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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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Contents

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

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 bar[1)] 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 ($T_c < -10$ °C)	Liquefiable gases	
	High pressure (-10 °C $\leq T_c \leq 70$ °C)	Low pressure ($T_c > 70$ °C)
Air Argon Helium Nitrogen Oxygen	Carbon dioxide Nitrous oxide	—

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	Min. 0.7	Min. 0.40
	Max. 1.3	Max. 1.3	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	Min. 0.40	
	Max. 1.0	Max. 0.8	Max. 0.15
Magnesium	Min. 0.6	Min. 0.40	Min. 0.8
	Max. 1.2	Max. 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 (T)	325 N/mm^2 min.
Specified minimum 0.2 % proof stress (Y)[1]	280 N/mm^2 min.
Elongation % on 5.65 $\sqrt{S_o}$	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 × charged pressure at 15 °C (for permanent gases);

b) $\frac{1}{0.85}$ × 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 UK[1)] 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 × 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):

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

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:

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

The thickness of the shell determined by equation (1) or equation (2) shall be not less than the value given by equation (3).

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

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.

17 Manufacture and workmanship — Tolerances

The difference between the maximum and minimum external diameter measured at any cross section of the cylindrical portion of the container shall not exceed 2 % of the nominal external diameter.

The wall thickness shall not at any point be less than the value of *t* calculated in accordance with **12.3**.

The length shall be such that the nominal water capacity for permanent gases and the minimum water capacity for liquefiable gases shall be obtained as agreed between purchaser and manufacturer.

18 Inspection and tests — Hardness test

Each aluminium alloy container after heat treatment shall be subjected to a hardness test. This shall be:

a) the Brinell hardness test as given in BS EN 10003-1, in which case:

$$\frac{\text{load (in kgf)}}{(\text{ball diameter})^2\ (\text{in mm}^2)} = 10;\ \text{or}$$

b) the Rockwell hardness test in accordance with BS EN 10109-1, in which case the value obtained shall be as given in **11.2**; or

c) other equivalent method approved by the Independent Inspecting Authority.

NOTE Should the hardness of any container fall below these minimum values it may be re-heat treated in accordance with **21.7** and then retested.

19 Inspection and tests — Mechanical tests

19.1 General

Mechanical tests shall be carried out on the material of finished containers in accordance with **19.2.1** for normal production and **19.2.2** for continuous line production.

Normal production is a manufacturing method where production is not totally machine controlled.

For the purpose of testing, a batch is a group of containers of the same design not exceeding 201 in number, from the same cast, heat treated at the same conditions of temperature and duration.

A continuous flow line production process is one where production is continuous and is totally machine controlled, the container manufacturer being satisfied that the process achieves consistently reproducible results as approved by an Independent Inspecting Authority.

19.2 Frequency of testing

19.2.1 For normal production, tensile and bend tests in accordance with **19.3** and **19.4** shall be carried out on the material of one finished container in every batch.

19.2.2 In the case of flow line production, tensile and bend tests in accordance with **19.3** and **19.4**, on the material of finished containers, shall be carried out as follows:

a) After a change of material cast: three containers shall be taken from the first 500 containers produced, including the first container.

b) After a significant break in production, e.g. a weekend: a minimum of one container shall be taken from the first 500 containers produced.

c) After the first 500 containers produced following start-up of a production run: testing shall be at regular intervals throughout the production run at the following minimum frequency:

Daily production rate	No. tested at even intervals
Up to 1 000	1 container
Up to 5 000	2 containers
Up to 10 000	3 containers
Up to 20 000	4 containers
Up to 30 000	5 containers

All containers shall be identified so that if a container fails a test, containers produced since the last successful test can be isolated and submitted to further tests (see **24.2** to **24.5**).

NOTE The frequency of tests may be increased to reduce the span of production between tests.

19.3 Tensile test

19.3.1 The tensile test specimen shall be made from a strip cut longitudinally from a finished container or test ring and its form and dimensions shall be in accordance with BS EN 10002-1. The cross-section shall either be formed by a portion of the wall of the container or (when the wall thickness permits) be circular with a diameter of not less than 7 mm for the central portion.

19.3.2 In preparing the test piece with the cross-section formed by a portion of the wall of the container, the face and back of the test piece shall not be machined, but shall represent the surface of the container as manufactured.

NOTE The ends only may be flattened for gripping in the testing machine.

19.3.3 The tolerance on form (difference between maximum and minimum values of a given dimension in any one test piece) for the unmachined surfaces of a test piece shall be to the tolerance grade IT9 of BS EN 20286-2. For test pieces of circular cross-section the machining tolerance on nominal dimensions (the tolerance, compliance with which permits the nominal cross section to be used in computing the test results without calculation of the individual cross-sectional area for each test piece) shall conform to the limit of tolerance IT12 of BS EN 20286-2.

19.3.4 The gauge length for test pieces shall conform to BS EN 10002-1. The use of non-proportional gauge lengths is permissible and the conversion of the elongation values obtained using such lengths shall be in accordance with BS EN ISO 2566-1.

19.3.5 Tensile testing shall be carried out in accordance with BS EN 10002-1.

The limit of error of measurement of ±0.5 % in each dimension prescribed in BS EN 10002-1 shall apply to each measurement. If individual measurements of the thickness of a test piece whose two faces are formed by the surfaces of the container wall differ from one another, the minimum thickness shall be taken for calculation.

When the parallel length of the specimen as specified in BS EN 10002-1 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.

19.3.6 The tensile testing machine shall be maintained to class 1 of BS EN 10002-3.

19.3.7 The results obtained shall be as given in Table 3.

19.4 Bend test

Cold bend tests shall be made on four strips cut from the same container or test ring as that used to provide the tensile test piece. A ring shall either be cut from the container or test ring and divided into four strips of equal length or, alternatively, two rings shall be cut from a container and each ring shall be cut into two strips of equal length. The width of the ring shall be 25 mm unless 25 mm is less than four times the minimum manufacturing thickness of the container as specified on the drawing (including corrosion allowance if any), in which case the width shall be not less than four times the minimum manufacturing thickness of the container or where machining of the test piece is permitted, not less than four times the thickness of the test piece. Except for large containers, the face and the back of the test piece shall not be machined but the edges may be rounded off. Where bending the full thickness of the container is impracticable, the test piece shall at the discretion of the Independent Inspecting Authority be thinned uniformly by machining from one side; the unmachined surface shall be bent in tension.

The test piece shall remain uncracked when bent inwards round a former radius not greater than three times the actual thickness of the specimen as specified in Table 3 until the gap between the ends is not greater than twice the radius of the former.

20 Inspection and tests — Examination of thickness, surface imperfections and neck folds

20.1 Application

The requirement for the examination of thickness, surface imperfections and neck folds applies only to those containers manufactured by normal production (see **19.1**).

20.2 Examination of thickness and surface defects

Before the closing-in operation each container shall be examined for minimum thickness and for external and internal surface defects by mechanical means or ultrasonic methods in accordance with annex B. Any defects shall be removed by local dressing. The wall thickness of the dressed area shall not be reduced below the minimum wall thickness shown on the manufacturer's drawing.

NOTE Superficial score marks, which in the opinion of the Independent Inspecting Authority do not constitute a defect, may be left undressed.

20.3 Examination of neck folds

Each container shall be examined for neck folds by means of an introscope or other suitable method.

Folds that are visible as a line running into the threaded portion as shown at the left-hand side of Figure 1 shall be removed by a machining operation, until the lines are no longer visible. Such machining shall generally be as shown on the right-hand side of Figure 1.

After this machining operation the thickness at the machined area shall not be less than twice the designed wall thickness of the container.

After machining, the whole area shall be re-inspected and measured for thickness. Where folding or lines have not been removed or cracks are visible the container shall be rejected.

Folds that extend beyond the machined area and are open depressions where no oxide skin has been forged into the metal shall be accepted provided that the peaks are smooth and the roots of the depressions are rounded.

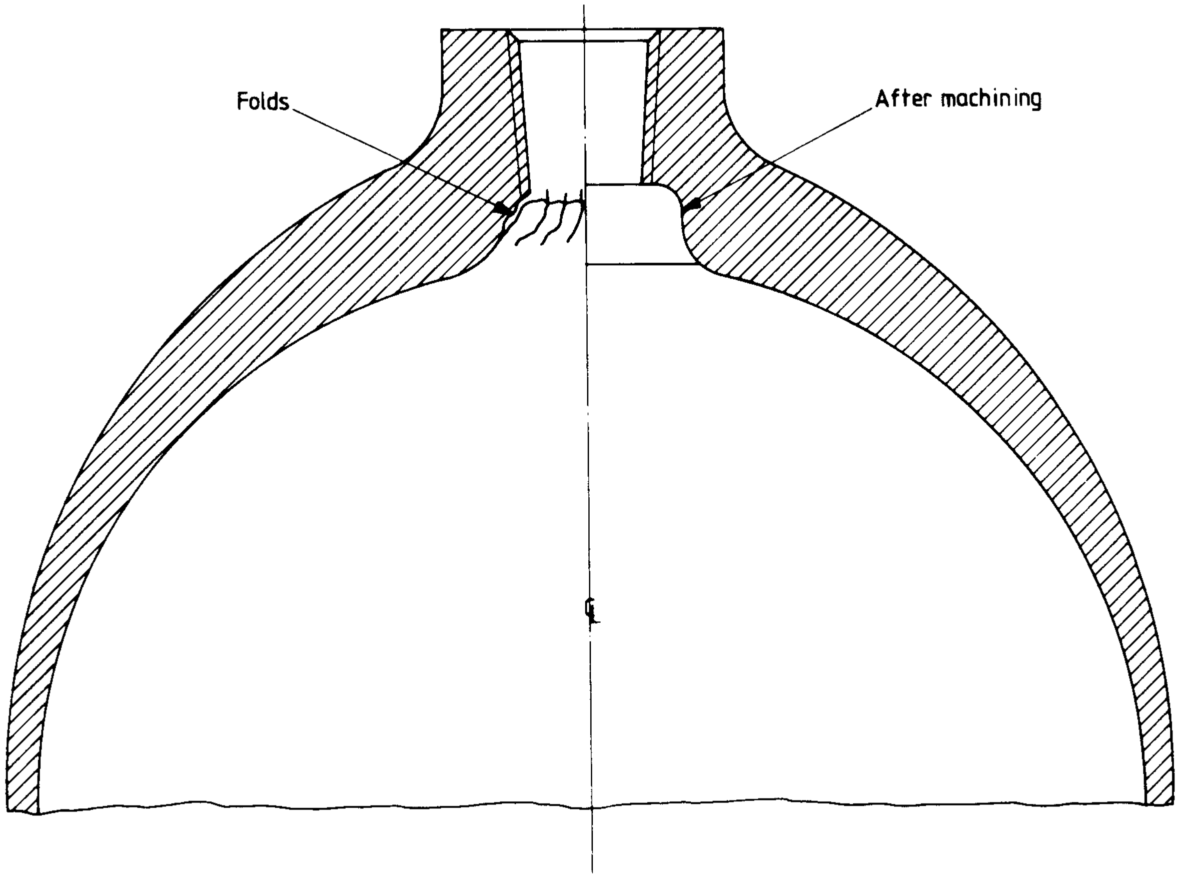

Figure 1 — Example of cylinder neck folds before and after machining

21 Inspection and tests — Hydraulic tests

21.1 General

Each container shall be subjected to a hydraulic test.

21.2 Type of test

21.2.1 When the examination required by **20.1** is carried out by the ultrasonic method specified in annex B, each completed container, other than those required for the tests specified in clause **19**, shall be subjected to either a volumetric expansion test in accordance with **21.4**, or a proof pressure test in accordance with **21.5**.

21.2.2 When the bar stock has been subjected to ultrasonic examination (as specified in annex B) and the containers have been produced by cold or hot extrusion from cast or extruded billet, each container need only be subjected to a proof pressure test as specified in **21.5**.

21.2.3 When ultrasonic examination is not carried out on either container or bar stock, each container shall be subjected to a volumetric expansion test in accordance with **21.4**.

21.3 Test pressure

The test pressure shall be determined in accordance with clause **12**. No pressure greater than 80 % of the test pressure shall have been applied to any container before the test.

21.4 Volumetric expansion test

21.4.1 The permanent volumetric expansion shown by the test expressed as a proportion of the total expansion under the test pressure shall not exceed 5 %.

21.4.2 If the test is made by the "non-jacket method" (see annex A) the container shall be examined for signs of leakage when subjected to the test pressure.

21.4.3 If the permanent volumetric expansion exceeds 5 % of the total expansion under the test pressure, the container shall be deemed not to conform to this standard.

NOTE Provided the container does not show visible deformation, it may be re-heat treated in accordance with **21.7** and then retested.

21.5 Proof pressure test

21.5.1 ***Test equipment***

All rigid pipework, flexible tubing, valves, fittings and components forming the pressure system of the test equipment shall be capable of withstanding a pressure twice the maximum test pressure of any container to be tested.

Pressure gauges shall conform to the requirements of accuracy class 1 of BS EN 837-1.

They shall be tested at regular intervals, and in any case not less frequently than once a month.

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

21.5.2 ***Test method***

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

The test pressure shall be established from the marking on the container. When applied to the container, it shall not be exceeded by more than 3 % or 10 bar, whichever is the lower.

On attaining the test pressure the container(s) shall be isolated from the pump and the pressure held for a minimum period of 1 min, during which period the pressure as registered on the test gauge shall remain constant. Under these conditions of test the container(s) shall not show any sign of leakage, visible deformation or defect.

If there is a leakage in the pressure system it shall be corrected and the container(s) shall be retested.

21.6 Drying out

The interior of each container shall be thoroughly dried immediately after hydraulic testing. Containers shall not be heated above 150 °C.

21.7 Re-heat treatment

Containers shall be re-solution treated no more than once.

NOTE 1 Where it can be established from the heat treatment furnace records that the artificial ageing treatment has not been adequate, additional time at the ageing treatment temperature is permissible.

NOTE 2 Where it can be established that the solution heat treatment was at fault, re-solution treatment and artificial ageing of the container are permissible (see **16.1**).

22 Inspection and tests — Checking of water capacity

The water capacity of each container shall be checked and recorded. 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.

23 Inspection and tests — Testing of prototype containers

23.1 New design

For the purposes of this clause a container shall be considered 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) the base profile and the base thickness have changed relative to the container diameter and calculated minimum wall thickness; or

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

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

f) a change in hydraulic test pressure requires a change in design wall thickness.

Where a container is to be used for a lower pressure duty than that for which design approval has been given, it shall not be deemed a new design.

23.2 Pressure cycling tests

23.2.1 In addition to the tests specified in clauses **18** to **21**, three containers made to a new design shall be submitted to the following pressure cycling tests. The containers shall be certified by the manufacturer to be representative of the design and of the manufacturing process.

23.2.2 The tests shall be carried out using a non-corrosive fluid with a range of pressure equivalent to the pressure or the filling pressure of the containers. 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 containers shall not exceed 50 °C during the test.

23.2.3 Containers shall be considered to have passed the test if they satisfactorily complete either 7000 cycles over a range equivalent to the test pressure or 60 000 cycles over a range equivalent to the charged pressure.

23.2.4 Following the test described in **23.2.2**, the containers shall be hydraulically tested to destruction. The containers shall remain in one piece after bursting.

23.2.5 Where these tests are not practicable the Health and Safety Executive shall be consulted.

23.2.6 The nominal hoop stress corresponding to the pressure at which destruction occurs shall be calculated from the formula:

where

$$P_b = \frac{20 f_b t'}{(D_o - t')}$$

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

t' is the actual minimum wall thickness (in mm) of the container being tested.

The value of f_b shall be not less than 0.95 of the minimum specified tensile strength of the material of the container.

23.3 Other prototype tests

Other prototype testing shall be as specified in **25.4**, **25.5** and **25.6**.

24 Inspection and tests — Results of tests

24.1 A record shall be kept of all tests made at the container manufacturer's works.

24.2 If any of the test specimens fail the mechanical tests and if the Independent Inspecting Authority considers that the failure was due to an error in carrying out the test, the authority may authorize a retest and the first test shall be ignored. Otherwise, at the manufacturer's discretion, either of the following applies.

a) The mechanical test in which the failure occurred shall be repeated on the container or test ring originally tested, and in addition the tests under **19.3** and **19.4** shall be carried out on another container or test ring from the same batch. Both containers or both test rings shall then conform to **19.3** and **19.4** for the batch to be accepted.

b) The batch shall be re-heat treated as specified in **21.7** and the mechanical tests called for in **19.3** and **19.4** shall be carried out. If the test specimens then comply with **19.3** and **19.4**, the batch shall be accepted.

24.3 If any of the specimens fail the mechanical tests required by **24.2** a) or b), the batch shall be re-heat treated as specified in **21.7** as appropriate, and re-tested as specified in **24.2**; if the test specimens then conform to **19.3** and **19.4** the batch shall be accepted.

24.4 Not more than two containers or two test rings from one batch shall be submitted for test and the limitations on re-heat treatments in **21.7** shall apply.

24.5 If after the permitted number of re-tests and re-heat treatments the mechanical requirements have not been conformed to, the containers in the batch shall be rendered unserviceable for holding gas under pressure, by one of the following methods.

a) The container shall be crushed by mechanical means.

b) An irregular hole shall be made in the top dome of the container, equivalent in area to approximately 10 % of the area of the top dome; or, in the case of thin walled containers, the containers shall be pierced in at least three places. Drilling a hole or holes in a container shall not be considered as satisfying the requirements of this clause.

NOTE Alternative methods may be used subject to consultation with the Health and Safety Executive.

25 Inspection and tests — Marking of containers

25.1 Each container shall be permanently and legibly marked with:

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

b) the test pressure (in bar) and date of the hydraulic test (indicated by the month and year, or by the year with a symbol to denote the quarter of the year) and the identification mark of the person or firm who carried out the test;

c) the identification mark(s) of the Independent Inspecting Authority;

d) the number of this standard, i.e. BS 5045-8[2)] and the code mark (see Table 2) of the material of construction, e.g. BS 5045/8/A;

e) the letter S; this letter shall follow the specification number referred to in d) above, e.g. BS 5045/8/A/S;

f) the design minimum water capacity of the container if it is intended to be used for the conveyance of liquefiable gas (in L);

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

h) the mass of the container only, if it is intended for the conveyance of permanent gases (in kg);

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

25.2 The manufacturer's mark shall be either on the base or the neck end of the container; all other marks shall be on the neck end.

25.3 No permanent marking shall be made on the body of the container but shall be at areas in the formed neck and/or base ends where the thickness of metal is greater than the design minimum and where it is adequate for marking to be carried out.

25.4 To verify the thickness of the metal at the ends of the container and the areas suitable for marking, a prototype container shall be sectioned at the end and the areas where marking is permitted shall be agreed between the manufacturer and the Independent Inspecting Authority.

25.5 A further prototype container shall be similarly sectioned and examined after marking. The marking shall cause no change in contour of the container.

25.6 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.

25.7 When the conditions set out in **25.2** to **25.6** cannot be satisfied the Independent Inspecting Authority shall be consulted.

[2)] Marking BS 5045-8 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification

Annex A (informative) Volumetric expansion testing of seamless containers

A.1 General

This annex gives details of two methods for determining the volumetric expansion of seamless aluminium alloy gas containers as required by **21.4**:

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 pressures 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 % or 0.1 mL.

A.2.3 Pressure gauges shall be to the requirements of accuracy class 1 of BS EN 837-1. They shall be tested at regular intervals and in any case not less frequently than once a month.

A.2.4 A suitable device shall be employed to ensure that the test pressure of the container is not exceeded by more than 3 % or 10 bar whichever is the lower.

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 of any container that may be tested and have sufficient wall thickness to prevent kinking.

A.2.6 All joints shall be leaktight.

A.2.7 Care shall be taken to avoid trapping air in the system.

A.3 Water jacket volumetric expansion

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 that 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 expansion 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 A.1, 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 container and jacket. A falling water level indicates a leaking joint between water jacket and 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 5 % of the total expansion as determined by the following:

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

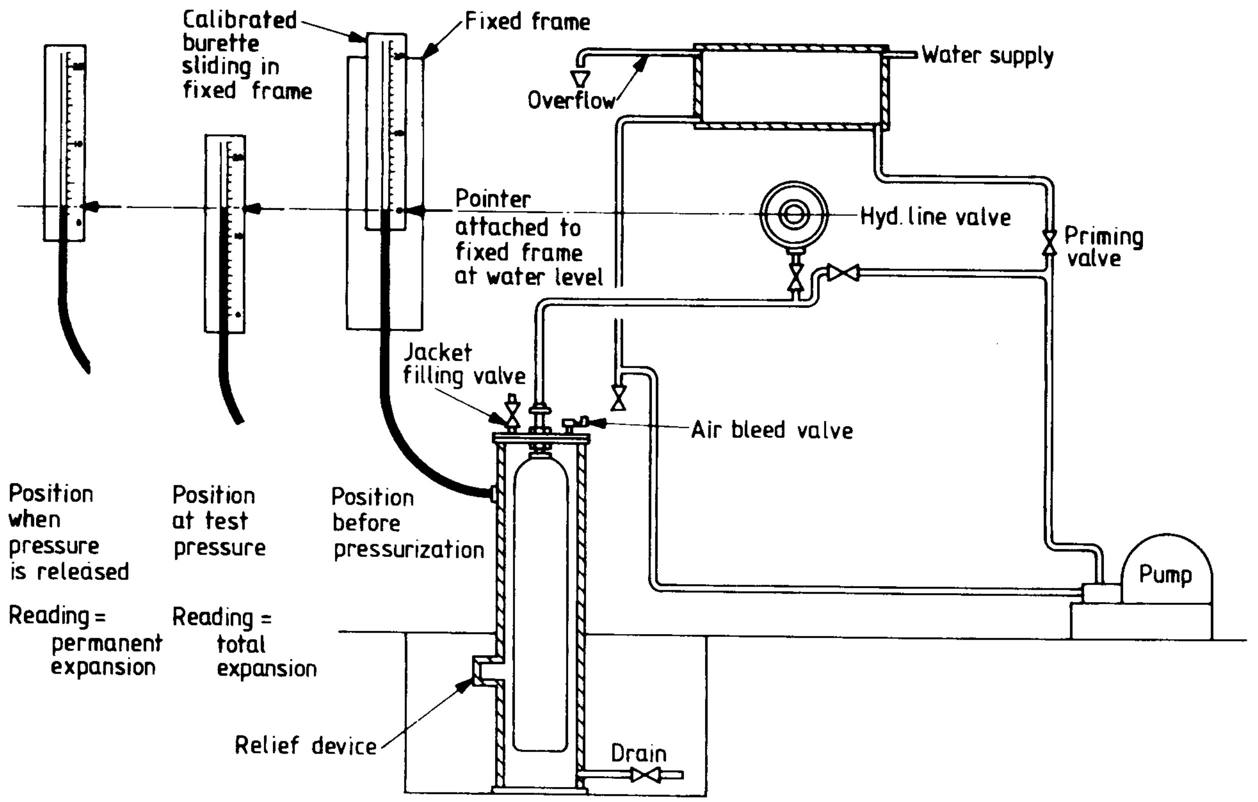

Figure A.1 — Water jacket volumetric expansion test (levelling burette)

A.3.3.3 *Water jacket volumetric expansion test: fixed burette method*

An example of the equipment required is shown in Figure A.2, 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 container and jacket. A falling water level indicates a leaking joint between water jacket and 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, and shall be recorded on the test certificate;

j) check that the permanent expansion does not exceed 5 % of the total expansion as determined by the following:

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

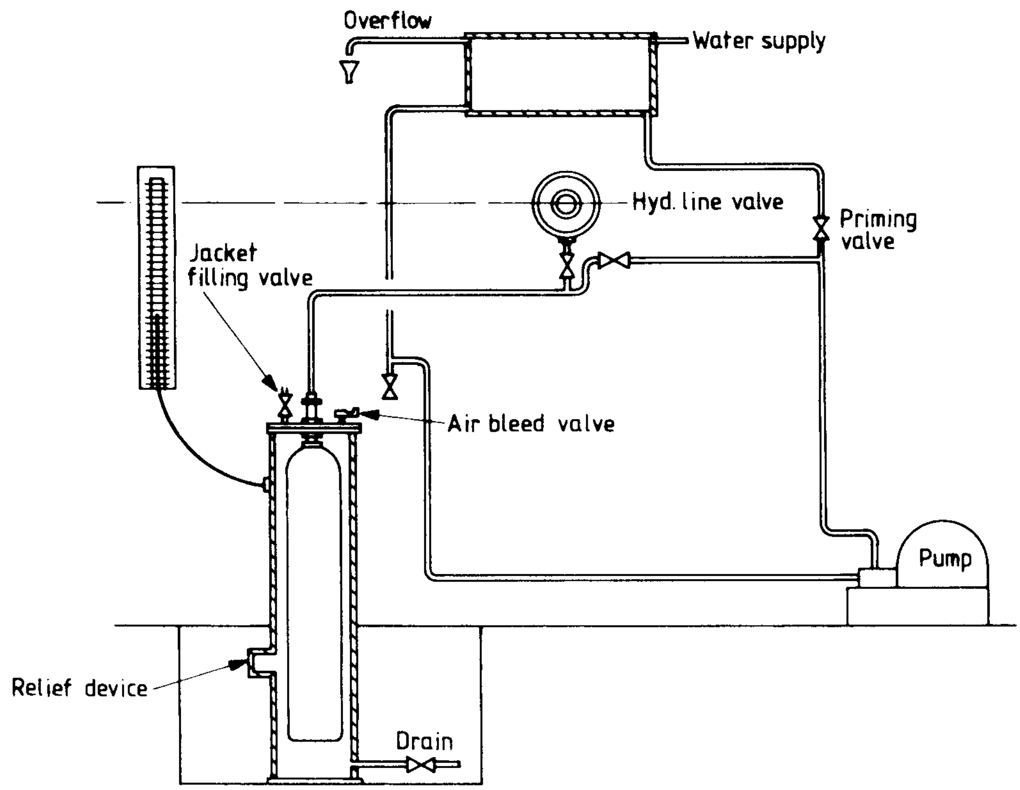

Figure A.2 — Water jacket volumetric expansion test (fixed burette)

A.4 Non-water jacket volumetric expansion test

A.4.1 *Principle*

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

A.4.2 *Apparatus*

The equipment shall be arranged so that all air can be removed. The glass tube reservoir shall be calibrated in millimetres 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.

NOTE The pressure gauges should be calibrated as specified in BS EN 837-1. Two gauges may be used for check purposes.

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 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 container and the water to attain a uniform constant temperature.

The equipment shall be installed as shown in Figure A.3. 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.

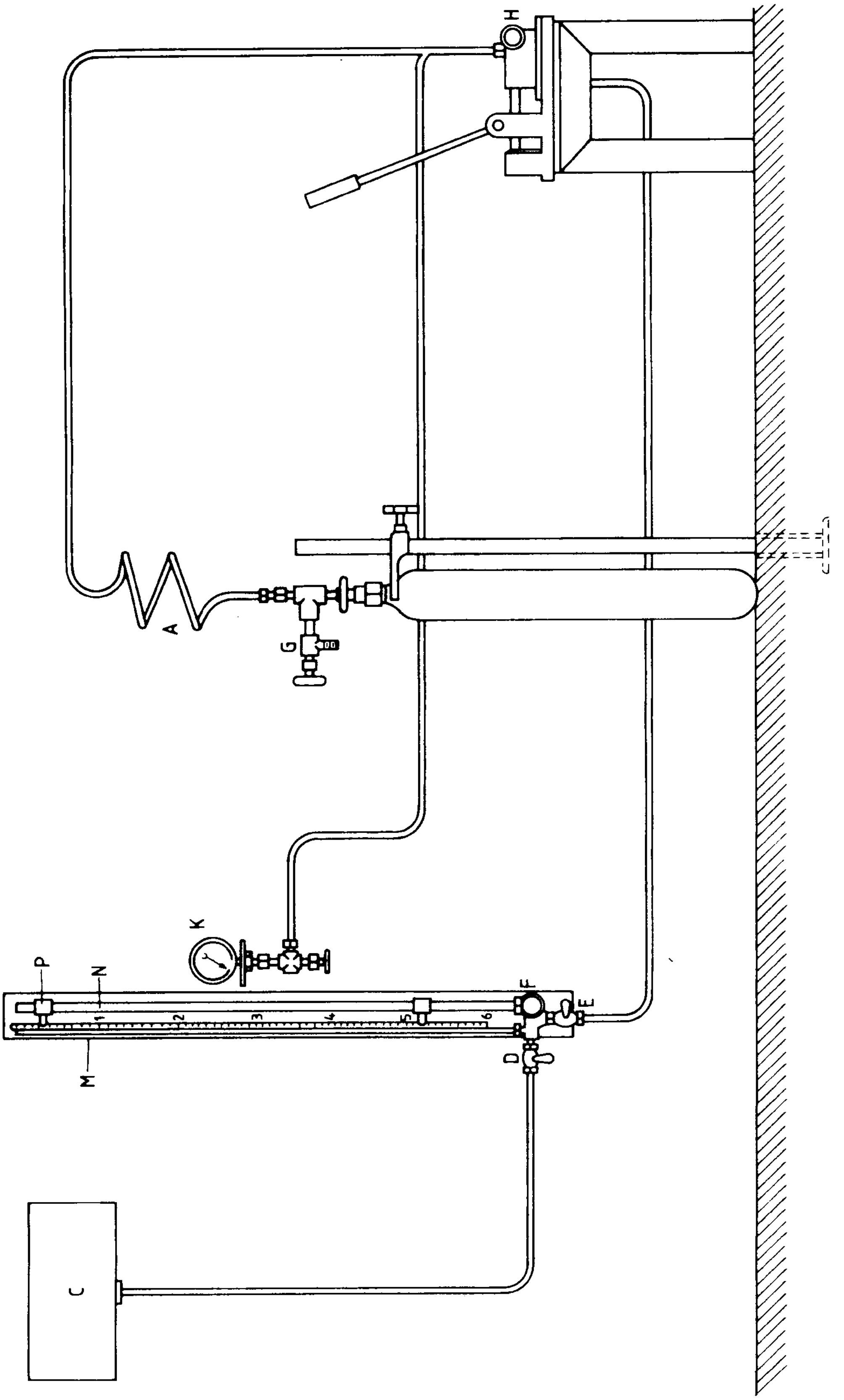

Figure A.3 — Non-water jacket volumetic expansion test

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 flexible pipe 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 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 pressure gauge(s) K indicates the required test pressure. Stop the pump. After approximately 30 s there should be no change in either water level or pressure. Change in level indicates leakage. Falling pressure, if there is no leakage, indicates that the cylinder is still expanding under pressure;

g) record the fall of water level in the glass tube. Providing there has been no leakage, the water drained from the glass tube will have been pumped into the container to achieve the test pressure. This difference in water level, corrected from the compressibility of water (see **A.4.4**), is the total volumetric expansion;

h) open valve H slowly to release pressure in the container and allow the 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 container;

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) above shall, however, be repeated at each subsequent test;

j) if permanent volumetric expansion has occurred, note the temperature of the 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 test determines 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 5 % of the total volumetric expansion.

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

The formula used for the calculation of the compressibility of water is:

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

where

C is the compressibility (in mL);

m is the mass of water at test pressure (in kg);

P is the test pressure (in bar);

K is the factor for individual temperatures as listed in Table A.1.

Table A.1 — *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 example calculation, allowance for pipe stretch is 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	= 1 745 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 Permanent expansion (PE)	= 1 742 mL= 3 mL
Permanent expansion (PE) = 1 745 − 1 742	= 3 mL
Table A.1, 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

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

= 1 224.25 mL

Total volumetric expansion (TE)

= 1 745 − 1 224.25 = 520.75 mL

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

Annex B (normative)
Ultrasonic defect detection and thickness measurement

B.1 defect detection: bar stock

B.1.1 ***General***

This method covers the pulse echo testing of the bar stock for the production of seamless aluminium containers.

B.1.2 ***Surface condition***

Both the testing and the reflecting surfaces of the container shall be clean and free from any materials that will interfere with the test.

B.1.3 ***Equipment***

The test equipment shall be of the pulse echo type and shall be capable of detecting the calibration hole to the degree required in the calibration procedure specified in **B.1.6**.

B.1.4 ***Couplant***

A coupling method that ensures adequate transmission of ultrasonic energy between the testing probe and the container shall be used.

B.1.5 ***Calibration standards***

B.1.5.1 A calibration standard of a convenient length shall be prepared from bar of a similar diameter, material, surface finish and metallurgical condition to the bar stock to be examined. The calibration standard shall be free from discontinuities which may interfere with the detection of the reference hole.

B.1.5.2 A flat bottomed hole 2 mm in diameter shall be introduced into the bar, parallel to its longitudinal axis.

B.1.6 ***Calibration of equipment***

Using the calibration standard specified in **B.1.5**, the equipment shall be subjected to produce a clearly identifiable indication from the calibration hole. The amplitude of this indication shall be used as the rejection level and for setting visual, electronic monitoring or recording devices.

The equipment shall be calibrated with the reference standard and/or probe moving in the same manner, in the same direction and at the same speed as will be used during the inspection of the bar.

B.1.7 ***Frequency***

The ultrasonic test frequency shall be between 2 MHz and 6 MHz.

B.1.8 ***Procedure***

This inspection shall be carried out on all bars of a cast.

Using a probe of suitable diameter, apply the search unit to the bar surface at one end of each of two intersecting perpendicular diameters, and scan the full length of the bar, using a suitable couplant in quantities that will maintain good coupling.

The scan shall be helical, the pitch, speed of rotation and translation of which shall be related to the effective beam width so as to ensure 100 % coverage of the bar.

B.1.9 ***Interpretation of results***

Any bar not showing a defect indication shall be considered to have passed this ultrasonic inspection.

A defect indication is one that is equal to or greater than the indication from the reference hole.

Any bar that does not conform to the above shall be rejected.

B.2 Defect detection: containers

B.2.1 ***General***

This method covers the pulse echo testing of seamless aluminium containers.

Containers less than 375 mm external diameter shall be tested for defects in the parallel walls. Containers of 375 mm and larger diameters shall be tested at the ends in addition to the testing of the parallel walls.

B.2.2 ***Surface condition***

Both the testing and the reflecting surfaces of the container shall be clean and free from any materials that will interfere with the test.

B.2.3 ***Equipment***

The test equipment shall be of the pulse echo type and shall be capable of detecting the calibration notches to the degree required in the calibration procedure specified in **B.2.6**.

B.2.4 ***Couplant***

A coupling method that ensures adequate transmission of ultrasonic energy between the testing probe and the container shall be used.

B.2.5 ***Calibration standards***

B.2.5.1 A calibration standard of a convenient length shall be prepared from a container of similar diameter and wall thickness, material, surface finish and metallurgical condition to the container to be inspected. The calibration standard shall be free from discontinuities which may interfere with the detection of the reference notches.

B.2.5.2 A longitudinal and a transverse reference notch shall be introduced on the outer and inner surfaces of the calibration standard. The transverse and longitudinal notches may be positioned within 25 mm of each other but the pairs of notches on the inner and outer surfaces shall be separated by at least 50 mm along the axis of the standard.

The reference notches shall be 25 ± 0.25 mm long and their width shall be not more than twice the nominal depth. The notches shall be 5 % of the minimum wall thickness. The tolerance on depth shall be ±10 % of the nominal notch depth with 0.025 mm minimum. The cross-section of the notch shall be nominally of rectangular section but if spark erosion methods are employed the bottom of the notch may be rounded.

B.2.6 ***Calibration of equipment***

Using the calibration standard specified in **B.2.5**, the equipment shall be adjusted to produce clearly identifiable indications from inner and outer surface notches. The relative response from notches shall be as near equal as possible. The indication of smallest amplitude shall be used as the rejection level and for setting visual, electronic monitoring or recording devices.

The equipment shall be calibrated with the reference standard and/or probe moving in the same manner, in the same direction and at the same speed as will be used during the inspection of the container.

B.2.7 ***Frequency***

The ultrasonic test frequency shall be between 2 MHz and 6 MHz.

B.2.8 ***Procedure***

B.2.8.1 *Parallel walls of containers*

The container to be inspected and the search unit shall have a rotating motion and a translation relative to one another such that a helical scan of the container surface will be described. The speed of rotation and translation shall be constant within ±10 %.

The pitch of the helix shall be less than the probe diameter and shall be related to the effective beam width so as to ensure 100 % coverage at the speeds and feeds used during the calibration procedure.

The container wall shall be tested for longitudinal defects with the ultrasonic energy transmitted in both circumferential directions and for transverse defects in both longitudinal directions.

The calibration of the equipment shall be periodically checked by passing the calibration standard through the test procedure. This check shall be carried out at a time interval of not more than 1 h or after 30 containers have been tested. If during this check the presence of the appropriate notch is not indicated, then all containers tested subsequent to the last acceptable calibration shall be retested after recalibration has been accomplished.

B.2.8.2 *Ends of containers*

The entire surface of the ends shall be manually examined using a 45° angle probe.

NOTE In order to ensure complete coverage it is recommended that the ends be divided into four segments, each segment being completely examined in turn.

The following scans shall be used:

a) with the probe parallel to the longitudinal axis;

b) with the probe at right angles to the longitudinal axis.

Each scan shall be carried out first with the probe pointing in one direction and then repeated with the probe reversed.

In addition a scan shall be carried out at the root of the neck with the probe held at an angle of 45° to the longitudinal axis of the container and then repeated with the probe turned through 90°. The scans shall be made using probes with maximum dimensions between 10 mm and 20 mm, the smaller probes being used to scan the root of the neck.

Scans shall begin or terminate at points 50 mm along the parallel part of the container and individual scans shall overlap the previous scan by 25 %.

B.2.9 ***Assessment of results***

Any container not showing a defect indication shall be considered to have passed this ultrasonic inspection.

NOTE A defect indication is one that is equal to or greater than the lesser indication of the reference notches.

Surface defects shall be removed by grinding. After correction the containers shall be resubjected to ultrasonic defect detection and thickness measurement.

Containers continuing to show defect indications at points of minimum design thickness shall be deemed not to comply with this standard and shall be rendered unserviceable.

B.3 Thickness measurement

B.3.1 *General*

This method covers the thickness measurement of seamless containers employing either the pulse echo or the resonance system. Either contact or immersion techniques may be used. The container shall be examined to ensure that the thickness is not below the design minimum:

a) on the base end;

b) on the parallel body; and

c) on any part of the container where surface blemishes have been removed by grinding, machining, etc.

B.3.2 *Surface condition*

Both the testing and the reflecting surfaces of the container shall be clean and free from any materials that will interfere with the test.

B.3.3 *Equipment*

The test equipment shall be of either the pulse echo or the resonance type and shall be capable of indicating a given thickness of material to any accuracy within ± 2.5 % of the set value.

B.3.4 *Couplant*

A coupling method that ensures adequate transmission of ultrasonic energy between the testing probe and the container shall be used.

B.3.5 *Calibration standards*

Where possible a calibration standard of similar diameter, material, surface finish and metallurgical condition to the containers under test and with a diameter machined or ground to the minimum specified thickness shall be used. When it is not possible to provide such a calibration standard, flat calibration standards shall be used.

B.3.6 *Calibration of equipment*

Using the calibration standard specified in **B.3.5**, the equipment shall be adjusted to produce a reject signal when the indicated thickness is less than a value equal to 2.5 % greater than the minimum design thickness.

The equipment shall be calibrated with the reference standard and/or probe moving in the same manner, in the same direction and at the same speed as will be used during the inspection of the container.

B.3.7 *Frequency*

The ultrasonic test frequency used shall be not less than 2 MHz.

B.3.8 *Procedure*

The container to be inspected and the search unit shall have a rotating motion and a translation relative to one another such that a helical scan of the container surface will be described. The speed of translation and rotation shall be constant within ± 10 %. The pitch of the helix shall be less than the probe diameter and shall be related to the effective beam width so as to ensure 100 % coverage at the speeds and feeds used during the calibration procedure.

The container shall be examined in such a manner as to check that nowhere does the thickness fall below the specified minimum allowed.

The calibration of the equipment shall be periodically checked by passing the calibration standard through the test procedure. This check shall be carried out at time intervals of not more than 1 h or after 30 containers have been tested. If during this check the presence of the minimum area is not indicated, then all the containers tested subsequent to the last acceptable calibration shall be retested after recalibration has been accomplished.

B.3.9 *Assessment of results*

All containers that are not acceptable when examined on a go, no-go system shall be re-examined using equipment capable of giving an actual measurement. Any container that is below the minimum wall thickness specified in the manufacturer's drawing shall be deemed not to conform to this British Standard.

Annex C (informative)

Examples of design calculations for cylindrical walls of seamless containers

EXAMPLE 1

Container for liquefied carbon dioxide

A container having an external diameter of 160 mm, made from either aluminium alloy given in Table 2, is to be charged with carbon dioxide to a 0.667 filling ratio to be used as a portable fire extinguisher in the UK. A safety device is to be fitted.

Determination of test pressure.

From **11.2** for CO_2, 0.667 filling ratio test pressure = 200 bar.

Minimum thickness of cylindrical wall

From equation (1) of **12.3**:

$$t = \frac{0.3 \times p_1 \times D_o}{7f_e - 0.4p_1}$$

where

p_1 = 200 bar

D_o = 160 mm

f_e= 0.875 × 280 = 245 N/mm^2

Thus

$$t = \frac{0.3 \times 200 \times 160}{7 \times 245 - 0.4 \times 200} = 5.9 \text{ mm}$$

However, the thickness of the cylindrical wall shall not be less than the value given by equation (3) of **12.3**; thus

$$t = 2.48 \times \sqrt{\left(\frac{D_i}{T}\right)} = 2.48 \times \sqrt{\left(\frac{148.2}{325}\right)} = 1.67 \text{ mm}$$

As this thickness does not exceed the value obtained by calculation from equation (1) of **12.3**, the required minimum thickness is 5.9 mm.

EXAMPLE 2

Container for permanent gas

A container having an external diameter of 117 mm, made from either aluminium alloy given in Table 2, is to be charged with nitrogen to a pressure (at the equilibrium temperature of 15 °C) not exceeding 300 bar, and be used for breathing apparatus in the UK.

Determination of test pressure

From **11.2** the ratio of test pressure to charged pressure is 1.5.

Charged pressure = 300 bar Test pressure = 450 bar

and pressure developed at 60 °C = 371 bar which is less than 85 % of the test pressure (from BS 5355).

Minimum thickness of cylindrical wall

As the charged pressure is over 210 bar, from **12.3**, either equation (1) or equation (2) may be used.

Using equation (1) of **12.3**:

$$t = \frac{0.3p_1D_o}{7f_e - 0.4p_1}$$

where

p_1 = 450 bar

D_o = 117 mm

f_e = 0.875 × 280 = 245 N/mm^2

thus

$$t = \frac{0.3 \times 450 \times 117}{7 \times 245 - 0.4 \times 450} = 10.3 \text{ mm}$$

Using equation (2) of **12.3**

$$t = \frac{p_1D_o}{20f_e + p_1}$$

where

p_1 = 450 bar

D_o = 117 mm

f_e = 0.875 × 280 = 245 N/mm^2

thus

However, the thickness of the cylindrical wall is not to be less than the value given by equation (3) of **12.3**; thus

$$t = 2.48 \times \sqrt{\left(\frac{D_1}{T}\right)} = 2.48 \times \sqrt{\left(\frac{96.4}{325}\right)} = 1.35 \text{ mm}$$

(if equation (1) is used)

$$= 2.48 \sqrt{\left(\frac{97.4}{325}\right)} = 1.36 \text{ mm (if equation (2) is used)}$$

As these thicknesses do not exceed the values obtained by calculation from equations (1) or (2) of **12.3**, either equation (1) or (2) may be used.

Annex D (informative)
Specimen certificates

D.1 Specimen acceptance certificate

An example of a specimen acceptance certificate is as follows.

Certificate number..........................

We certify that cylinders manufactured to specification ....

drawing number..against order number ....

for: customer

address

comply with the following requirements.

1. **Minumum wall thickness.** The minimum wall thickness has been measured by inspection personnel to a minimum of ...mm for all cylinders.

2. **Minimum hardness value**. All cylinders have been checked to satisfy the minimum hardness value of ....

3. **Heat treatment.** Each cylinder has been heated for...h at 520 °C to 550 °C followed by water quenching, and...h at 150 °C to 200 °C followed by air cooling to conform to the properties given in Table 3 of BS 5045-8:2000.

4. **Hydraulic pressure test**. Each cylinder had been subjected to a hydraulic pressure test of ...bar.

The total volumetric expansions at test pressure were within the range...mL to ...ml. The permanent volumetric expansions as a percentage of the total volumetric expansion were within the range ...% to ...%.

5. **Material.** All cylinders have been manufacuring from material conforming in chemical analysis to alloy...

as given in Table 2 of BS 5045-8:2000. The cast numbers used were..........

6. **Tare and capacities are within the limits stated**

Tare...

Capacity...

The test report numbers are ....

The cylinders covered by the above certification are serial numbers ....

Date:

Signature: . ... Signature: ....

Chief Inspector Independent Inspecting Authority

D.2 Laboratory test certificate

Test report number	Mechanical test results				Cast analysis (impurities not quoted are less than 0.01 % each)								
	0.2 % proof stress	Tensile strength	Elongation	180° bend test result former radius 3*t*	Cast number	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
	N/mm^2	N/mm^2	%										

blank

Bibliography

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BS 1957, *Presentation of numerical values (fineness of expression, rounding of numbers)*

BS 5045-3, *Transportable gas containers — Part 3: Specification for seamless aluminium alloy gas containers above 0.5 l water capacity and up to 300 bar charged pressure at 15 °C*

BS EN 1975, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless aluminium and aluminium alloy gas cylinders of capacity from 0.5 litre up to 150 litre*

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