall be fitted to the highest point of the jacket.

### A.3.3 Procedure

**A.3.3.1** *General.* Two methods of performing this test are described in **A.3.3.2** and **A.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.

**A.3.3.2** *Water jacket volumetric expansion test: levelling burette method.* An example of the equipment required is shown in figure 4, but other types of installation may be acceptable. The following procedure shall be carried out.

(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 pressure supply 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 pressure line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic pressure 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. This reading is the total expansion and shall be recorded on the test certificate.

(h) Open the hydraulic pressure 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. This reading is the permanent expansion, if any, and shall be recorded on the test certificate.

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

$$\frac{\text{permanent expansion} \times 100}{\text{total expansion}} = \%$$

A.3.3.3 *Water jacket volumetric expansion test: fixed burette method.* An example of the equipment required is shown in figure 5, but other types of installation may be acceptable. The following procedure shall be carried out.

(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.

(e) Raise the pressure in the container to two-thirds of the test pressure. Close the hydraulic pressure supply 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 pressure line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic pressure line valve.

(g) Read the level of the water in the burette. This reading is the total expansion and shall be recorded on the test certificate.

(h) Open the hydraulic pressure 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. This reading is the permanent expansion, if any, which shall be recorded on the test certificate.

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

$$\frac{\text{permanent expansion} \times 100}{\text{total expansion}} = \%$$

## A.4 Non-water jacket volumetric expansion test

### A.4.1 Principle

The 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 burette. 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.

### A.4.2 Apparatus

The apparatus shall be arranged such that all air can be removed. The glass tube reservoir shall be calibrated in millilitres and be accurate to 1 % of reading. It shall 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 large containers, it may be necessary to augment the glass tube with metal tubes arranged in a manifold.

The pressure gauge shall be accurate to the requirements of BS 1780.

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

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

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

The equipment shall be installed as shown in figure 6. This figure illustrates diagrammatically the different parts of the apparatus. The water supply pipe shall be connected to an overhead tank as shown, or to some other supply giving a sufficient head of water.

### A.4.3 Test method

The following procedure shall be carried out.

(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 records the required test pressure. Stop the pump. After approximately 30 s there should be no change in either water level or pressure. 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. Provided 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.

(h) Open valve H slowly to release the pressure in the container and allow water so released to return to the glass tube. The water level should return to the original level marked by pointer P. 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

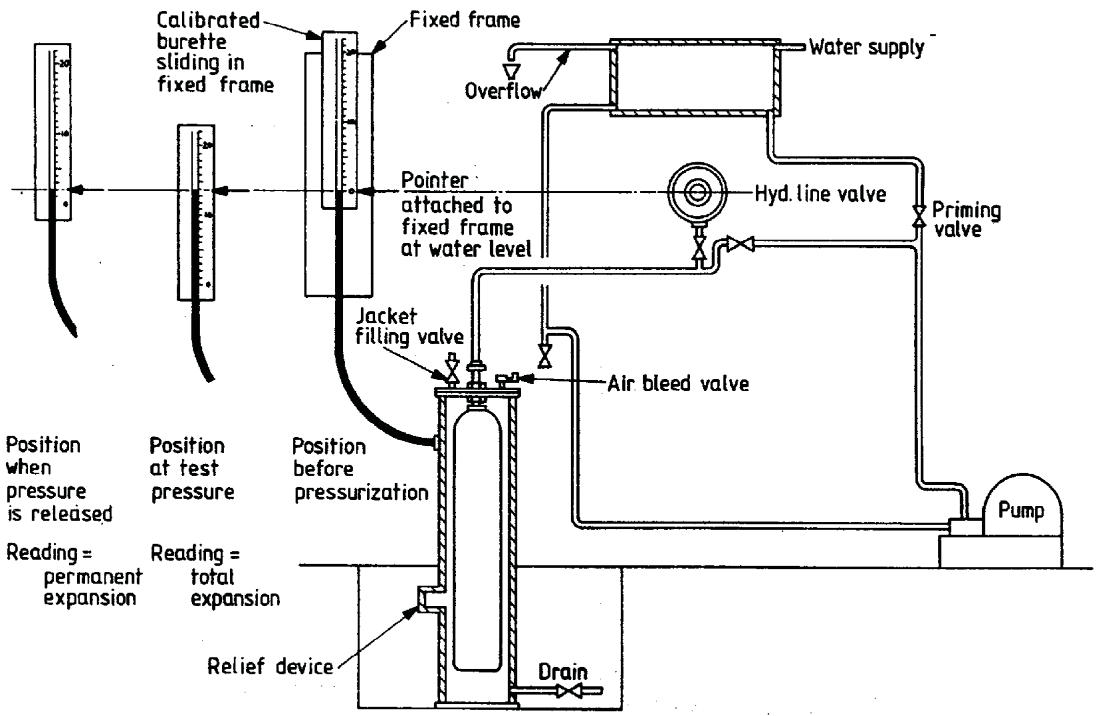



**Figure 4. Water jacket volumetric expansion test (levelling burette)**

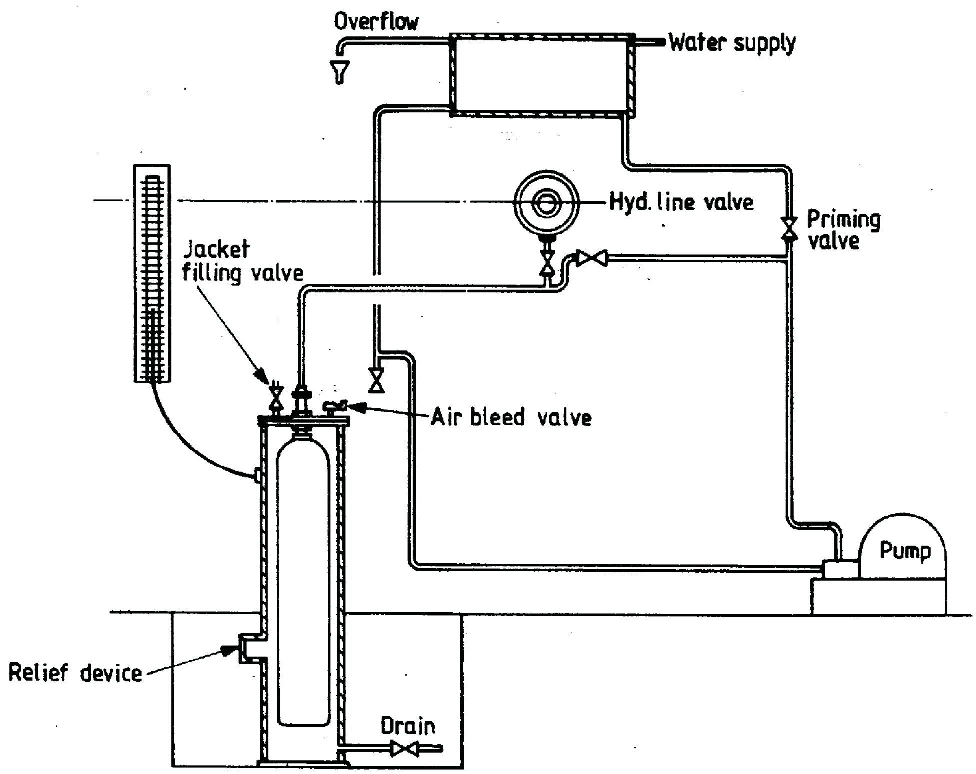



**Figure 5. Water jacket volumetric expansion test (fixed burette)**

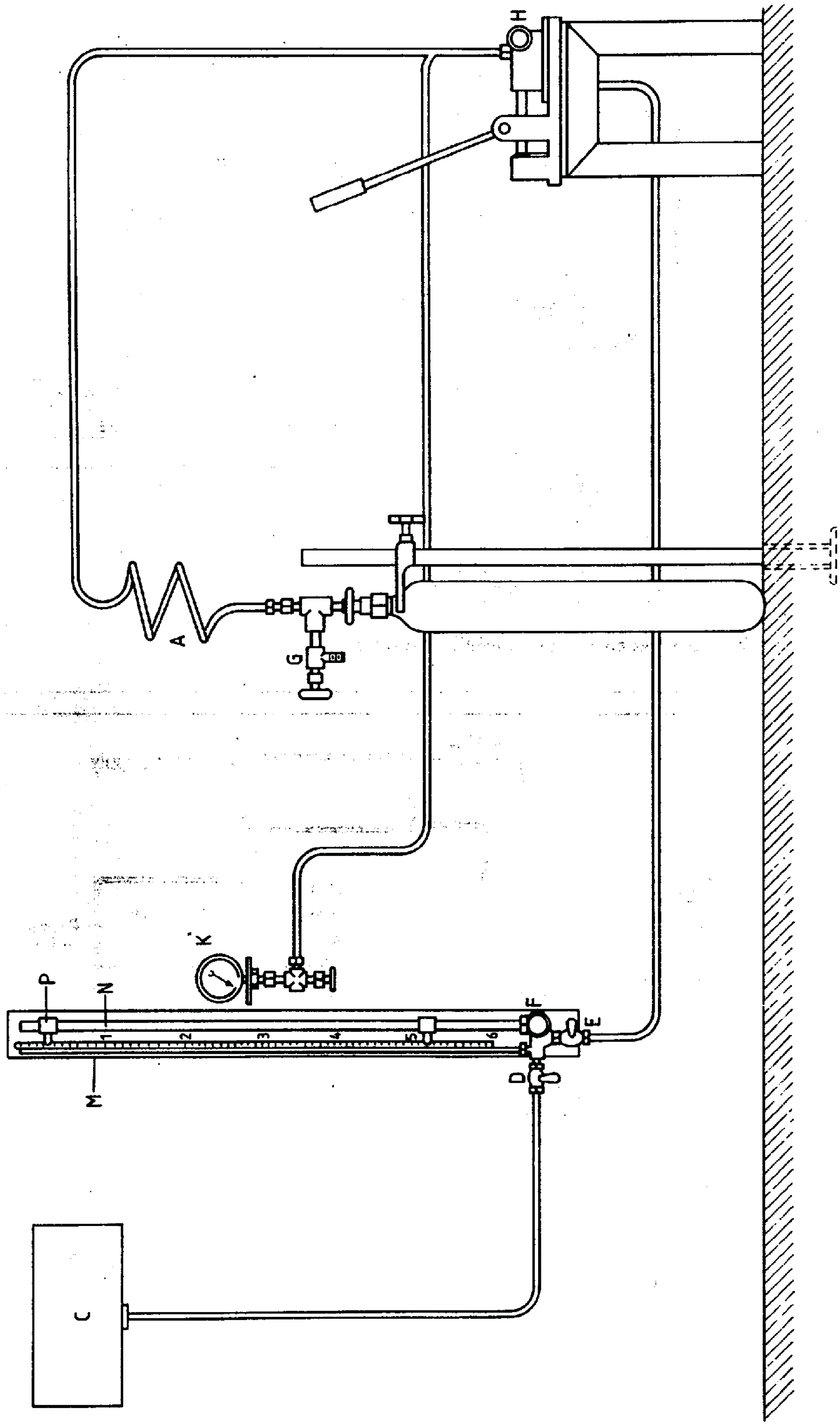



Figure 6. Non-water jacket volumetric expansion test

container, neglecting the effect of compressibility of the water at test pressure. The true permanent volumetric expansion of the container is obtained by correcting for compressibility of the water.

(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. Action (d) shall, however, be 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 **A.4.6.**

**A.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 change in volume of the water in the container due to its compressibility to be calculated. The volume of water expelled from the container when depressurized is known. Thus total volumetric expansion (TE) and permanent volumetric expansion (PE) can be determined.

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

**A.4.5 Calculation of compressibility of water**

The compressibility of water is calculated from the following formula:

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

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, with values listed in table 9.

**Table 9. $K$ factors for the compressibility of water**

| °C | $K$ | °C | $K$ | °C | $K$ |
|---|---|---|---|---|---|
| 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 68 | 26 | 0.045 94 |

**A.4.6 Example calculation**

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

| | |
|---|---|
| Test pressure | = 232 bar gauge |
| Mass of water in container at zero gauge pressure | = 113.8 kg |
| Temperature of water | = 15 °C |
| Water forced into container to raise pressure to 232 bar | = 1745 mL or 1.745 kg |
| Total mass of water ($m$) in container at 232 bar = 113.8 + 1.745 | = 115.545 kg |
| Water expelled from container to depressurize | = 1742 mL |
| Permanent expansion (without correction for compressibility) = 1745 − 1742 | = 3 mL |
| From table 9, $K$ factor for 15 °C water temperature | = 0.047 25 |

From the formula $C = mP\left(K - \frac{0.68P}{10^5}\right)$

Reduction in volume of water due to compressibility at 232 bar and 15 °C

$$= 115.545 \times 232\left(0.047\ 25 - \frac{0.68 \times 232}{10^5}\right) = 1224.25\ \text{mL}$$

Total volumetric expansion (TE)
= 1745 − 1224.25 = 520.75 mL

$$\frac{\text{Permanent expansion}}{\text{Total volumetric expansion}} = \frac{3 \times 100}{520.75} = 0.58\ \%$$

## Appendix B. Example of design procedure

### B.1 Container required

A container of 300 mm internal diameter made from type A material given in tables 2 and 3 is to be charged with 15 kg of commercial propane having a liquid density of 0.505 g/cm$^3$ at 15 °C and containing less than 2 mol % of $C_2$ hydrocarbons

### B.2 Minimum water capacity

From clause 8 the reference temperature for the filling ratio is 45 °C and from BS 5355 the required filling ratio is therefore 0.442.

The required minimum water capacity = 15/0.442 = 33.94 L

## B.3 Overall dimensions

The internal diameter is required to be 300 mm so the effective internal length is not to be less than 480 mm.

The actual length is to be determined taking into account the volume enclosed by the ends.

## B.4 Construction

The conditions do not make class I construction obligatory. Assuming class II construction is selected and that the container is to be made from two deep pressings with a central circumferential weld, one of the domed ends having a bung secured by welding, to accommodate the container valve. Such a construction will allow the container to be designed as class IIA provided that the requirements of **9.4.2** are met.

## B.5 Calculation of minimum test pressure ($P_1$)

From table 4 the reference temperature for developed pressure is 55 °C and from BS 5355, table 7 the developed pressure, $p$, at 55 °C for commercial propane is 22.13 bar.

From table 3, material type A has a minimum tensile strength of 295 N/mm$^2$ and a minimum 0.2 % proof stress of 255 N/mm$^2$.

From table 6 the test pressure ($P_1$) is:

$$P_1 = 22.13 \times \frac{255}{295 \times 0.7} = 27.33 \text{ bar}$$

## B.6 Thickness of cylindrical wall (see 10.3)

Equation (1) gives:

$$t = \frac{0.3 P_1 D_i}{7 f_e - P_1}$$

where

$t$ is the minimum thickness of cylindrical wall (in mm);

$P_1$ is the test pressure = 27.33 bar;

$D_i$ is the internal diameter of container = 300 mm;

$f_e$ is the maximum permissible equivalent stress at test pressure (in N/mm$^2$) = 0.75 x 255 x 0.85 = 162.56 N/mm$^2$;

thus $t = \frac{0.3 \times 27.33 \times 300}{7 \times 162.56 - 27.33} = 2.21$ mm.

However the thickness of the cylindrical wall shall not be less than the value given by equation (2)

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

where $T$ is the minimum tensile strength of the material

$$= 2.48 \sqrt{\left(\frac{300}{295}\right)} = 2.5 \text{ mm}$$

The required minimum wall thickness is thus 2.5 mm and the resultant increased test pressure $P_2$ is derived from equation (3)

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

$$= \frac{7 \times 162.56}{1 + 0.12 \sqrt{(300 \times 295)}} = 31 \text{ bar}$$

## B.7 Thickness of domed ends (see 10.5)

Assuming that the domed end is of semi-ellipsoidal form and the external height ($h_o$) is 89.0 mm.

External diameter $D_o = D_i + 2t = 300 + 5 = 305$ mm
ratio $h_o/D_o = 89/305 = 0.292$ (this value is greater than 0.192 required by **10.5.3(c)**).

Shape factor $K$ depends on the values $h_e/D_o$ and $t_e/D_o$. The value of $t$ is not highly critical in establishing the value of $K$ so the calculated wall thickness of 2.5 mm may be used; thus:

$D_o = 305$ mm

$h_e = h_o$ for semi-ellipsoidal end = 89 mm

$t_e = t = 2.5$ mm

$h_e/D_o = 89/305 = 0.292$

$t_e/D_o = 2.5/305 = 0.0082$

and from figure 1, factor $K = 0.80$.

From **10.5.2** the thickness of the domed end $t_e$ is the greater of:

(a) shell thickness calculated in B.5 = 2.5 mm; or

(b) $t \times K = 2.5 \times 0.80 = 2$ mm

therefore $t_e = 2.5$ mm.

## B.8 Minimum bursting pressure (see clause 21)

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

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

Hence the required minimum bursting pressure is

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

where

$f_b = 0.95 \times 295 = 280$ N/mm$^2$

$D_i = 300$ mm

$t_m = 2.5$ mm

Thus $P_b = \frac{280 \times 20 \times 2.5}{300} = 46.67$ bar

## B.9 Summary

| | |
|---|---|
| Minimum wall thickness (shell and ends) | = 2.5 mm |
| Test pressure | = 31 bar |
| Minimum bursting pressure | = 46.67 bar |

## Appendix C. Specimen certificate of compliance for welded aluminium alloy gas containers

Certificate number . . . . . . . . . . . . . . . . . . . . .
Date . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Concerning the manufacture and testing of (quantity) aluminium alloy containers for (designation or type of gas) according to BS . . . for class . . . construction

| | | |
|---|---|---|
| **Manufacturer:** | **Name**<br>**Address** | **Symbol** |
| **Purchaser:** | **Name**<br>**Address** | |

To purchaser's order number . . . . . . . . . . . . . . . . . . . . and container reference . . . . . . . . . . . . . . . . . . . . .
Manuf. nos. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . to . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Purchaser's nos. . . . . . . . . . . . . . . . . . . . . . . . . . . . . to . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

### Technical data

**Containers**

The above containers are manufactured in accordance with the requirements of BS . . . and as detailed on approved drawing nos. . . . . . . . . . . . . . . . . . . . . . .

Container test pressure . . . . . . . . . . . . . . . . . . . . . bar.

Container max. attainable pressure . . . . . . . . . . . . . . bar.

**Materials**

| | | |
|---|---|---|
| **Aluminium alloy manufacturer:** | **Name**<br>**Address**<br>**Ref. no.** | **Aluminium alloy specification**<br>. . . . . . . . . . . . . . . . . |

| Cast no. | Chemical composition | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Al | Si | Fe | Cu | Mg | Mn | Cr | Zn | Ti* | |
| | rem | | | | | | | | | |
| | rem | | | | | | | | | |
| | rem | | | | | | | | | |

*Or other grain refining elements.

**Container heat treatment**

Each of the above containers has been solution heat treated within the range . . . . . . °C and . . . . . . °C followed by water quenching and then artificially aged within the range . . . . . . °C to . . . . . . °C followed by air cooling.

**Water capacity**

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

**Pressure test**

Each of the above containers has been hydraulic pressure tested at . . . . . . bar and subsequently pneumatically 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* | 0.2 % proof stress | Tensile strength | % elongation on . . . mm gauge | Symbol* | Result | Symbol* | Result | Wall | End |
| | | | $N/mm^2$ | $N/mm^2$ | | | | | | mm | mm |
| | | T1 | | | | B1 | | NB1 | | | |
| | | T2 | | | | B2 | | NB2 | | | |
| | | T3 | | | | B3 | | NB3 | | | |
| | | T4 | | | | B4 | | NB4 | | | |
| | | | | | | B5 | | | | | |
| | | | | | | B6 | | | | | |
| | | T1 | | | | B1 | | NB1 | | | |
| | | T2 | | | | B2 | | NB2 | | | |
| | | T3 | | | | B3 | | NB3 | | | |
| | | T4 | | | | B4 | | NB4 | | | |
| | | | | | | B5 | | | | | |
| | | | | | | B6 | | | | | |
| | | T1 | | | | B1 | | NB1 | | | |
| | | T1 | | | | B2 | | NB2 | | | |
| | | T3 | | | | B3 | | NB3 | | | |
| | | T4 | | | | B4 | | NB4 | | | |
| | | | | | | B5 | | | | | |
| | | | | | | B6 | | | | | |

*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 bar | | Nature of failure |
|---|---|---|---|---|---|
| | | | Calculated minimum | Actual | |
| | | | | | |
| | | | | | |
| | | | | | |

Certified by . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Date . . . . . . . . . . . . . . . . . . . . .
(For manufacturer)

On behalf of . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Date . . . . . . . . . . . . . . . . . . . . .
(Independent Inspecting Authority)

Accepted by . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Date . . . . . . . . . . . . . . . . . . . . .

## Appendix D. Inspection and testing facilities

**D.1** The purchaser and the Independent Inspecting Authority should have free access at all reasonable times to that part of the manufacturer's works engaged upon the order, and be at liberty to inspect the fabrication at any stage and to reject any container or part of a container that does not comply with the requirements of this standard.

**D.2** The manufacturer should supply the labour and appliances for such inspection and tests as are required and for any additional checks which may be agreed between the Independent Inspecting Authority and the manufacturer.

**D.3** The manufacturer should give reasonable notice to the Independent Inspecting Authority, as agreed between them, of when the containers will reach a stage at which inspection is required.

## Publications referred to

| | |
|---|---|
| BS 18 | Methods for tensile testing of metals<br>Part 1 Non-ferrous metals |
| BS 341 | Valve fittings for compressed gas cylinders<br>Part 1 Valves with taper stems (excluding valves used for breathing and medical purposes)<br>Part 2 Valves with taper stems for use with breathing apparatus (excluding medical gas cylinders to BS 1319) |
| BS 499 | Welding terms and symbols<br>Part 1 Glossary for welding, brazing and thermal cutting |
| BS 1319 | Specification for medical gas cylinders, valves and yoke connections |
| BS 1470 | Wrought aluminium and aluminium alloys for general engineering purposes — plate, sheet and strip |
| BS 1471 | Wrought aluminium and aluminium alloys for general engineering purposes — drawn tube |
| BS 1472 | Wrought aluminium and aluminium alloys for general engineering purposes — forging stock and forgings |
| BS 1474 | Wrought aluminium and aluminium alloys for general engineering purposes — bars, extruded round tubes and sections |
| BS 1610 | Methods for the load verification of testing machines |
| BS 1639 | Methods for bend testing of metals |
| BS 1780 | Specification for bourdon tube pressure and vacuum gauges |
| BS 1957 | Presentation of numerical values (fineness of expression; rounding of numbers) |
| BS 2901 | Filler rods and wires for gas-shielded arc welding<br>Part 4 Aluminium and aluminium alloys and magnesium alloys |
| BS 2915 | Specification for bursting discs and bursting disc devices |
| BS 3019 | TIG welding<br>Part 1 Specification for TIG welding of aluminium, magnesium and their alloys |
| BS 3451 | Methods of testing fusion welds in aluminium and aluminium alloys |
| BS 3571 | MIG welding<br>Part 1 Specification for MIG welding of aluminium and aluminium alloys |
| BS 4500 | ISO limits and fits |
| BS 4870 | Approval testing of welding procedures<br>Part 2 TIG or MIG welding of aluminium and its alloys |
| BS 4871 | Approval testing of welders working to approved welding procedures<br>Part 2 TIG or MIG welding of aluminium and its alloys |
| BS 5306 | Code of practice for 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 | Unfired fusion welded pressure vessels |

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## Committees responsible for this British Standard

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Aluminium Federation
Associated Offices Technical Committee
Association of Drum Manufacturers
Association of Manufacturers of Domestic Electrical Appliances
British Compressed Gases Association
British Fire Protection Systems Association Ltd.
British Railways Board
British Sub-aqua Club
Chief and Assistant Chief Fire Officers' Association
Department of Trade and Industry (Mechanical and Electrical Engineering Division)
Department of Trade and Industry (National Engineering Laboratory)
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Engineering Equipment and Materials Users' Association
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Health and Safety Executive
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