

Transportable gas containers —

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

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Foreword

This British Standard has been prepared under the direction of the Pressure Vessel Standards Committee. It is one of a series which deal 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 present revision has been prepared to include requirements both for containers for the carriage of dissolved acetylene and for those containers permanently fitted to trailers in hydrogen service.

This particular standard deals with the materials, design, construction and testing of new containers and is being prepared in a number of Parts to cover the various forms of manufacture. Those Parts either already published or in preparation are as follows:

- *Part 1: Specification for seamless steel gas containers above 0.5 litre water capacity;*
- *Part 2: Steel containers up to 130 litres water capacity with welded seams;*
- *Part 3: Specification for seamless aluminium alloy containers;¹⁾*
- *Part 4: Specification for steel containers of over 450 litres water capacity with circumferential and longitudinal welded seams;¹⁾*
- *Part 5: Specification for welded aluminium alloy containers of water capacity 1 litre up to 130 litres;¹⁾*
- *Part 6: Specification for seamless containers of up to and including 0.5 litre water capacity.*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

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

¹⁾ In course of preparation.

Section 1. General

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 for the conveyance of gases under pressure. Such containers are suitable also for storing gas under pressure.

It includes appendices giving examples of design calculations, a description of the methods for pressure testing of containers, a description of the methods for ultrasonic examination of containers, model forms of design and acceptance certificates and the special requirements for steel containers that are permanently fitted to trailers for use in hydrogen service.

2 References

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

3 Manufacture and testing of containers

The manufacture, inspection and testing of containers complying with 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 $-10\text{ }^{\circ}\text{C}$.
- b) *Liquefiable gases*. Those gases that are liquefiable by pressure at $-10\text{ }^{\circ}\text{C}$ and that are completely vaporized at $17.5\text{ }^{\circ}\text{C}$ and 1 013 mbar²⁾.

High pressure liquefiable gases are those having a critical temperature between $-10\text{ }^{\circ}\text{C}$ and $70\text{ }^{\circ}\text{C}$.

Low pressure liquefiable gases are those having a critical temperature above $70\text{ }^{\circ}\text{C}$.

Those toxic substances that are liquids at 1 013 mbar at $0\text{ }^{\circ}\text{C}$ but that boil at or below $30\text{ }^{\circ}\text{C}$ at that pressure shall be treated as low pressure liquefiable gases.

c) *Dissolved gas (acetylene)*. 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.

Gases that are currently conveyed in commercial quantities are classified 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 $15\text{ }^{\circ}\text{C}$;
- e) for liquefiable gases, the mass of gas or filling ratio at the prescribed reference temperature or the required developed pressure in service;
- f) 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.

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⁾ 1 mbar = 10^2 N/m^2 = 0.1 kPa.

Table 1 — Classification of gases

Permanent gases ($T_c < -10\text{ }^{\circ}\text{C}$)	Liquefiable gases		Dissolved gases
	High pressure ($-10\text{ }^{\circ}\text{C} \leq T_c \leq 70\text{ }^{\circ}\text{C}$)	Low pressure ($T_c > 70\text{ }^{\circ}\text{C}$)	
Air Argon Boron trifluoride ^a Carbon monoxide ^{ab} Coal gas ^{ab} (including coke oven gas) Fluorine ^{ac} Helium Hydrogen ^b Methane ^b (natural gas) Neon Nitrogen Oxygen Town gas ^{ab} (other than coal gas)	Bromotrifluoromethane (R 13B1) Carbon dioxide Chlorotrifluoromethane (R 13) Ethane ^b Ethylene ^b Hydrogen chloride ^{ac} Nitrous oxide Sulphur hexafluoride	Ammonia ^a Boron trichloride ^{ac} Bromochlorodifluoromethane (R 12B1) Butadiene ^b Butane ^b Carbonyl chloride ^{ac} Chlorine ^{ac} Chlorine trifluoride ^{ac} 1-Chloro-1,1-difluoroethane (R 142b) 2-Chloro-1,1,1-trifluoroethane (R 133a) Chlorodifluoromethane (R 22) Chloropentafluoroethane (R 115) Cyanogen chloride ^a Cyclopropane ^b Dichlorodifluoromethane (R 12) Dichlorofluoromethane (R 21) 1,2-Dichlorotetrafluoroethane (R 114) 1,1-Difluoroethane (R 152a) ^b Dimethylamine ^b Dimethyl ether ^b Ethylamine ^b Ethyl chloride ^b Ethylene oxide ^{ab} Hydrogen cyanide ^{ab} Hydrogen fluoride ^{ac} Hydrogen sulphide ^{ac} Isobutane ^b Methyl bromide ^a Methyl chloride ^{ab} Monomethylamine ^b Nitrogen tetroxide ^{ac} Nitrosyl chloride ^{ac} Octafluorocyclobutane (R C318) Propane ^b Propylene ^b Sulphur dioxide ^{ac} Trimethylamine ^b Vinyl chloride ^b <i>Gas mixtures</i> Azeotrope R 500 (73.8 % R 12 and 26.2 % R 152a) Azeotrope R 502 (48.8 % R 22 and 51.2 % R 115) Ethylene oxide ^a 12 % and R 12 88 %	Acetylene ^b

NOTE 1 T_c is the critical temperature.

NOTE 2 Reference to refrigerants by number designation (e.g. R 12) is in accordance with international agreements (see BS 4580).

NOTE 3 The above list is not intended to be comprehensive as other gases may be transported.

^a These gases are poisonous and are the ones referred to in this standard as toxic gases requiring special treatment. Other gases not so marked may have poisonous properties to a lesser degree or be suffocating in high concentrations.^b For the purposes of transport these gases are considered to be flammable.^c These gases are considered corrosive for the purpose of periodic testing (see BS 5430-1).

- 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 comply with 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 29);
- e) certificates of test for materials and container (see Appendix 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 Appendix D.

Section 2. Permissible materials

7 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 Chemical composition

8.1 The ladle analyses shall comply with the appropriate requirements of Table 2.

In the event of one melt being divided between more than one ladle, samples shall be analysed 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 Table 4 and Table 5.

NOTE 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 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 comply with 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 comply with the requirements of this standard.

8.5 Samples for product analysis shall be taken in accordance with BS 1837.

9 Steelmaker's certificate

The steelmaker shall supply a certificate stating:

- a) the steelmaking process, and
- b) the ladle analysis.

10 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	Sulphur	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 Steels made by the oxygen process shall not contain more than 0.008 % of nitrogen	% 0.15	% 0.25	% 0.05	% 0.35	% 0.40	% 0.90	% 0.050	% 0.050	% —	% —	% —	% —	% —	% —
	C		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. Steels made by the oxygen process shall not contain more than 0.010 % nitrogen.	—	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		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.				
Carbon steels	M	normalized or normalized and tempered	N/mm ² 430	N/mm ² 510	N/mm ² 250	—	% 22	$1\frac{1}{2}t_a^c$
	C	normalized or normalized and tempered	570	680	310	—	19	$2t_a$
Carbon manganese steels	Mn	normalized or normalized and tempered at not less than 550 °C and cooled in air	650	760	445	—	20	$2\frac{1}{2}t_a$
	MnH ^b	hardened from 800 °C to 850 °C and tempered at 530 °C to 670 °C	890 max.	1 030	755	0.85 max.	14	$3t_a$
Chromium molybdenum alloy steel	CM	hardened from 850 °C to 920 °C and tempered at 550 °C to 720 °C ^b	890 max. ^b	1 030 ^b	755	0.85 max.	14	$3t_a$
Nickel chromium molybdenum alloy steel	NCM	hardened from 820 °C to 850 °C and tempered at 550 °C to 660 °C ^b	890 max. ^b	1 030 ^b	755	0.85 max.	14	$3t_a$

NOTE For hardness properties see Figure 1.

^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 See Appendix E for containers permanently fixed to trailers in hydrogen service.

^c t_a is the actual thickness of the specimen.

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 > 0.25 to 0.50	0.02 0.03
Silicon		0.03
Manganese	≤ 1.0 > 1.0 to 1.5 > 1.5	0.04 0.08 0.10
Phosphorus		0.008
Sulphur		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 > 0.25 to 0.50	0.01 0.02
Silicon		0.03
Manganese	≤ 0.70 > 0.70 to 1.0 > 1.0 to 2.0	0.03 0.04 0.05
Phosphorus		0.004
Sulphur		0.005
Chromium	≤ 0.60 > 0.60 to 1.25	0.03 0.04
Molybdenum	≤ 0.50 > 0.50	0.02 0.03
Nickel	≤ 1.0 > 1.0 to 3.0	0.03 0.05

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

Section 3. Design

11 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 size of container and 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 Reference temperatures for filling ratios of low pressure liquefiable gases in uninsulated containers vary with the size of container. The relationships are expressed in Table 7. Examples of design calculations are given in Appendix C.

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

Type of contents	Container volume V (water capacity)			
	≤ 130 L	> 130 L ≤ 1 m ³ (see note)	> 1 m ³ ≤ 5 m ³ (see note)	> 5 m ³ (see note)
Low pressure liquefiable gas	55 °C	50 °C	47.5 °C	42.5 °C
High pressure liquefiable gas	52.5 °C ^b	52.5 °C ^b	50 °C	45 °C
Permanent gas	60 °C			

NOTE For the purpose of the above table, when the ratio of the overall length of the container to the diameter exceeds 4.5, the volume of the container is assumed to be that volume contained in a length 4.5 times the external diameter.

^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.

Table 7 — Reference temperatures for filling ratio for low pressure liquefiable gases in the UK in uninsulated containers

Container volume V (water capacity)	≤ 130 L	> 130 L ≤ 1 m ³	> 1 m ³ ≤ 5 m ³	> 5 m ³
Reference temperature	45 °C	42.5 °C	42.5 °C	38 °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 given in BS 5355.

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 the requirements given 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 and Table 7 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) 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_o	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 (= $0.75 \times$ minimum specified yield stress Y of the material of construction, or

= $0.875 \times$ minimum specified yield stress of the material of construction for containers covered by 12.4)

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 Table 3 and Table 9.

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.

- The maximum pressure (p) developed in service by the gaseous contents at the nominated reference temperature, as given in BS 5355.
- 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 8; 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):

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

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

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

For dissolved acetylene containers the wall thickness shall be not less than $0.018 D_i$.

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):

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

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 for P_1 in Table 8.

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.

Table 8 — 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 excluding hydrogen trailer service, 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) $1.5 \times$ charged pressure at 15 °C except that P_1 shall not exceed $\frac{pY}{0.63T}$
Permanent gases in uninsulated containers including hydrogen trailer service, 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
Low and 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) $\frac{pY}{0.7T}$; or b) $\frac{p}{0.85}$ except that P_1 shall not be less than 200 bar for carbon dioxide or nitrous oxide
Dissolved acetylene containers	$P_1 = 60$ bar	$P_1 = 60$ bar
NOTE See Appendix C for examples and Figure 6, which shows the calculation procedure.		

Table 9 — Design stresses for permissible steels

Steel type	Code	Ratio of yield (Y) to tensile (T)	f_e value
Carbon steel	M	0.58	N/mm ² 186
Carbon steel	C	0.54	232
Carbon manganese steel normalized	Mn	0.68	330
Carbon manganese steel, quenched and tempered ^b	MnH	0.85 max.	0.75 Y
Alloy steels ^a			
Chromium molybdenum	CM	0.85 max. ^b	0.75 Y
Nickel chromium molybdenum	NCM	0.85 max. ^b	0.75 Y
Steels ^a under the conditions described in 12.4			
Carbon manganese steel, quenched and tempered ^b	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

^a Attention is drawn to the need for caution when designing containers intended for the carriage of substances that require the addition of a stenching agent containing sulphur, or that may contain either sulphur compounds or hydrocyanic acid as impurities. It is desirable that gas to be compressed into these containers be purified as far as possible from sulphur-containing compounds and hydrocyanic acid but it is technically more convenient to dry the gas so that its dew point is below the lowest temperature to which the containers may be exposed in service. Until further information becomes available it is recommended that, when such conditions are to be met, the f_e value to be used in the design of these containers should not exceed 370 N/mm²

^b See Appendix E for containers permanently fixed to trailers in hydrogen service.

12.4 Special portable containers. For portable containers of not more than 15 L water capacity used in aircraft, for breathing apparatus, for underwater breathing dress apparatus, for resuscitation apparatus, for fire extinguishers and those for life raft inflation the permissible maximum equivalent stress in the steels, codes MnH, CM and NCM, specified in Table 2 and Table 3 shall be as given in Table 9.