

# Transportable gas containers —

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

UDC 661.772.43:66.076.5:621.642.2.02:669.715

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

**BSI**  
Documents

**AVA**

Document Sharing Hub

# Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Pressure Vessel Standards Committee (PVE/-) to Technical Committee PVE/3 upon which the following bodies were represented:

- Aluminium Federation
- Associated Offices Technical Committee
- Association of Drum Manufacturers
- British Compressed Gases Association
- 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)
- Department of Trade and Industry (National Physical Laboratory)
- Department of Transport (Marine Directorate)
- Engineering Equipment and Materials Users' Association
- Fire Extinguishing Trades Association
- Health and Safety Executive
- Home Office
- Industrial Safety (Protective Equipment) Manufacturers' Association
- Institute of Refrigeration
- Institution of Chemical Engineers
- Institution of Fire Engineers
- Liquefied Petroleum Gas Industry Technical Association (UK)
- Ministry of Defence
- Motor Industry Research Association
- National Association of Soft Drinks Manufacturers
- Society of Motor Manufacturers and Traders Limited
- Coopted members

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

British Steel Industry

This British Standard, having been prepared under the direction of the Pressure Vessel Standards Committee, was published under the authority of the Board of BSI and comes into effect on 28 September 1984

© BSI 02-1999

The following BSI references relate to the work on this standard:  
Committee reference PVE/3  
Draft for comment 82/76240 DC

ISBN 0 580 13971 9

## Amendments issued since publication

| Amd. No. | Date of issue  | Comments                              |
|----------|----------------|---------------------------------------|
| 5604     | September 1987 |                                       |
| 6073     | May 1989       |                                       |
| 6573     | November 1990  |                                       |
| 6320     | January 1991   | Indicated by a sideline in the margin |

# Contents

|                                                                                                                           | Page               |
|---------------------------------------------------------------------------------------------------------------------------|--------------------|
| Committees responsible                                                                                                    | Inside front cover |
| Foreword                                                                                                                  | ii                 |
| <hr/>                                                                                                                     |                    |
| Section 1. General                                                                                                        |                    |
| 1 Scope                                                                                                                   | 1                  |
| 2 Manufacturing and testing of containers                                                                                 | 1                  |
| 3 Classification of gases                                                                                                 | 1                  |
| 4 Information to be supplied by the purchaser and manufacturer                                                            | 1                  |
| 5 Certificate of compliance                                                                                               | 2                  |
| <hr/>                                                                                                                     |                    |
| Section 2. Permissible materials                                                                                          |                    |
| 6 General                                                                                                                 | 4                  |
| 7 Chemical composition                                                                                                    | 4                  |
| 8 Aluminium producer's certificate                                                                                        | 4                  |
| 9 Identification of aluminium alloy                                                                                       | 4                  |
| <hr/>                                                                                                                     |                    |
| Section 3. Design                                                                                                         |                    |
| 10 Service conditions for design                                                                                          | 5                  |
| 11 Design of container shell                                                                                              | 5                  |
| 12 Fittings                                                                                                               | 6                  |
| <hr/>                                                                                                                     |                    |
| Section 4. Manufacture and workmanship                                                                                    |                    |
| 13 Approval of design and construction details                                                                            | 8                  |
| 14 Permissible processes                                                                                                  | 8                  |
| 15 Heat treatment                                                                                                         | 8                  |
| 16 Tolerances                                                                                                             | 8                  |
| <hr/>                                                                                                                     |                    |
| Section 5. Inspection and tests                                                                                           |                    |
| 17 Hardness test                                                                                                          | 9                  |
| 18 Mechanical tests                                                                                                       | 9                  |
| 19 Examination of thickness, surface imperfections and neck folds                                                         | 10                 |
| 20 Hydraulic tests                                                                                                        | 10                 |
| 21 Checking of water capacity                                                                                             | 12                 |
| 22 Testing of prototype containers                                                                                        | 12                 |
| 23 Results of tests                                                                                                       | 13                 |
| 24 Marking of containers                                                                                                  | 13                 |
| <hr/>                                                                                                                     |                    |
| Appendix A Volumetric expansion testing of seamless containers                                                            | 15                 |
| Appendix B Ultrasonic defect detection and thickness measurement                                                          | 20                 |
| Appendix C Examples of design calculations for cylindrical walls of seamless containers                                   | 22                 |
| Appendix D Specimen certificates                                                                                          | 24                 |
| <hr/>                                                                                                                     |                    |
| Figure 1 — Example of cylinder neck folds before and after machining                                                      | 1                  |
| Figure 2 — Water jacket volumetric expansion test (levelling burette)                                                     | 1                  |
| Figure 3 — Water jacket volumetric expansion test (fixed burette)                                                         | 1                  |
| Figure 4 — Non-water jacket volumetric expansion test                                                                     | 1                  |
| <hr/>                                                                                                                     |                    |
| Table 1 — Classification of gases suitable for conveyance in seamless aluminium alloy containers                          | 1                  |
| Table 2 — Cast analysis                                                                                                   | 1                  |
| Table 3 — Mechanical properties                                                                                           | 1                  |
| Table 4 — Reference temperatures for developed pressure for conveyance in the UK in uninsulated containers                | 1                  |
| Table 5 — Reference temperatures for filling ratio for low pressure liquefiable gases in the UK in uninsulated containers | 2                  |
| Table 6 — <i>K</i> factors for the compressibility of water                                                               | 4                  |
| Publications referred to                                                                                                  | Inside back cover  |

## Foreword

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

This particular standard deals with the materials, design, construction and testing of new containers and 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<sup>1)</sup>;*
- *Part 5: Specification for welded aluminium alloy containers of water capacity 1 litre up to 130 litres<sup>1)</sup>;*
- *Part 6: Specification for seamless containers of up to and including 0.5 litre water capacity.*

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

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

### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 26, an inside back cover and a back cover.

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

---

<sup>1)</sup> In course of preparation.

# Section 1. General

## 1 Scope

This Part of BS 5045 specifies requirements for the materials, design, construction and testing of aluminium alloy containers of water capacity greater than 0.5 litre and up to and including 300 bar<sup>2)</sup> charging pressure at 15 °C, for the conveyance of gases under pressure. Such containers are suitable also for storing gas under pressure.

It includes appendices giving examples of design calculations, a description of the methods for pressure testing containers, a description of the methods for ultrasonic defect detection and thickness measurement and model forms of design and acceptance certificates.

It does not cover the design and manufacture of portable fire extinguishers having a working pressure up to and including 25 bar at 60 °C; these are specified in BS 5423.

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

## 2 Manufacturing and testing of containers

The manufacture, inspection and testing of containers shall be carried out to the satisfaction of an Independent Inspecting Authority on the Health and Safety Executive list of approved inspecting authorities, hereinafter referred to as the 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 gases*. Those gases that have a critical temperature below – 10 °C.

b) *Liquefiable gases*. Those gases that are liquefiable by pressure at – 10 °C, but which vaporize below 17.5 °C when at not more than 1 013 mbar.

High pressure liquefiable gases are those having a critical temperature between – 10 °C and 70 °C

Lost pressure liquefiable gases are those having a critical temperature above 70 °C.

Those toxic substances that are liquids at 1 013 mbar at 0 °C, but which boil at or below 30 °C at that pressure shall be treated as low pressure liquefiable gases.

Gases that may be conveyed in aluminium alloy containers are classified in Table 1.

### 3.2 Gases not to be contained in aluminium alloy containers

Subject to the exceptions 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  
Bromotrifluorethylene  
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 conveyance 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 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:

- name or classification of gas(es);
- service application;
- volumetric capacity (minimum for liquefiable gases);
- for permanent gases the charged pressure at 15 °C;
- for liquefiable gases, the mass of gas or filling ratio at the prescribed reference temperature or the required developed pressure in service;
- material of construction;
- preferred dimensions;
- shape of base;

<sup>2)</sup> 1 bar = 10<sup>5</sup> N/m<sup>2</sup> = 100 kPa.

- 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.

#### **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) specification of the aluminium alloy;
  - 5) test pressure;

- 6) minimum and maximum masses of container;
- 7) statement that the container will be constructed to the requirements of this standard;
- 8) design approval reference (see clause **13**);
- 9) corrosion allowance if any.
- b) method of manufacture;
- c) fittings to be supplied;
- d) maximum valving torque;
- e) marking arrangement drawing (applicable to the container, see clause **25**);
- f) certificates of test for material and container (see Appendix D).

#### **5 Certificate of compliance**

The Independent Inspecting Authority to be approved by the Health and Safety Executive shall certify that the manufacture, inspection and testing of the container were carried out in accordance with this standard.

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

**Table 1 — Classification of gases suitable for conveyance in seamless aluminium alloy containers**

| Permanent gases<br>( $T_c < -10\text{ °C}$ )                                                                                                                                                                                                                                                              | Liquefiable gases                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                           | High pressure<br>( $-10\text{ °C} \leq T_c \leq 70\text{ °C}$ )                                                                                                                                                                                                                                                                                          | Low pressure<br>( $T_c > 70\text{ °C}$ )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Air<br>Argon<br>Carbon monoxide <sup>ab</sup><br>Carbon tetrafluoride (R14)<br>Coal gas <sup>ab</sup><br>Deuterium <sup>a</sup><br>Helium<br>Hydrogen <sup>a</sup><br>Krypton<br>Methane (natural gas) <sup>a</sup><br>Neon<br>Nitrogen<br>Oxygen<br>Town gas (excluding coal gas) <sup>ab</sup><br>Xenon | Bromotrifluoromethane (R13B1)<br>Carbon dioxide<br>Chlorotrifluoromethane (R13)<br>Diborane <sup>b</sup><br>1,1-Difluoroethylene (R1132a) <sup>a</sup><br>Ethane <sup>a</sup><br>Ethylene <sup>a</sup><br>Hexafluoroethane (R116)<br>Nitric oxide<br>Nitrous oxide<br>Phosphine <sup>b</sup><br>Silane<br>Sulphur hexafluoride<br>Trifluoromethane (R23) | Allene <sup>a</sup><br>Ammonia <sup>b</sup><br>Arsine <sup>ab</sup><br>Bromochlorodifluoromethane (R12B1)<br>Butadiene <sup>a</sup><br>Butane <sup>a</sup><br>1 Butene <sup>a</sup><br>2 Butene <sup>a</sup><br>Carbonyl sulphide <sup>ab</sup><br>Chlorodifluoromethane (R22)<br>1-Chloro-1,1-difluoroethane (R142B)<br>Chloropentafluoroethane (R115)<br>2-Chloro-1,1,1-trifluoroethane (R133a)<br>Cyanogen <sup>ab</sup><br>Cyclopropane <sup>a</sup><br>Dichlorodifluoromethane (R12)<br>Dichlorofluoromethane (R21)<br>1,1-Difluoroethane (R152a) <sup>a</sup><br>1,2-Dichlorotetrafluoroethane (R114)<br>Dimethylamine <sup>a</sup><br>Dimethyl ether <sup>a</sup><br>2,2 Dimethyl propane <sup>a</sup><br>Ethyl acetylene<br>Ethylamine <sup>ad</sup><br>Hexafluoropropene<br>Hydrogen cyanide <sup>ab</sup><br>Hydrogen selenide<br>Hydrogen sulphide <sup>ab</sup><br>Isobutane <sup>a</sup><br>Isobutylene <sup>a</sup><br>Methyl acetylene <sup>a</sup><br>Methylamine <sup>abd</sup><br>3 Methyl-1-butane <sup>a</sup><br>Methyl mercaptan <sup>ab</sup><br>Nitrogen tetroxide <sup>b</sup><br>Nitrogen trioxide<br>Octafluorocyclobutane (RC318)<br>Perfluoro-2-butene <sup>b</sup><br>Perfluoro propane<br>Propane <sup>a</sup><br>Propylene <sup>a</sup><br>Sulphur dioxide <sup>b</sup><br>Trimethylamine <sup>ad</sup><br>Vinyl bromide <sup>be</sup><br>Vinyl chloride <sup>ae</sup><br>Vinyl fluoride <sup>ae</sup><br>Vinyl methyl ether <sup>a</sup><br>Gas mixtures<br>Azeotrope R500 (73.8 % R12 and 26.2 % R152a)<br>Azeotrope R502 (48.8 % R22 and 51.2 % R115) |

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 shipped in aluminium cylinders are to be free from reactive halogens.

<sup>a</sup> For the purpose of transport, these gases are considered to be flammable.

<sup>b</sup> 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 high concentrations.

<sup>c</sup> Normally only available as a component of a mixture.

<sup>d</sup> Special care is necessary to ensure that these gases are dry to less than 20 vpm of moisture.

<sup>e</sup> As a mixture component only up to 1 % by volume of total cylinder contents.

## Section 2. Permissible materials

### 6 General

Containers shall be made only from materials whose compositions are given in Table 2; the mechanical properties of the finished container shall be as given in Table 3.

### 7 Chemical composition

**7.1** The cast analysis and product analysis shall be as given in Table 2.

**7.2** 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 tapped from the furnace without any further addition of metal having been made (when a continuous melting process is employed); or

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

### 8 Aluminium producer's certificate

The container manufacturer shall obtain from the aluminium alloy producer a certificate stating that the material specified therein complies with the limits given in Table 2.

### 9 Identification of aluminium alloy

The aluminium alloy shall be marked and records shall be kept so as to enable the cast from which a container is made to be identified.

**Table 2 — Cast analysis**

| Element                  | Material code                               |                                              |                                             |
|--------------------------|---------------------------------------------|----------------------------------------------|---------------------------------------------|
|                          | BS alloy 6082 <sup>a</sup><br>(code mark A) | IAA alloy 6351 <sup>b</sup><br>(code mark B) | BS alloy 6061 <sup>a</sup><br>(code mark C) |
| Silicon                  | %<br>Min. 0.7<br>Max. 1.3                   | %<br>Min. 0.7<br>Max. 1.3                    | %<br>Min. 0.40<br>Max. 0.8                  |
| Iron                     | Max. 0.50                                   | Max. 0.50                                    | Max. 0.7                                    |
| Copper                   | Max. 0.10                                   | Max. 0.10                                    | Min. 0.15<br>Max. 0.40                      |
| Manganese                | Min. 0.40<br>Max. 1.0                       | Min. 0.40<br>Max. 0.8                        | Max. 0.15                                   |
| Magnesium                | Min. 0.6<br>Max. 1.2                        | Min. 0.40<br>Max. 0.8                        | Min. 0.8<br>Max. 1.2                        |
| Chromium                 | Max. 0.25                                   | —                                            | Min. 0.04<br>Max. 0.35                      |
| Zinc                     | Max. 0.20                                   | Max. 0.20                                    | Max. 0.25                                   |
| Titanium                 | Max. 0.10                                   | Max. 0.20                                    | Max. 0.15                                   |
| Others each <sup>c</sup> | Max. 0.05                                   | Max. 0.05                                    | Max. 0.05                                   |
| Others total             | Max. 0.15                                   | Max. 0.15                                    | Max. 0.15                                   |
| Aluminium                | The remainder                               | The remainder                                | The remainder                               |

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

<sup>a</sup> As specified in BS 1474 and the Aluminium Association Register.

<sup>b</sup> As specified in the Aluminium Association Register.

<sup>c</sup> In addition to this limit it is necessary to restrict lead to 0.003 % max.

**Table 3 — Mechanical properties**

| Mechanical properties                                          | IAA alloy 6351<br>BS alloy 6082<br>BS alloy 6061 |
|----------------------------------------------------------------|--------------------------------------------------|
| Tensile strength ( <i>T</i> )                                  | 325 N/mm <sup>2</sup> min.                       |
| Specified minimum 0.2 % proof stress ( <i>Y</i> ) <sup>a</sup> | 280 N/mm <sup>2</sup> min.                       |
| Elongation % on 5.65 $\sqrt{S_0}$                              | 12 min.                                          |
| Bend test former radius                                        | 3 $t_a$ <sup>b</sup> max.                        |
| Hardness equivalent to:                                        |                                                  |
| Brinell                                                        | 90 min.                                          |
| or                                                             |                                                  |
| Rockwell B                                                     | 45 min.                                          |

<sup>a</sup> Values in excess of this should not be used for calculation purposes.

<sup>b</sup>  $t_a$  is the actual thickness of the specimen.

## Section 3. Design

### 10 Service conditions for design

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

NOTE 1 The maximum permissible pressure in service is the pressure developed by the contents at the pressure reference temperature.

NOTE 2 Reference temperatures for filling ratios of low pressure liquefiable gases in uninsulated containers vary with the size of container. The relationships are expressed in Table 5. Examples of design calculations are given in Appendix C.

**10.2** The test pressure on which the design of the container is based shall be not less than the greater of a) or b):

- a)  $1.5 \times$  charged pressure at 15 °C (for permanent gases);
- b)  $\frac{1}{0.85} \times$  the pressure developed by the gas at the reference temperature (for permanent and liquefiable gases).

For carbon dioxide and nitrous oxide in UK services, the test pressure shall not be less than 200 bar.

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

**10.4** The internal volume of a container for a permanent gas shall be such as to provide a nominated gas content at 15 °C and 1 013 mbar.

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

## 11 Design of container shell

### 11.1 Nomenclature

The following symbols are used in this standard.

- $t$  is the minimum wall thickness (in mm) to resist internal pressure and external forces due to normal handling but excluding any additional thickness for other influences;
- $p_1$  is the test pressure (in bar) applicable to the design governed by equations (1) and (2);
- $D_o$  is the external diameter of the container (in mm);
- $D_i$  is the internal diameter of the container (in mm);
- $f_e$  is the maximum permissible equivalent stress (in N/mm<sup>2</sup>) at test pressure

(=  $0.75 \times$  minimum specified 0.2 % proof stress ( $Y$ ) of the material of construction, or =  $0.875 \times$  minimum specified 0.2 % proof stress ( $Y$ ) of the material of construction, for containers covered by 11.4);

$T$  is the minimum tensile strength (in N/mm<sup>2</sup>);

$Y$  is the minimum specified 0.2 % proof stress (in N/mm<sup>2</sup>).

NOTE Values of  $T$  and  $Y$  for the permissible materials are given in Table 3.

### 11.2 Permissible pressure

The pressure developed by a permanent gas at 60 °C or by a high pressure liquefiable gas (see Table 4) shall not exceed 85 % of the test pressure. Carbon dioxide and nitrous oxide containers shall be designed for a test pressure in accordance with 10.1.

### 11.3 Thickness of cylindrical shell

The thickness of the cylindrical shell of a container for liquefiable gases and permanent gases up to and including a charged pressure at 15 °C at 210 bar shall be not less than the value given by equation (1)

$$t = \frac{0.3p_1 D_i}{7f_e - p_1} \quad \text{or} \quad t = \frac{0.3p_1 D_o}{7f_e - 0.4p_1} \quad (1)$$

For containers for permanent gas, equation (1) or equation (2) may be used where the charged pressure at 15 °C is greater than 210 bar:

$$t = \frac{p_1 D_i}{20 f_e - p_1} \quad \text{or} \quad t = \frac{p_1 D_o}{20 f_e + p_1} \quad (2)$$

NOTE For those containers covered by 11.4, an increased maximum equivalent stress as given in 11.1 is permissible. The thickness of the shell determined by equation (1) or equation (2) shall be not less than the value given by equation (3).

$$t = 2.48 \sqrt{\left(\frac{D_i}{T}\right)} \quad (3)$$

See Appendix C for examples of wall thickness calculations using equations (1) and (2).

NOTE 1 *Additional thickness.* Influences other than those of internal pressure and of external forces due to ordinary handling may require the provision of additional wall thickness above the calculated value of  $t$ . Additional thickness may 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 the user of the containers.

NOTE 2 *Shape and thickness of ends.* Rules for the design of container ends are not given, but see clause 14.

**Table 4 — Reference temperatures for developed pressure for conveyance in the UK<sup>a</sup> in uninsulated containers**

| Gas classification                                                                                                                                                                                                                          | Container volume <i>V</i> (water capacity) |                                             |                                                        |                                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---------------------------------------------|--------------------------------------------------------|----------------------------------|
|                                                                                                                                                                                                                                             | ≤ 130 L                                    | > 130 L<br>≤ 1 m <sup>3</sup><br>(see note) | > 1 m <sup>3</sup><br>≤ 5 m <sup>3</sup><br>(see note> | > 5 m <sup>3</sup><br>(see note> |
|                                                                                                                                                                                                                                             | Reference temperature                      |                                             |                                                        |                                  |
| <b>Low pressure liquefiable gas</b>                                                                                                                                                                                                         | 55 °C                                      | 50 °C                                       | 47.5 °C                                                | 42.5 °C                          |
| <b>High pressure liquefiable gas</b>                                                                                                                                                                                                        | 52.5 °C <sup>b</sup>                       | 52.5 °C <sup>b</sup>                        | 50 °C                                                  | 45 °C                            |
| <b>Permanent gas</b>                                                                                                                                                                                                                        | 60 °C                                      |                                             |                                                        |                                  |
| NOTE For the purpose of the above table, when the ratio of the overall length of the container to the diameter exceeds 4.5, the volume of the container is assumed to be that volume contained in a length 4.5 times the external diameter. |                                            |                                             |                                                        |                                  |
| <sup>a</sup> For containers to be used outside the United Kingdom, reference should be made to BS 5355 for the relevant reference temperature and developed pressure.                                                                       |                                            |                                             |                                                        |                                  |
| <sup>b</sup> When safety devices are fitted to carbon dioxide containers, this reference temperature may be reduced to 50 °C.                                                                                                               |                                            |                                             |                                                        |                                  |

**Table 5 — Reference temperatures for filling ratio for low pressure liquefiable gases in the UK in uninsulated containers**

| Container volume <i>V</i> (water capacity) | ≤ 130 L | > 130 L<br>≤ 1 m <sup>3</sup> | > 1 m <sup>3</sup><br>≤ 5 m <sup>3</sup> | > 5 m <sup>3</sup> |
|--------------------------------------------|---------|-------------------------------|------------------------------------------|--------------------|
| <b>Reference temperature</b>               | 42.5 °C | 42.5 °C                       | 42.5 °C                                  | 38 °C              |

#### 11.4 Special portable containers

For portable containers of not more than 15 L water capacity used in aircraft, for breathing apparatus, for underwater breathing dress apparatus, for resuscitation apparatus, for fire extinguishers and those for life raft and life jacket inflation, the increased maximum equivalent stress given in 11.1 is permissible, but only equation (1) shall be used to calculate wall thickness.

## 12 Fittings

### 12.1 Valve fittings

Valve fittings shall comply with BS 341-1 or BS 341-2 or BS 1319, as appropriate, in respect of quality and materials.

Fittings manufactured with materials of construction that are not compatible with aluminium alloys, the product conveyed in the container or the environment in which the container is used, shall be protected with a suitable coating or plating.

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:

- containers of 130 L water capacity and below intended for the transport of non-toxic flammable gases and carbon monoxide and mixtures thereof where direct consignments are made between filler and user;
- 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 reference temperature.