BRITISH STANDARD

BS 5045-7:2000

Transportable gas containers —

Part 7: Specification for seamless steel gas containers of water capacity 0.5 L up to 15 L for special portable applications

Committees responsible for this British Standard

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

Associated Offices Technical Committee
Association of Shell Boilermakers
British Chemical Engineering Contractors' Association
British Compressed Gases Association
British Gas Corporation
British Insurance (Atomic Energy) Committee
British Steel Industry
Chemical Industries Association
Department of Trade (Marine Division)
Engineering Equipment Users' Association
Health and Safety Executive
Institution of Chemical Engineers
Institution of Gas Engineers
Institution of Mechanical Engineers
Lloyd's Register of Shipping
Oil Companies Materials Association
Process Plant Association
United Kingdom Atomic Energy Authority
University of Manchester (Institute of Science and Technology)
Water-tube Boilermakers' Association
Welding Institute

The following bodies were also represented in the drafting of this standard, through subcommittee PVE/3:

Aluminium Federation
Association of Drum Manufacturers
British Railways Board
British Sub-aqua Club
Chief and Assistant Chief Fire Officers' Association
Department of Industry (National Engineering Laboratory)
Department of Industry (National Physical Laboratory)
Fire Extinguishing Trades Association
Home Office
Industrial Safety (Protective Equipment) Manufacturers' Association
Institute of Refrigeration
Institution of Fire Engineers
Liquefied Petroleum Gas Industry Technical Association (UK)
Ministry of Defence
National Association of Soft Drinks Manufacturers
Society of Motor Manufacturers and Traders Limited
Coopted members

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Contents

Foreword

This British Standard has been prepared under the direction of the Pressure Vessel Standards Committee. Together with BS EN 1964-1:2000 it supersedes BS 5045-1:1982 which is withdrawn. When first published, BS 5045-1:1982 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 for seamless steel containers for general applications in BS 5045-1:1982 were superseded by the publication of BS EN 1964-1:2000. However, requirements for small portable containers for special applications remain current.

This new edition therefore renumbers BS 5045-1:1982 as BS 5045-7:2000 and modifies its scope to restrict its applicability to these special application containers. It does not, however, constitute a full revision of the standard.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 29 and a back cover.

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1 Scope

This part of BS 5045 specifies the requirements for the materials, design, construction and testing of seamless steel containers of water capacity greater than 0.5 litre up to 15 litres 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 appendices giving examples of design calculations, a description of the methods for pressure testing of containers, a description of the methods for ultrasonic examination of containers, model forms of design and acceptance certificates.

2 Normative references

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

BS 341-1, *Transportable gas container valves — Part 1: Valves with taper stems (excluding valves used for breathing and medical purposes).*

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 3894-1, *Method for converting elongation values for steel — Part 1: Carbon and low alloy steels.*

BS 4500-1, *ISO limits and fits — Part 1: General tolerances and deviations.*

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

BS 6200-2-2.1:1993, *Sampling and analysis of iron, steel and other ferrous metals — Part 2: Sampling and sample preparation — Section 2.1: Methods for iron and steel.*

BS 10109-1:1996, *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 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.*

3 Manufacture and testing of containers

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

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 and that are completely vaporized at 17.5 °C and 1 013 mbar[1].

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.

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

This classification is illustrated in Table 1.

5 Information to be supplied by the purchaser and the manufacturer

5.1 Information to be supplied by the purchaser

The purchaser shall inform the manufacturer of the following, as appropriate:

a) name or classification of gas(es);

b) service application;

c) volumetric capacity (for liquefiable gases this shall be the minimum);

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

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

[1] 1 mbar = 10^2 N/m^2 = 0.1 kPa.

f) material of construction;

g) preferred dimensions;

h) shape of base;

i) internal and/or external neck screwing dimensions;

j) fittings required;

k) external/internal finish required;

l) any special or adverse conditions under which the container will be required to operate, and any corrosion allowance required (see note 2 of **12.3**);

m) any requirements in excess of those specified in this standard;

n) the name of the Independent Inspecting Authority.

Table 1 — Classification of gases

Permanent gases	Liquefiable gases		Dissolved gases
	High pressure	Low pressure	
($T_c < -10$ °C)	(-10 °C $\leq T_c \leq 70$ °C)	($T_c > 70$ °C)	
Air Argon Helium Nitrogen Oxygen	Carbon dioxide Nitrous oxide	—	—
NOTE T_c is the critical temperature.			

5.2 Information to be supplied by the manufacturer

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

a) fully dimensioned sectional drawing of the container including:

1) name or classification of gas(es);

2) volumetric capacity (for liquefiable gases this shall be the minimum);

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

4) material of construction;

5) test pressure;

6) minimum and maximum masses of container;

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

8) design approval (see clause **14**);

9) corrosion allowance (if any);

b) method of manufacture;

c) fittings to be supplied;

d) drawing showing layout of stamped marking (see clause **28**);

e) certificates of test for materials and container (see annex D).

6 Certificate of compliance

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

The Independent Inspecting Authority shall certify acceptance of the above certification.

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

7 Permissible materials — General

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

8 Permissible materials — Chemical composition

8.1 The ladle analyses shall conform to the appropriate requirements of Table 2.

In the event of one melt being divided between more than one ladle, samples shall be analyzed from each ladle and separate analyses provided for each ladle. Each of these ladles shall subsequently be regarded as a specific cast and identified accordingly.

8.2 Variation between the product analysis and the ladle analysis, which occurs because of heterogeneity arising during the casting and solidification of the ingot, shall not exceed the permitted deviations given in Tables 4 and 5.

NOTE 1 Product analysis is any analysis of the steel subsequent to the ladle analysis.

The deviations are permitted in the individual elements either above or below the specified range but shall not be applied both above and below the specified range for any one element from any one ladle of steel.

NOTE 2 When maxima only are specified, the deviations are positive only.

8.3 Any ingot, bar or container that on chemical analysis is outside the limits of permissible deviation from the specified composition range for a specified element shall be deemed not to conform to the requirements of this standard.

8.4 In the event of a single sample falling outside the permitted deviations on the product analysis, further samples shall be selected for check analysis from the remainder of the consignment as follows:

— at least two samples from the same ladle for delivered masses up to 5 t;

— at least five samples from the same ladle for delivered masses up to 20 t; and

— at least eight samples from the same ladle for delivered masses over 20 t.

These samples shall fall within the permitted deviations. If any of these further samples are proved to be outside the permitted deviations for any specified element, the consignment shall be deemed not to conform to the requirements of this standard.

8.5 Samples for product analysis shall be taken in accordance with BS 6200-2-2.1.

9 Permissible materials — Steelmaker's certificate

The steelmaker shall supply a certificate stating:

a) the steelmaking process; and

b) the ladle analysis.

10 Permissible materials — Identification of steel

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

Table 2 — Steelmaking process and chemical composition of permissible materials

Material	Code	Steelmaking process	Chemical composition													
			Carbon		Silicon		Manganese		Phosphorus	Sulfur	Chromium		Molybdenum		Nickel	
			min.	max.	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.
			%	%	%	%	%	%	%	%	%	%	%	%	%	%
Carbon steels	M	Open hearth electric furnace or basic oxygen process	0.15	0.25	0.05	0.35	0.40	0.90	0.050	0.050	—	—	—	—	—	—
	C	Steels made by the oxygen process shall not contain more than 0.008 % of nitrogen	0.35	0.45	0.05	0.35	0.60	1.00	0.050	0.050	—	—	—	—	—	—
Carbon manganese steels	Mn and MnH		—	0.40	0.10	0.35	1.30	1.70	0.050	0.050	—	—	—	—	—	—
Chromium molybdenum alloy steel	CM	Open hearth, electric furnace or basic oxygen process	—	0.37	0.10	0.35	0.40	0.90	0.050	0.050	0.80	1.20	0.15	0.25	—	0.50[a]
Nickel chromium molybdenum alloy steel	NCM	Steels made by the oxygen process shall not contain more than 0.010 % nitrogen	0.27	0.35	0.10	0.35	0.50	0.70	0.050	0.050	0.50	0.80	0.40	0.70	2.30	2.80

[a] Residual nickel.

Table 3 — Heat treatment and mechanical properties of steel in finished containers

Material	Code	Heat treatment	Tensile strength		Yield stress (Y)[a], specified min. value	Ratio of specified min. yield stress to specified min. tensile strength $\frac{Y}{T}$	Minimum elongation on $5.65\sqrt{S_0}$	Max. radius of bend test forming tool
			Specified min. (T)	Max.				
			N/mm²	N/mm²	N/mm²		%	
Carbon steels	M	normalized or normalized and tempered	430	510	250	—	22	1½ t_a[b]
	C	normalized or normalized and tempered	570	680	310	—	19	2 t_a
Carbon manganese steels	Mn	normalized or normalized and tempered at not less than 550 °C and cooled in air	650	760	445	—	20	2½ t_a
	MnH	hardened from 800 °C to 850 °C and tempered at 530 °C to 670 °C	890 max.	1 030	755	0.85 max.	14	3 t_a
Chromium molybdenum alloy steel	CM	hardened from 850 °C to 920 °C and tempered at 550 °C to 720 °C	890 max.	1 030	755	0.85 max.	14	3 t_a
Nickel chromium molybdenum alloy steel	NCM	hardened from 820 °C to 850 °C and tempered at 550 °C to 660 °C	890 max.	1 030	755	0.85 max.	14	3 t_a

[a] Yield stress refers to the upper yield stress (R_{eh}) or, if applicable, the 0.2 % non-proportional elongation proof stress ($R_{p0,2}$). Values in excess of this shall not be used for calculation purposes.

[b] t_a is the actual thickness of the specimen.

NOTE For hardness properties see Figure 1.

Table 4 — Permissible deviation on product analysis from specified range for carbon and carbon manganese steels

Element	Maximum of the specified range	Permissible deviation[a] on product analysis
	%	%
Carbon	≤ 0.25	0.02
	> 0.25 to 0.50	0.03
Silicon		0.03
Manganese	≤ 1.0	0.04
	> 1.0 to 1.5	0.08
	> 1.5	0.10
Phosphorus		0.008
Sulfur		0.008

[a] Maximum and minimum values do not apply simultaneously for individual elements (see **8.2**).

Table 5 — Permissible deviation on product analysis from specified range for alloy steels

Element	Maximum of the specified range	Permissible deviation[a] on product analysis
	%	%
Carbon	≤ 0.25	0.01
	> 0.25 to 0.50	0.02
Silicon		0.03
Manganese	≤ 0.70	0.03
	> 0.70 to 1.0	0.04
	> 1.0 to 2.0	0.05
Phosphorus		0.004
Sulfur		0.005
Chromium	≤ 0.60	0.03
	> 0.60 to 1.25	0.04
Molybdenum	≤ 0.50	0.02
	> 0.50	0.03
Nickel	≤ 1.0	0.03
	> 1.0 to 3.0	0.05

[a] Maximum and minimum values do not apply simultaneously for individual elements (see **8.2**).

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 specified in Table 6, the values of which vary with the type of gas it contains.

NOTE 1 The maximum permissible pressure in service to which the test pressure of the container is related (see **12.2**) is the pressure developed by the contents at the pressure reference temperature, taking into account the filling ratio for high pressure liquefiable gases and the intended filling pressure at 15 °C for permanent gases. The necessary data on the relationship between filling pressure (or filling ratio) and developed pressure at the reference temperature are given in BS 5355.

NOTE 2 Examples of design calculations are given in annex C.

11.2 The water capacity of a container for a liquefiable gas shall be not less than the intended maximum mass of contents divided by the filling ratio. The necessary data on the physical properties of the liquefiable gases are specified in BS 5355.

Table 6 — Reference temperatures for developed pressure for conveyance in the UK[a] in uninsulated containers

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

[a] For containers to be used outside the UK, reference should be made to BS 5355 for the relevant reference temperature and developed pressure.
[b] When safety devices are fitted to carbon dioxide containers, this reference temperature may be reduced to 50 °C.

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

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

11.4 When gases are being conveyed in insulated containers, the reference temperature for design shall be sought from the Independent Inspecting Authority; Table 6 shall not apply.

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

12 Design formulae

12.1 Nomenclature

- t Minimum wall thickness (in mm) to resist internal pressure and external forces due to normal handling, but excluding any additional thickness for corrosion and other influences
- P_1 Test pressure [in bar[2)]] applicable to design governed by formula (1) (see **12.3**)
- P_2 Test pressure (in bar) applicable to design governed by formula (2) (see **12.3**)
- P Pressure (in bar) developed by the contents of a container at the pressure reference temperature
- D_0 External diameter of container (in mm)
- D_i Internal diameter of container (in mm)
- f_e Maximum permissible equivalent stress (in N/mm^2) at test pressure (= 0.875 × minimum specified yield stress of the material of construction)
- T Minimum specified tensile strength (in N/mm^2) of the material of construction
- Y Minimum specified yield stress (in N/mm^2) of the material of construction

NOTE Values of Y, T and f_e for the permissible materials are given in Tables 3 and 8.

12.2 Test pressure

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

Test pressure P_1 shall be deduced in terms of the container's contents and material of construction. Test pressure P_2 is applicable only to those containers whose minimum wall thickness is governed by formula (2) of **12.3**.

Test pressure P_1 shall be derived from a consideration of the following.

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

b) The yield and tensile properties (Y and T) of the container material, as given in Table 3.

Formulae and requirements to be used for deriving minimum values of test pressure P_1 shall be as specified in Table 7; they are applicable to the various gas classifications.

12.3 Thickness of cylindrical shell

The thickness of the cylindrical shell of a container shall be not less than the value given by formula (1):

$$t = \frac{0.3P_1D_i}{7f_e - P_1} \text{ or } t = \frac{0.3P_1D_o}{7f_e - 0.4P_1} \quad (1)$$

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

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

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

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

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

NOTE 1 *Shape and thickness of ends.* Rules for the design of container ends are not given (but see clause **14**).

NOTE 2 *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 to allow for corrosion during service, and may also be necessary on containers for liquefied gases so that the container can withstand stresses due to horizontal acceleration and retardation in road transportation.

The variety of conditions occurring in practice makes it impracticable to give a general specification of the necessary allowances; they should be carefully considered and agreed upon in each particular case by the manufacturer and the user of the containers.

2) 1 bar = 10^5 N/mm^2 = 100 kPa.

Table 7 — Formulae for deriving minimum values of test pressure P_1

Gas classification	Test pressure P_1	
	$\frac{Y}{T} \leq 0.7$	$\frac{Y}{T} > 0.7$
Permanent gases in uninsulated containers, the charged pressure not exceeding 300 bar	$P_1 = \frac{p}{0.9}$	P_1 shall be the greater of: a) $\frac{p}{0.85}$; or b) 1.5 × charged pressure at 15 °C except that P_1 shall not exceed $\frac{pY}{0.63T}$
Permanent gases in uninsulated containers, and liquefiable gases in insulated containers	$P_1 = \frac{p}{0.9}$ except that P_1 shall not be less than 200 bar for carbon dioxide or nitrous oxide	$P_1 = \frac{pY}{0.63T}$ except that P_1 shall not be less than 200 bar for carbon dioxide or nitrous oxide
High pressure liquefiable gases in uninsulated containers	$P_1 = p$ except that P_1 shall not be less than 200 bar for carbon dioxide or nitrous oxide	P_1 shall be the lower of: a) $\frac{pY}{0.77T}$; or b) $\frac{p}{0.85}$ except that P_1 shall not be less than 200 bar for carbon dioxide or nitrous oxide
NOTE See annex C for examples and Figure C.1, which shows the calculation procedure.		

Table 8 — Design stresses for permissible steels

Steel type	Code	Ratio of yield (*Y*) to tensile (*T*)	f_e value
			N/mm^2
Carbon steel	M	0.58	186
Carbon steel	C	0.54	232
Carbon manganese steel normalized	Mn	0.68	330
Carbon manganese steel, quenched and tempered	MnH	0.85 max.	0.875 *Y*
Chromium molybdenum	CM	0.85 max.	0.875 *Y*
Nickel chromium molybdenum	NCM	0.85 max.	0.875 *Y*

13 Design — Fittings

13.1 Valve fittings

Valve fittings shall conform to the requirements of BS 341-1 or −2 or BS 850, as appropriate, in respect of quality and materials. 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.

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.

Pressure relief devices shall be capable, under the most severe temperature conditions including exposure to fire, of a discharge rate that prevents the pressure of the container contents from exceeding the test pressure of the container.

The outlets from all pressure relief devices shall be so sited that free discharge from the device 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 conform to the requirements of 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*

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

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

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 the 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 the Independent Inspecting Authority.

15 Manufacture and workmanship — Permissible processes

The containers shall be made from:

a) billets, pierced hot or cold (back extruded) followed by hot and/or cold drawing; or

b) plates, cupped hot or cold, followed by hot and/or cold drawing; or

c) seamless tube manufactured by extrusion or other process and subsequently hot and/or cold drawn as necessary.

They shall be made only by processes including heat treatment processes, that have 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. Where closure of a tube is necessary in order to form a neck or a base, this shall be carried out by forging, cupping or spinning.

Ends shall not be welded on and metal shall not be added at any time during or after the closing operation. Ends may be drilled and threaded and a screwed plug inserted. Such plugs shall not be soldered, welded or secured in position by any similar process.

16 Manufacture and workmanship — Heat treatment

Each container, after the completion of all forming operations, except the machining of the neck and the forming of the neck threads, shall be uniformly heat treated to produce the required mechanical properties.

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

When hardening is involved the quenchant shall be one of the following:

a) air, when full air hardening is practicable;

b) oils commonly used for this purpose;

c) liquid quenchants, other than oil, provided that the quenching severity produced is similar to that of oils commonly used for this purpose.

The choice of quenchant shall take into account the type of steel, size and thickness of containers, and changes in profile and section.

The temperature of the bath, concentration of quenchant, (where quenchants other than oil are used), time of immersion and the container temperature on withdrawing shall be controlled so as to ensure that all necessary metallurgical changes have been completed and that possibilities of quench cracking are minimized.

Where normalizing, i.e. air cooling from the austenitizing temperature, or tempering is involved, the containers shall be uniformly cooled in still air.

NOTE See Table 3 for details of the heat treatments allowed for the various steels.

17 Manufacture and workmanship — Tolerances

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

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

The length of the container 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 — General

The inspection and testing of containers shall be carried out to the satisfaction of an Independent Inspecting Authority who shall certify that the containers conform to the requirements of this standard.

The purchaser and the Independent Inspecting Authority shall have access at all reasonable times to those parts of the manufacturer's works engaged upon the order. They shall be at liberty to carry out any inspection deemed necessary to ensure that the containers conform to the requirements of this standard.

The manufacturer shall give reasonable notice to the Independent Inspecting Authority, as agreed between them, of when the containers will reach a stage at which inspection is required. Adequate facilities for inspection and witnessing of tests shall be provided by the manufacturer.

19 Inspection and tests — Hardness tests

Each container after final heat treatment shall be subjected to a hardness test employing a spherical indentor in accordance with BS EN 10003-1 or BS EN 10109-1. The diameter of the ball and the applied load shall conform to these standards and shall be such as not to damage the container.

The indentation shall be made on the cylindrical portion of the container. The surface of the container shall be prepared by lightly polishing where the impression is to be placed, but the thickness of the wall shall not thereby be reduced below the minimum calculated in accordance with **12.3**.

The hardness values for a given tensile range shall be in accordance with Figure 1.

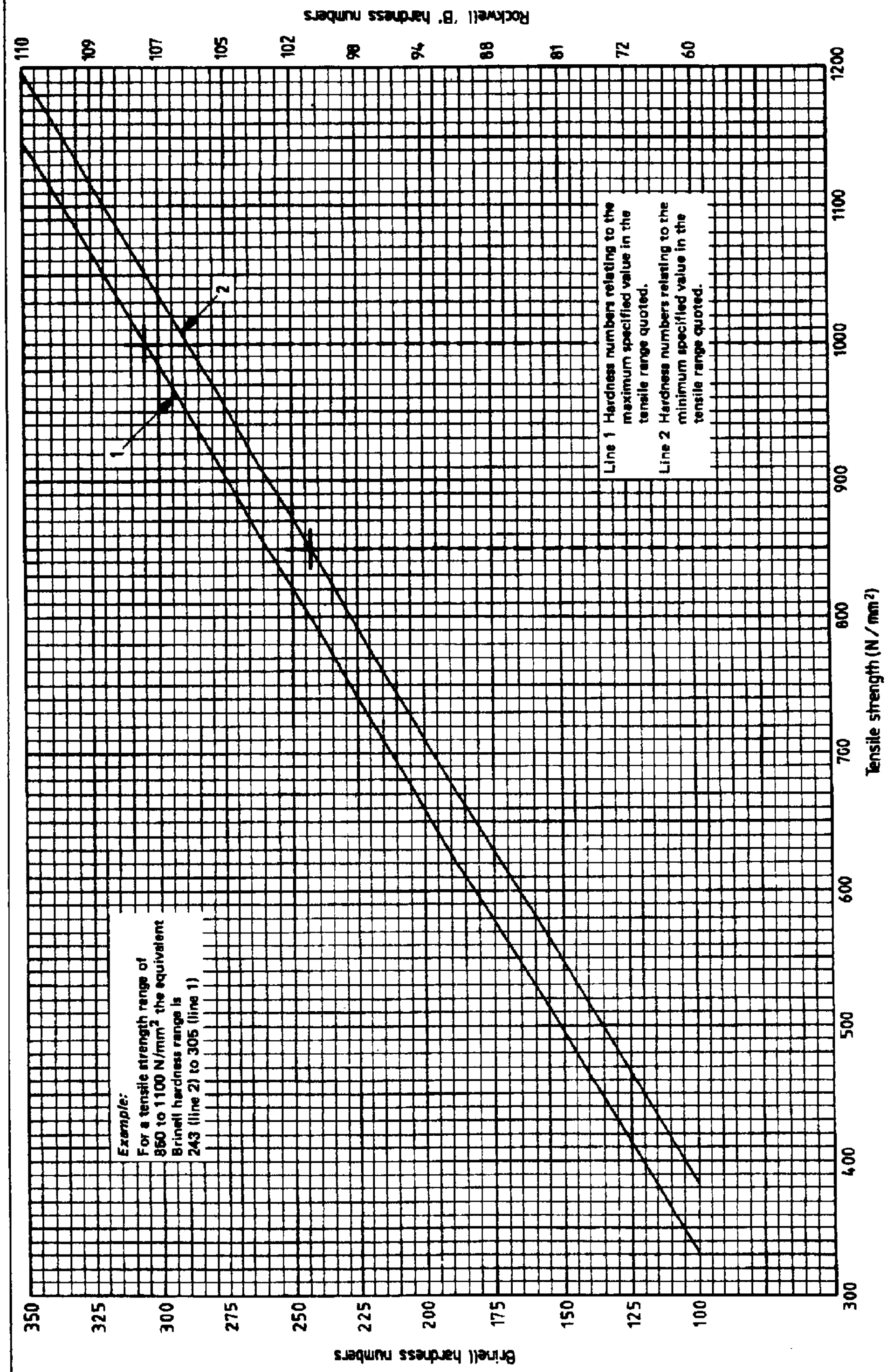


Figure 1 — Hardness numbers related to tensile strengths

20 Inspection tests — Mechanical tests

20.1 Test samples

One test sample shall be taken from every batch[3], except where the number in the batch exceeds 200 containers, in which case one sample shall be taken in every 201 or part thereof.

The test sample shall comprise material from a finished container.

The following tests shall be carried out on each test sample:

a) tensile test (see **20.2**);

b) bend test (see **20.3**).

20.2 Tensile tests

20.2.1 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 or the container or (when the wall thickness permits) be circular with a diameter of not less than 7 mm for the central portion.

20.2.2 In preparing a 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. The ends only may be flattened for gripping in the test machine.

20.2.3 The tolerance on form (difference between maximum and minimum values of a given dimension in any one test piece) for the machined surfaces of a test piece shall be to tolerance grade IT 9 of BS EN 20286-2. For test pieces of circular cross-section the machining tolerance on nominal dimensions (the tolerance that 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 limit of tolerance IT 12 of BS EN 20286-2.

20.2.4 The gauge length for test pieces and the test results shall conform to the requirements specified in 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 conform to BS 3894-1.

20.2.5 Tensile testing shall be carried out as specified in BS EN 10002-1. If individual measurements of the thickness of a test piece whose two faces are formed by the surfaces of the container wall differ somewhat from one another, the minimum thickness shall be taken for calculation.

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

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

20.2.7 The results obtained shall conform to Table 2.

20.3 Bend tests

Cold bend tests shall be made on four strips cut from the container or test ring used to provide the tensile test piece. The strips shall be taken from a ring (or two rings if one is insufficient) cut from the container. The width of the test specimens shall be 25 mm or four times the design thickness of the container (including any corrosion allowance) whichever is the greater. Where bending of the full thickness of a thick container is impracticable the test piece may, at the discretion of the Independent Inspecting Authority, be thinned uniformly from the inside surface, in which case the width of the specimen shall be not less than four times its thickness. The test pieces shall not be machined on the surfaces corresponding to the outside and inside surface of the container (except as permitted for thick containers) but the corners may be rounded off to a radius approximately to 0.25 times the thickness of the test specimen.

The test specimens shall be bent round a forming tool of radius not greater than that given in Table 3 until the gap between the ends of the specimen is not greater than twice the radius of the forming tool. The face of the test specimen which corresponds to the outside surface of the container shall be in tension during the test and shall remain uncracked.

NOTE The diameter of the rolls supporting the test piece and the distance between them may be varied to suit the specimens being tested in order that the radius of curvature of the specimen may be made to correspond with that of the forming tool.

21 Inspection and tests — Examination for thickness, surface imperfections and neck folds

21.1 Thickness and surface imperfections

Each container shall be examined for minimum thickness and for external and internal surface defects either by mechanical means or by an ultrasonic method in accordance with annex B.

[3] A "batch" refers to a group of containers of the same size, design and material specification heat treated under the same conditions of temperature and duration.

When mechanical means are used, the examination shall be carried out before the closing in operation.

Any removal of surface defects by local dressing shall be such that the wall thickness of the dressed area is not less than the minimum wall thickness shown on the manufacturer's drawing.

21.2 Examination for neck folds

Each container shall be examined for neck folds and, in the case of containers made from seamless tube, for base folds by means of an introscope or other suitable appliance.

Folds that are clearly visible as depressions having rounded peaks and roots shall not be deemed to constitute defects, but those which have sharp profiles or whose shape cannot definitely be identified, particularly those that are only discernible as a crack or a line of oxide on the container surface or in the threaded portion, as shown in Figure 2, shall be removed by a machining operation which produces a contour similar to that in Figure 2.

After machining, the whole area shall be re-inspected and measured for thickness. If the defects have not been completely removed, or, if the thickness at any part of the machined area is less than twice the minimum wall thickness shown on the drawing, the container shall be deemed not to conform to the requirements of this standard.

22 Inspection and tests — Hydraulic tests

22.1 General

All containers shall be subjected to a hydraulic test.

22.2 Type of test

When the examination required by **21.1** is carried out by an ultrasonic method (see annex B), each completed container, other than those used for the tests specified in clause **20**, shall be subjected to either a proof pressure test or a volumetric expansion test. When an ultrasonic method is not used, then each completed container shall be subjected to a volumetric expansion test as specified in annex A.

22.3 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.

22.4 Volumetric expansion test

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

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.

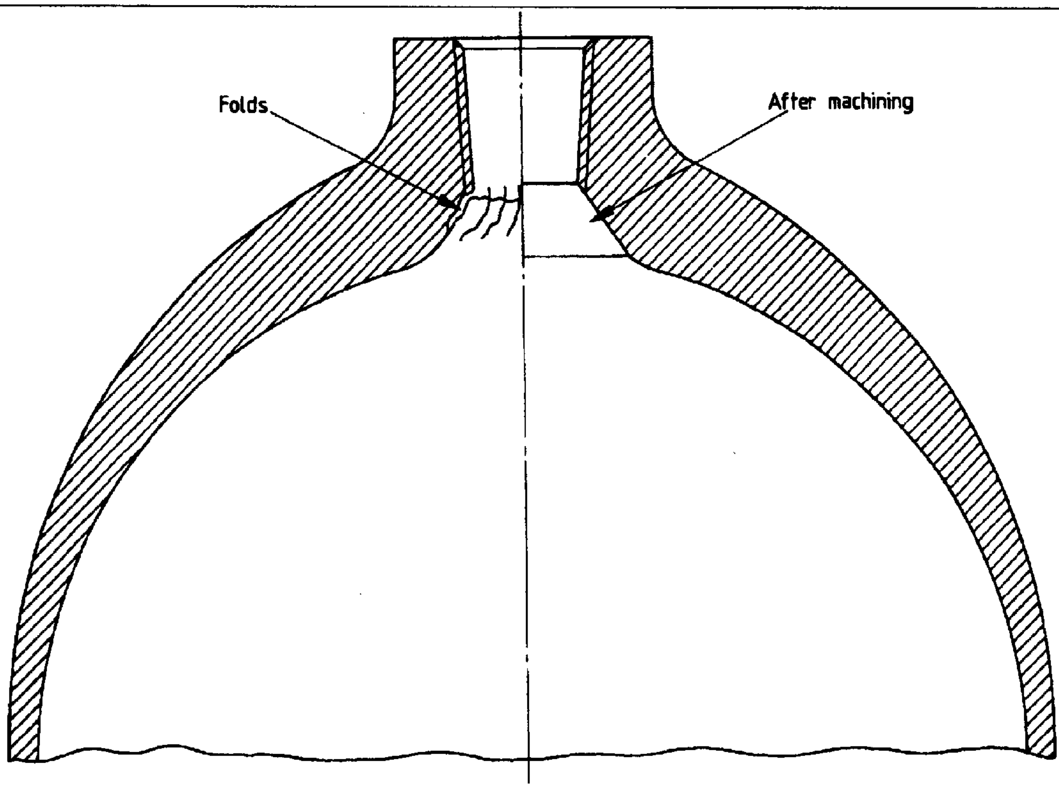


Figure 2 — Cylinder neck folds before and after machining

If the permanent volumetric expansion exceeds 5 % of the total expansion under the test pressure, the container shall be deemed not to conform to the requirements of this standard or, provided the container does not show visible deformation, re-heat treated in accordance with clause **23** and then re-tested.

22.5 Proof pressure test

22.5.1 *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.

22.5.2 *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) retested.

22.6 Drying out

The interior of each container shall be thoroughly dried immediately after hydraulic testing. Containers shall not be heated above 350 °C.

23 Inspection and tests — Re-heat treatment

23.1 General

No container shall be normalized or hardened more than three times or tempered more than four times. If after the permitted number of treatments a container does not satisfy the requirements of Table 2 or the hydraulic volumetric expansion test specified in clause **22**, it shall be rendered unserviceable for holding gas under pressure.

If more than five containers in a batch are re-heat treated, they shall constitute a new batch for the purposes of clause **20**, except in the following cases.

a) Containers that are found to be too hard in the Brinell test and are re-heat treated need not be considered as constituting a new batch unless the retempering temperature differs by more than 20 °C from the original tempering temperature;

b) Containers that are found to be too soft in the Brinell test or show excessive stretch in the hydraulic stretch test and are re-heat treated need not be considered as constituting a new batch unless the austenitizing temperature or the tempering temperature differs by more than 20 °C from the original temperature.

23.2 Normalized and normalized and tempered steels — Codes M, C and Mn

Containers that have been normalized only shall be either tempered or renormalized or renormalized and tempered. Containers that have been normalized and tempered shall be either retempered or renormalized or renormalized and tempered.

23.3 Hardened and tempered steels — Codes MnH, CM and NCM

Containers shall be either retempered or be re-hardened and tempered.

24 Inspection and tests — Tightness test

The manufacturer shall apply tests appropriate to the manufacturing process to ensure that there is no leakage from the cylinder.

25 Inspection and tests — Testing of prototype containers

25.1 New design

For the purposes of **25.2.1** and **25.2.2** 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) it is manufactured from a steel of different nominal chemical composition; or

d) it is given a different heat treatment; or

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

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

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

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

i) a change in hydraulic test pressure 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 to be of a new design.)

25.2 Pressure cycling and burst tests

25.2.1 In addition to the tests specified in clauses **19**, **20**, **22**, **24**, and **25.1**, three containers from the first batch made to a new design (see **25.1**) shall be submitted to the following pressure cycling test. The containers shall be certified by the manufacturer to be representative of the manufacturer's design and manufacturing procedure. In the case of large containers, or of small batches where this test is impracticable, the Independent Inspecting Authority shall be consulted.

25.2.2 The test shall be carried out using a non-corrosive fluid with the difference between the maximum and minimum pressure equivalent to either 0.9 or 0.6 times the test pressure of the container. The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure. The frequency of reversals shall not exceed 15 cycles/min. The temperature measured on the outside surface of the container shall not exceed 50 °C during the test.

25.2.3 Cylinders shall be considered to have passed the test if they satisfactorily complete either:

— 7 000 cycles over a range equivalent to 0.9 times test pressure; or

— 60 000 cycles over a range equivalent to 0.6 times test pressure

25.2.4 Following the test required by **25.2.2**, two of the containers shall be hydraulically pressure tested to destruction. The remaining container shall be either hydraulically pressure tested or pressure cycle tested to destruction. The containers shall remain in one piece after bursting.

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

$$f_b = \frac{P_b D_i}{20t'}$$

where

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

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

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

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

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

25.2.6 Where the tests are not practicable, the Independent Inspecting Authority shall be consulted.

25.3 Other prototype tests

Other prototype testing shall be as specified in **28.3**.

26 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, in order to ensure compliance with the required minimum specified water capacity.

27 Inspection and tests — Results of tests

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

27.2 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 the test, the authority may authorize a retest, the first test being ignored. Otherwise the following may be applied at the manufacturer's discretion.

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 specified in **20.2** and **20.3** shall be carried out on another container or test ring from the same batch. Both containers or both test rings shall then conform to the test requirements of **20.2** and **20.3**, for the batch to be accepted.

b) The batch shall be re-heat treated as specified in **23.2**, or **23.3** and the mechanical tests called for in **20.2** and **20.3** shall be carried out.

In the case of containers that have been re-hardened, the tests shall be carried out on a container that has not previously been tested, but in all other cases the tests shall be carried out on material cut from the original test container provided that this material has been subjected to the same re-heat treatment as the batch of containers it represents.

27.3 If any of the test specimens fail the mechanical tests required by **27.2**a) or b), the batch may be re-heat treated as specified in **23.2**, or **23.3** and retested as specified in **27.2**.

Not more than five containers or test rings from one batch shall be submitted for test and the limitations on re-heat treatments in **23.1** shall apply.

27.4 If after the permitted number of re-tests and re-heat treatments containers do not conform to the requirements for mechanical tests, the containers in the batch shall be rendered unserviceable for holding gas under pressure.

28 Inspection and tests — Marking of containers

28.1 Each container that conforms to the requirements of this standard shall be permanently and legibly marked with the following information:

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

b) the test pressure (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 5045-7[4]), and the code mark (see Table 1) of the material of construction, e.g. BS 5045/7/CM;

e) the letter S. This letter shall follow the specification number referred to above, e.g. BS 5045/7/CM/S;

f) the design minimum water capacity of the container if it is intended to be used for the conveyance of liquefiable gases (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 filling pressure at 15 °C if the container is intended to be used for permanent gases (in bar).

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

28.2 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.

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

28.3 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 ends and the areas where marking will be permitted is agreed between the manufacturer and the Independent Inspecting Authority.

Another prototype container shall also be similarly sectioned and examined after marking. The marking shall cause no change in contour of the container. The characters in the marking should normally be at least 6 mm in height. On small containers this height may be reduced but in no case shall the characters be less than 3 mm in height.

28.4 When the conditions specified in **28.2** and **28.3** cannot be satisfied, the Independent Inspecting Authority shall be consulted.

[4]) Marking BS 5045-7 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 clamaint'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 steel gas containers as required by clause **22**:

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 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.

A.2.4 A 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 test

A.3.1 ***Principle***

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

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

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:

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

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 permitted.

A.4.2 *Apparatus*

The equipment shall be arranged such 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.

The pressure gauges should be calibrated as specified in BS 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 "black" 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.

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 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 for the compressibility of water (see **A.4.5**), 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 millimetres 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	= 1 742 mL
Permanent expansion (PE) = 1 745 − 1 742	= 3 mL
From Table A.1, K factor for 15 °C water temperature	= 0.047 25
From the formula $C = mP\left(K - \frac{0.68\,P}{10^5}\right)$	
Reduction in volume of water due to compressibility at 232 bar and 15 °C	= 1 224.25 mL
$= 115.545 \times 232\left(0.047\,25 - \frac{0.68 \times 232}{10^5}\right)$	
Total volumetric expansion (TE) = 1745 − 1 224.25	= 520.75 mL
$\frac{\text{Permanent expansion}}{\text{Total volumetric expansion}} = \frac{3 \times 100}{520.75}$	= 0.58 %

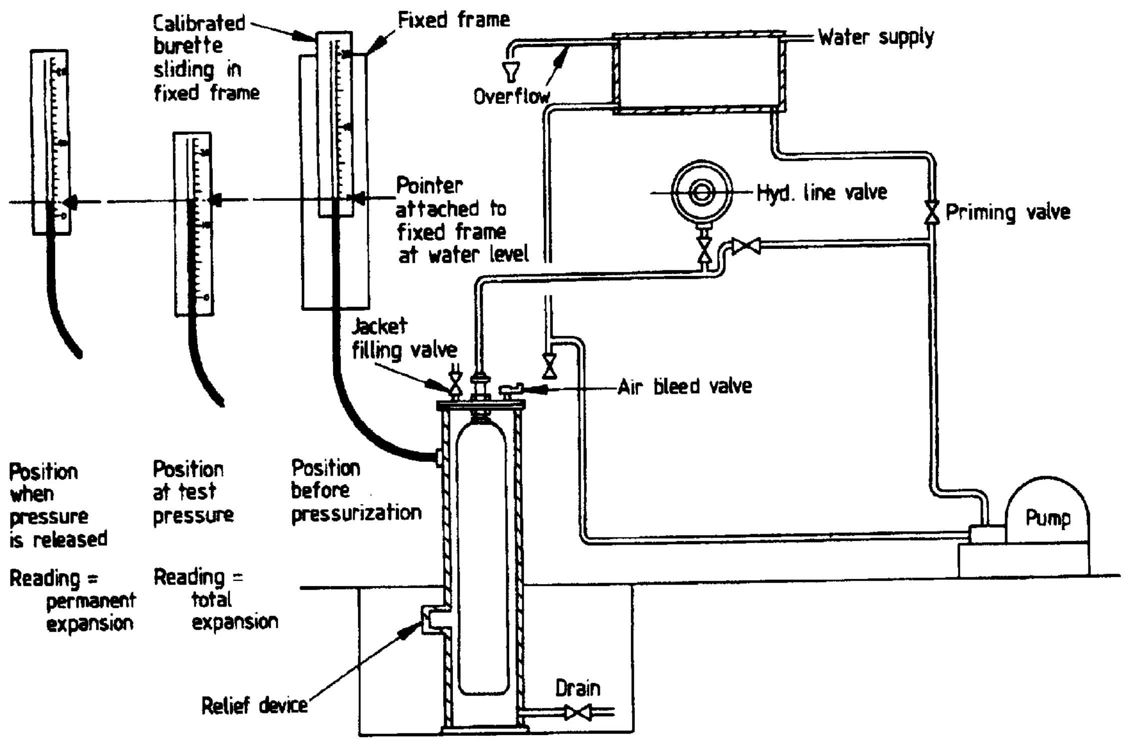


Figure A.1 — Water jacket volumetric expansion test (levelling burette)

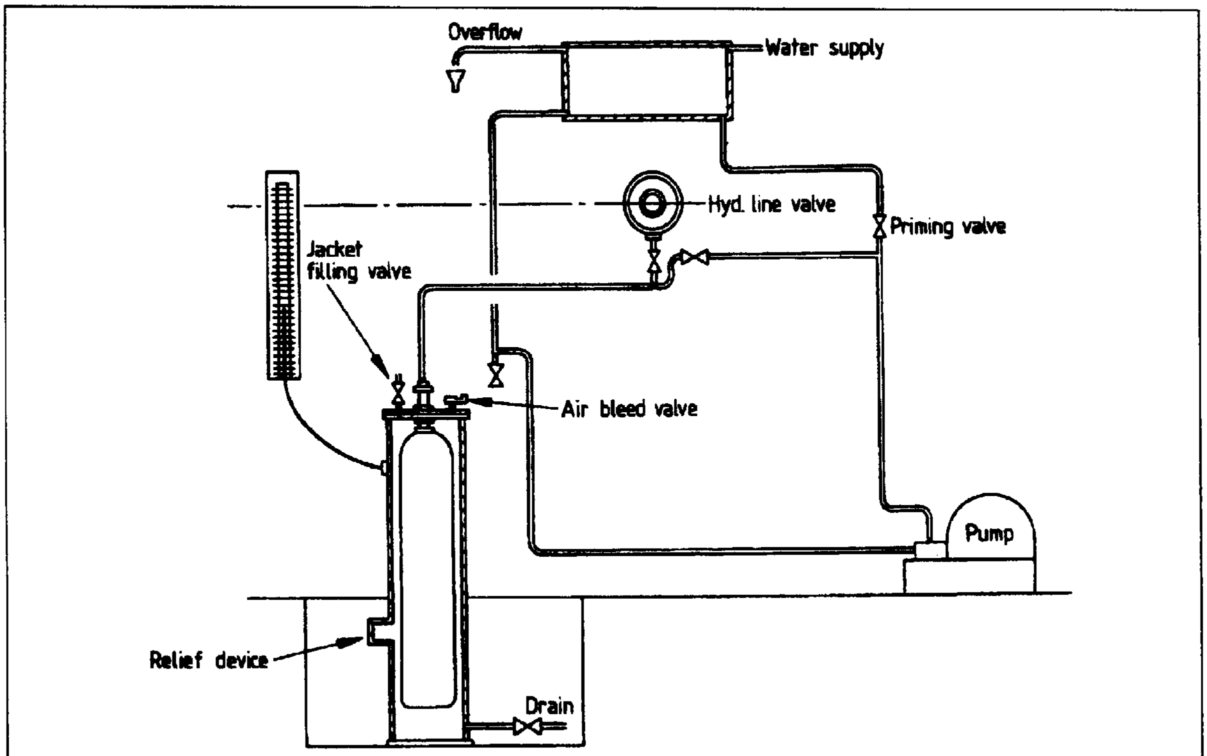


Figure A.2 — Water jacket volumetric expansion (fixed burette)

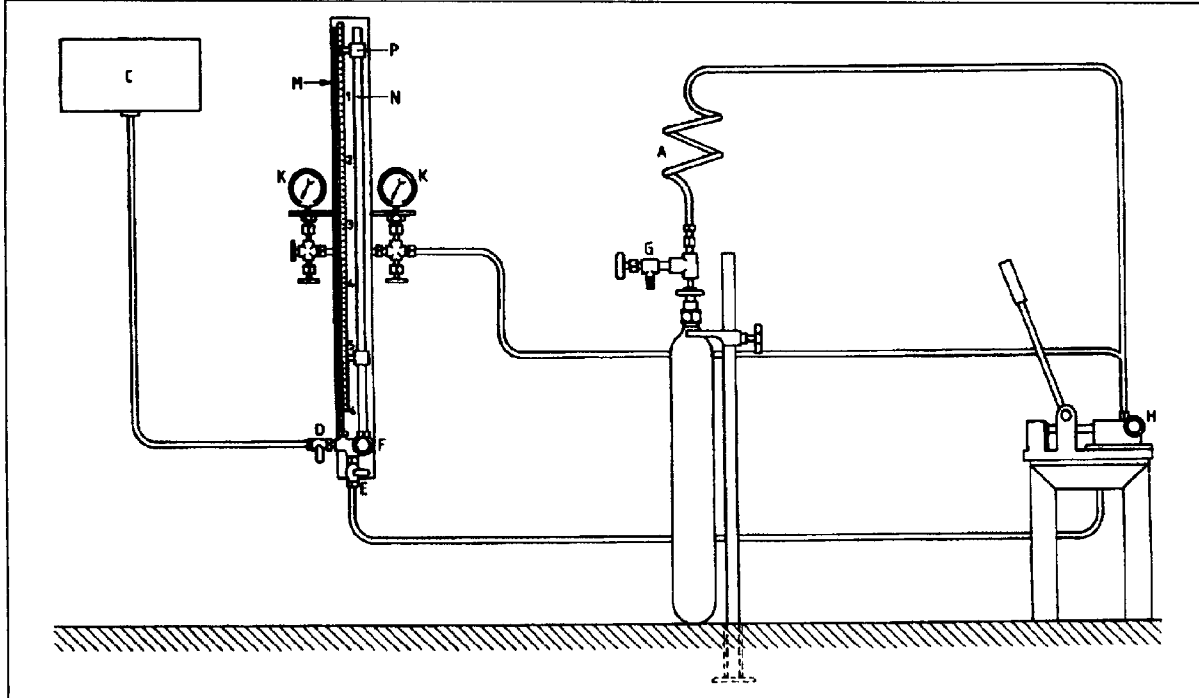


Figure A.3 — Non-water jacket volumetric expansion test

Annex B (normative)
Ultrasonic defect detection and thickness measurement

B.1 Defect detection

B.1.1 ***General***

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

Containers shall be tested for defects in the parallel walls.

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, e.g. loose scale.

B.1.3 ***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.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 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.1.5.2 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 standard 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.1.6 ***Calibration of equipment***

Using the calibration standard specified in **B.1.5** 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.1.7 ***Frequency***

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

B.1.8 ***Procedure***

B.1.8.1 *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 time intervals 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.1.8.2 *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.1.9 ***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.

If surface defects are removed by grinding then after correction the containers shall be re-subjected to ultrasonic defect detection and thickness measurement.

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

B.2 Thickness measurement

B.2.1 ***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.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, e.g. loose scale.

B.2.3 ***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 an accuracy within ±2.5 % of the set value.

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***

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 allowable thickness shall be used. When it is not possible to provide such a calibration standard, flat calibration standards shall be used.

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

Using the calibration standard specified in **B.2.5** 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.2.7 ***Frequency***

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

B.2.8 ***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 speed and feeds used during the calibration procedure.

The container shall be examined to ensure that the thickness is not below the specified minimum value.

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 is accomplished.

B.2.9 ***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 shown to be below the minimum wall thickness shown on the manufacturer's drawing shall be deemed not to conform to the requirements of this British Standard.

Annex C (informative)

Examples of design calculations for cylindrical walls of seamless containers

Example 1. Container for permanent gas. A container of 12 litre water capacity, having an external diameter of 176 mm, made from chromium molybdenum alloy steel to the chemical compositions given in Table 2, is to be filled with oxygen for resuscitation purposes to a pressure of 136.5 bar gauge at the equilibrium temperature of 15 °C. The minimum yield stress and the minimum tensile strength specified by the container manufacturer are 755 N/mm^2 and 890 N/mm^2 respectively.

Calculation of test pressure. From Table 6 the reference temperature for permanent gas is 60 °C.

From BS 5355 for oxygen filled at 136.5 bar at 15 °C, the developed pressure at 60 °C is 166 bar.

The ratio of

$\frac{\text{yeild stress } (Y)}{\text{tensile strength } (T)}$ for the steel is $\frac{755}{890} = 0{,}848$

i.e. within the specified limit of 0.85 maximum.

This value is greater than 0.7; thus from Table 7 P_1 shall be the greater of:

$$1.5 \times \text{charged pressure or } \frac{p}{0.85},$$

i.e. 1.5×136.5 or $\frac{166}{0.85}$

i.e. 205 bar or 196 bar

The greater is 205 bar.

But from Table 7 P_1 shall not exceed $\frac{pY}{0.63T}$

i.e. P_1 shall not exceed $\frac{166 \times 755}{0.63 \times 890} = 224$ bar.

Since 205 bar does not exceed 224 bar, the minimum permissible value of test pressure P_1 is 205 bar.

Minimum thickness of cylindrical wall.
From formula (1) of **12.3**:

$$t = \frac{0.3\,P_1 D_1}{7\,f_e \times 0.4\,P_1}$$

P_1 = 205 bar;

D_0 = 176 mm;

f_e = 0.875 × 755 N/mm² (from Table 8).

Thus

$$t = \frac{0.3 \times 205 \times 176}{(7 \times 610.62) - 0.4 \times 205} = 2.39 \text{ mm}$$

However, the thickness of the cylindrical wall is not to be less than the value given by $t = 2.48 \sqrt{(D_i/T)}$ (formula (2) of **12.3**); thus

$$t = 2.48 \times \sqrt{\left(\frac{176 - 2 \times 2.39}{890}\right)} = 1.09 \text{ mm}$$

As this thickness does not override the value obtained by calculation from formula (1) of **12.3**, the required minimum thickness is 2.39 mm.

Example 2. Container for high pressure liquefiable gas. A container of 6.8 litre water capacity having an internal diameter of 40 mm is to be manufactured from hardened and tempered carbon manganese steel, to the compositions given in Table 2, is to be filled with carbon dioxide for use as a fire extinguisher. The minimum yield stress (Y) and the minimum tensile strength (T) specified by the container manufacturer are 720 N/mm² and 860 N/mm² respectively.

Calculation of test pressure. From Table 6, the reference temperature for carbon dioxide (high pressure liquefiable gas) is 50 °C when a safety device is fitted.

From BS 5355 the developed pressure (p) at 50 °C for carbon dioxide used for fire extinguishers (with filling ratio of 0.67) is 136.8 bar.

The ratio of Y/T for the steel is

$$\frac{720}{860} = 0.837$$

i.e. within the specified limit of 0.85 maximum.

This value is greater than 0.7; thus from Table 7 P_1 shall be the lower of:

$$\frac{pY}{0.7T} \text{ or } \frac{p}{0.85}$$

i.e. $\frac{136.8 \times 720}{0.7 \times 860}$ or $\frac{136.8}{0{,}85}$

i.e. 164 bar or 161 bar.

The lower is 161 bar.

But from Table 7 P_1 shall not be less than 200 bar for carbon dioxide.

Since 161 bar is less than 200 bar, the minimum permissible value of test pressure P_1 is 200 bar.

Minimum thickness of cylindrical shell. From formula 1 of **12.3**:

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

where

P_1 200 bar

D_i 140 mm

f_e 0.875 × 720 N/mm² (from Table 8) = 630 N/mm²

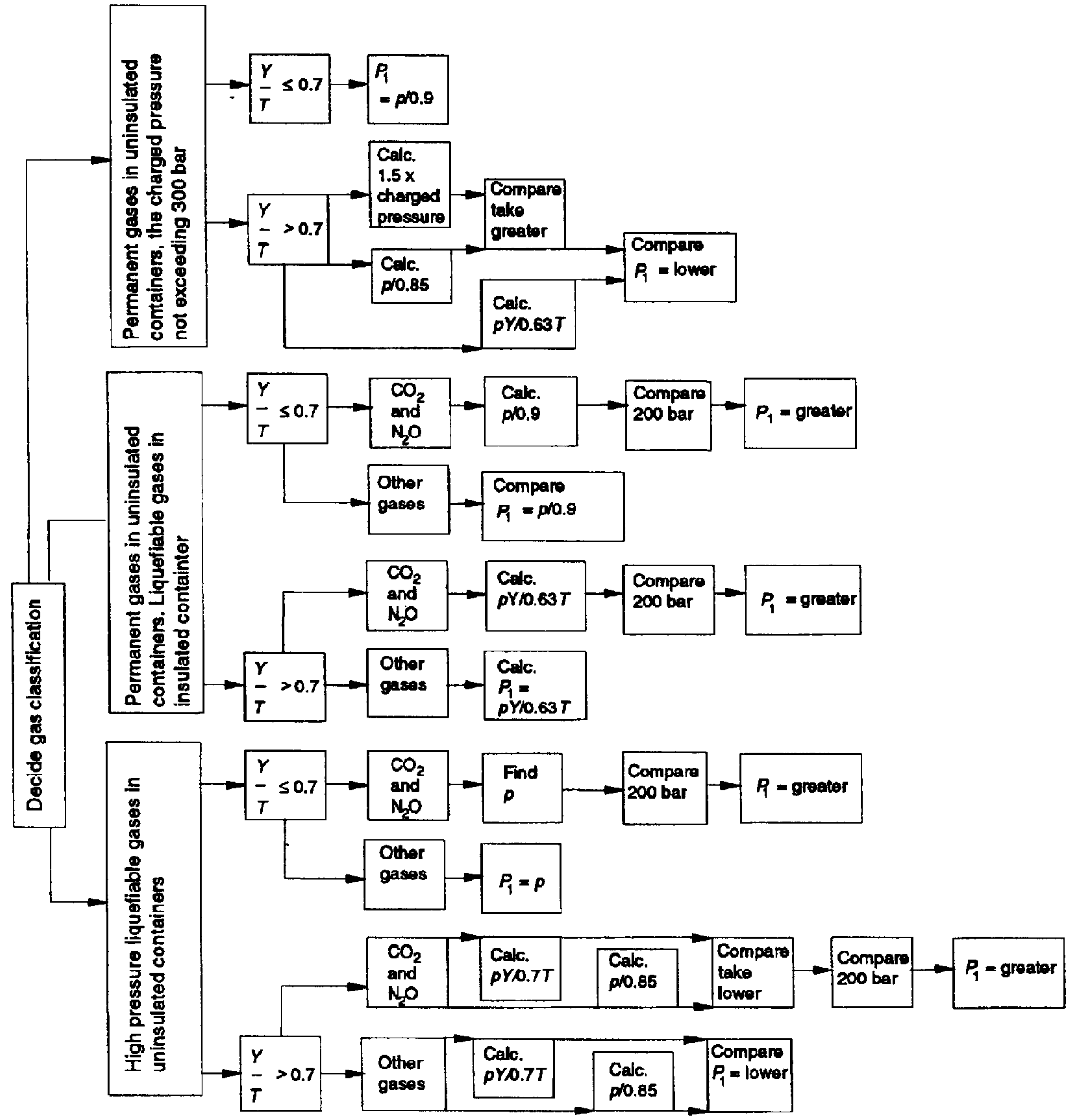
thus

$$t = \frac{0.3 \times 200 \times 140}{(7 \times 630) - 200} = 2.00 \text{ mm}$$

However, the thickness of the cylindrical shell is not to be less than the value given by $t = 2.48\sqrt{(D_i/T)}$ (formula (2) of **12.3**); thus

$$t = 2.48\sqrt{\left(\frac{140}{160}\right)} = 1.00 \text{ mm}$$

As this thickness does not override the value obtained by calculation from formula (1) of **12.3**, the required minimum wall thickness is 2.00 mm.



NOTE "Calc" is an abbreviation for "Calculate".

Figure C.1 — Diagram for deriving minimum values of test pressure P_1

Annex D (informative) Specimen certificates

D.1 Specimen design certificate for seamless steel gas containers

Certificate no ....

Date ....

Specification ....

Gas ....

Material code ....

Minimum specified tensile strength ....

Minimum specified yeild stress ....

Customer ....

Manufacturer ....

Order no. { Customer ....
Manufacturer ....

Serial no(s). { Customer ....
Manufacturer ....

Quantity ordered ....

Drawing No.	Test pressure	Min. thickness		[a]External/ internal diameter	Nominal length without cap or valve	Min. water capacity	Mass	
		Cylindrical shell	Base				min.	max.
	bar	mm	mm	mm	mm	L	kg	kg
[a] Delete as appropriate.								

Identification marks stamped on container shoulder

a) manufacturer's marks;

b) the number of this British Standard and the code marked required by **28.1**;

c) filling pressure at 15 °C (applicable to permanent gases only);

d) water capacity, design minimum (applicable to liquefiable gases only);

e) date of hydraulic test;

f) Independent Inspecting Authority mark(s);

g) test pressure;

h) customer's mark (if any) or design gas capacity;

i) container serial number;

j) mass of container and valve (for liquefiable gas containers);

or

mass of container without valve (for permanent gas containers);

k) stamping drawing reference number.

D.2 Specimen acceptance certificate for seamless steel gas containers

Manufacturer .... Date ....
Customer .... Regulation/specification ....
Size .... Inspection ....
Gas .... Manufacturer's order no. ....
Serial nos. { Customer .... Customer's order no. ....
Manufacturer ....
Batch no(s) ....

We hereby certify that the containers produced to design certificate number.......... .... conform to the following requirements

Minimum cylindrical shell thickness
The wall thickness of all containers has been measured and found to be not less than .... mm.

Hardness range
All containers have been controlled within the following hardness values:
Min .... HB
Max. .... HB

Heat treatment
All containers have been heat treated at the following temperatures:
*Oil quench from .... °C
*Normalize at .... °C
*Temper at .... °C

Hydraulic pressure test
1. Volumetric expansion test (see separate test certificate) or
2. Proof pressure test and ultrasonic test
2.1 *Proof pressure test.* Each container has been proof tested to a pressure of .... bar.......... and found to be satisfactory.
2.2 *Ultrasonic test.* Each container has been ultrasonically examined on the parallel walls to a 5 % standard and found to be satisfactory.
3. Date of pressure test.

Water capacity and tare
Water capacity between .... and .... L.
Tare between .... and .... kg including allowance of .... kg for fittings.

Material
The container in batch(es) .... were manufactured from the following cast(s) of steel:
Steelmaker: ....
Tubemakers: ....

Cast	Code	C	Si	Mn	P	S	Cr	Mo	Ni

* Delete as appropriate

Mechanical tests

Batch no.	Code	Test piece dimensions	Upper yield stress or 0.2 % proof stress	Tensile strength	Elongation
		mm	N/mm2	N/mm2	%
Bend tests satisfactory at					

For and on behalf of the manufacturer .... For and on behalf of the Independent Inspecting Authority ....

D.3 Specimen hydraulic volumetric expansion test certificate

Customer's order no. .... Tested to a pressure of .... bar and conforming to BS 5045-7.
Manufacturer's no. ....

Container no.	Cast no.	Total expansion	Permanent expansion	Permanent/ total expansion ratio	Mass full	Mass empty	Water capacity	Dated tested	Customer's serial no.
		mL	mL	%	kg	kg	L		

Certified by .... on behalf of .... Date...
(for manufacturer)

Accepted by .... Date
(Independent Inspecting Authority)

Bibliography

BS EN 1964-1:2000, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres — Part 1: Cylinders made of seamless steel with an R_m value of less than 1 100 MPa.*

BS 5045-1:1985, *Transportable gas containers — Specification for seamless steel gas containers above 0.5 litre water capacity.*

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