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Transportable gas containers —

**Part 8: Specification for seamless
aluminium alloy gas containers of water
capacity 0.5 L up to 15 L and up to
300 bar charged pressure at 15 °C for
special portable applications**

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Standards Committee Pressure Vessels PVE/3/-, 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

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Foreword

This British Standard has been prepared under the direction of the Pressure Vessel Standards Committee. Together with BS EN 1975:2000 it supersedes BS 5045-3:1984 which is withdrawn. When first published BS 5045-3:1984 was one of a series which dealt with materials, design, construction, testing, filling and maintenance of containers intended for the conveyance by road of permanent, liquefiable and dissolved gases under pressure.

The requirements of seamless aluminium and aluminium alloy containers for general applications in BS 5045-3:1984 were superseded by the publication of BS EN 1975 in 2000. However requirements for small portable containers for special applications remain current.

This new edition therefore renumbers BS 5045-3:1984 as BS 5045-8:2000 and modifies its scope to restrict its applicability to these special application containers. It does not, however, constitute a full revision of the standard.

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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 23 and a back cover.

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General

1 Scope

This part of BS 5045 specifies requirements for the materials, design, construction and testing of seamless aluminium alloy containers of water capacity greater than 0.5 litre up to 15 litres and up to and including 300 bar¹⁾ charging pressure at 15 °C, for the conveyance and storage of gases under pressure used in the following portable applications:

- for use in aircraft;
- for breathing apparatus;
- for underwater breathing dress apparatus;
- for resuscitation apparatus;
- for fire extinguishers;
- for life raft inflation apparatus.

It includes annexes 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.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications so not apply. For undated references, the latest edition of the publication referred to applies.

BS 341-1, *Transportable gas container valves — Part 1: Specification for industrial valves for working pressures up to and including 300 bar*

BS 341-2, *Transportable gas container valves — Part 2: Valves with taper stems for use with breathing apparatus*

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

BS EN 837-1:1998, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing*

BS EN 850:1997, *Transportable gas cylinders — Pin-index, yoke-type valve outlet connections for medical use*

BS EN 10002-1:1990, *Tensile testing of metallic materials — Part 1: Method of test at ambient temperature*

BS EN 10002-3:1995, *Tensile testing of metallic materials — Part 3: Calibration of force proving instruments used for the verification of uniaxial testing machines*

BS EN 10003-1:1995, *Metallic materials — Brinell hardness test — Part 1: Test method*

BS EN 10109-1, *Metallic materials — Hardness test — Part 1: Rockwell test (scales A, B, C, D, E, F, G, H, K) and Rockwell superficial test (scales 15 N, 30 N, 45 N, 15 T, 30 T and 45 T)*

BS EN 20286, *ISO system of limits and fits*

BS EN ISO 2566-1:1999, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

3 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.

4 Classification of gases

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

a) Permanent gases

Those gases that have a critical temperature below -10 °C .

b) Liquefiable gases

Those gases that are liquefiable by pressure at -10 °C , but 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 .

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

This classification is illustrated in Table 1.

¹⁾ 1 bar = 10^5 N/m^2 = 100 kPa.

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

Permanent gases ($T_c < -10\text{ °C}$)	Liquefiable gases	
	High pressure ($-10\text{ °C} \leq T_c \leq 70\text{ °C}$)	Low pressure ($T_c > 70\text{ °C}$)
Air	Carbon dioxide	—
Argon	Nitrous oxide	
Helium		
Nitrogen		
Oxygen		
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 shall be free from reactive halogens.		

5 Information to be supplied by the purchaser and manufacturer

5.1 Information to be supplied by the purchaser

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

- a) service application;
- b) volumetric capacity (minimum for liquefiable gases);
- c) for permanent gases the charged pressure at 15 °C;
- d) for liquefiable gases, the mass of gas or filling ratio at the prescribed reference temperature or the required developed pressure in service;
- e) material of construction;
- f) preferred dimensions;
- g) shape of base;
- h) internal and/or external neck screwing dimensions;
- i) fittings required;
- j) external/internal finish required;
- k) any special or adverse conditions under which the container will be required to operate and any corrosion allowance required;
- l) whether any addition is required to the requirements of this standard;
- m) the name of the Independent Inspecting Authority.

5.2 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 14);
 - 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 annex D).

6 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 An example of a certificate is shown in annex D.

7 Permissible materials — General

Containers shall be made only from materials whose compositions are specified in Table 2; the mechanical properties of the finished container shall conform to those specified in Table 3.

8 Permissible materials — Chemical composition

8.1 The cast analysis and product analysis shall be as specified in Table 2.

8.2 The cast shall be one of the following:

- 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.

9 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.

Table 2 — Cast analysis

Element	Material code		
	BS alloy 6082 ¹⁾ (code mark A)	IAA alloy 6351 ²⁾ (code mark B)	BS alloy 6061 ³⁾ (code mark C)
	%	%	%
Silicon	Min. 0.7 Max. 1.3	Min. 0.7 Max. 1.3	Min. 0.40 Max. 0.8
Iron	Max. 0.50	Max. 0.50	Max. 0.7
Copper	Max. 0.10	Max. 0.10	Min. 0.15 Max. 0.40
Manganese	Min. 0.40 Max. 1.0	Min. 0.40 Max. 0.8	Max. 0.15
Magnesium	Min. 0.6 Max. 1.2	Min. 0.40 Max. 0.8	Min. 0.8 Max. 1.2
Chromium	Max. 0.25	—	Min. 0.04 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 ³⁾	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

¹⁾ As specified in BS 1474 and the Aluminum Association Register.

²⁾ As specified in the Aluminum Association Register.

³⁾ In addition to this limit it is necessary to restrict lead to 0.003 % max.

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

10 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 3 — Mechanical properties

Mechanical properties	IAA alloy 6351 BS alloy 6082 BS alloy 6061
Tensile strength (<i>T</i>)	325 N/mm ² min.
Specified minimum 0.2 % proof stress (<i>Y</i>) ¹⁾	280 N/mm ² min.
Elongation % on 5.65 $\sqrt{S_0}$	12 min.
Bend test former radius	3 t_a ²⁾ max.
Hardness equivalent to:	
Brinell	90 min.
or	
Rockwell B	45 min.
¹⁾ Values in excess of this should not be used for calculation purposes.	
²⁾ t_a is the actual thickness of the specimen.	

11 Design — Service conditions for design

11.1 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 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 Examples of design calculations are given in annex C.

11.2 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 be not less than 200 bar.

11.3 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 specified in BS 5355.

11.4 The internal volume of a container for a permanent gas shall be such as to provide a nominated gas content at 15 °C and 1013 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.

Table 4 — Reference temperatures for developed pressure for conveyance in the UK¹⁾ in uninsulated containers

Gas classification	Reference temperature
High pressure liquefiable gas	52.5 °C ²⁾
Permanent gas	60 °C

¹⁾ For containers to be used outside the United Kingdom, reference should be made to BS 5355 for the relevant reference temperature and developed pressure.
²⁾ When safety devices are fitted to carbon dioxide containers, this reference temperature may be reduced to 50 °C.

12 Design of container shell

12.1 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/mm²) at test pressure ($= 0.875 \times$ minimum specified 0.2 % proof stress (Y) of the material of construction);
- T is the minimum tensile strength (in N/mm²);
- Y is the minimum specified 0.2 % proof stress (in N/mm²).

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

12.2 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 11.1.

12.3 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):

$$t = \frac{0.3p_1D_i}{7f_e - p_1} \text{ or } t = \frac{0.3p_1D_o}{7f_e - 0.4p_1} \quad (1)$$

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:

$$t = \frac{p_1D_i}{20f_e - p_1} \text{ or } t = \frac{p_1D_o}{20f_e + p_1} \quad (2)$$

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 annex 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 during 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 specified, but see clause 15.

13 Design — Fittings

13.1 Valve fittings

Valve fittings shall conform to BS 341-1 or BS 341-2 or BS EN 850, 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.

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.

13.2 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.

13.3 Pressure relief devices

13.3.1 General requirements

A pressure relief device may be fitted.

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

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.

13.3.2 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.

13.3.3 Bursting discs

A bursting disc may be fitted. Bursting discs, if fitted, shall comply with BS 2915, except that flat discs may be used, and shall be so designed as to ensure that rupture occurs at a pressure not greater than the test pressure of the container.

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.

13.3.4 Fusible plugs

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

NOTE The Health and Safety Executive should be consulted if it is proposed to fit containers with one or more fusible plugs.

14 Manufacture and workmanship — Approval of design and construction details

Before manufacture is commenced, three copies of detailed drawings showing each new design of container together with the method of manufacture shall be submitted to an Independent Inspecting Authority for approval.

No alteration shall be made to the design or method of manufacture after approval unless such alteration has received prior agreement of an Independent Inspecting Authority.

15 Manufacture and workmanship — Permissible processes

The container shall be made:

- a) by cold or hot extrusion from cast or extruded billets; or
- b) by cold or hot extrusion followed by cold drawing from cast or extruded billets; or
- c) by cupping and cold drawing sheet or plate; or
- d) by necking at both ends extruded or cold drawn tube.

They shall be made only by a process that has been shown to produce containers free from cracks or other flaws that could adversely affect the safety of the containers.

The ends shall be of an approved shape and shall be formed by forging, swaging, or spinning.

Ends shall not be welded on and the metal shall not be added in the process of closing.

16 Manufacture and workmanship — Heat treatment

16.1 Each container shall be solution heat treated at a temperature within the range 515 °C to 545 °C and water quenched and then artificially aged at a temperature selected within the range 150 °C to 200 °C.

16.2 Minimum mechanical properties required in the finished container after heat treatment and at room temperature shall be as given in Table 3.

16.3 The operations involving heat treatment shall be carried out carefully in furnaces equipped to control temperatures accurately, and the containers shall be maintained at the stipulated temperatures for the length of time necessary to ensure that all parts have reached the required temperature and all necessary metallurgical changes have been effected.