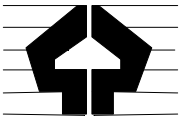

H S E
Health & Safety
Executive

Specification Number

HSE - SSGC - 1

SPECIFICATION
FOR HIGH-STRENGTH SEAMLESS STEEL TRANSPORTABLE GAS CYLINDERS FROM 0.5 LITRE TO 100 LITRES.

Issue 5 **July 1999**

CONTENTS:

1. SCOPE

1.1 Permitted gases

Permanent gases except hydrogen, carbon monoxide and gases containing any free hydrogen or sulphides.

1.2 Filling pressure at 15 degrees C

310 bar maximum.

1.3 Nominal Water Capacity

0.5 litre to 100 litres inclusive.

2. CERTIFICATE OF COMPLIANCE

The Verification Body shall certify that manufacture, inspection and testing of the cylinders was carried out in compliance with the requirements of this Specification.

Note: A suitable form of certificates are shown in Appendix 1A, B, C and D.

3. MATERIALS OF CONSTRUCTION

3.1 Permissible steelmaking process

Electric arc furnace or Oxygen process with secondary refinement.

3.2 Controls on Chemical Composition

3.2.1

The chemical composition of all steels shall be defined at least by:

- maximum sulphur and phosphorus content in all cases.
- carbon, manganese and silicon contents in all cases.
- nickel, chromium and molybdenum contents where these elements are alloying elements intentionally added.

Carbon, manganese, silicon contents and as appropriate nickel, chromium and molybdenum contents shall be given with tolerances such that the differences between the maximum and minimum values in the specified analysis do not exceed the figures in the following table :-

Table 1

Element	Maximum Content	Maximum Range
Carbon	<0.30%	0.03%
	>0.30%	0.04%
Manganese	All values	0.20%
Silicon	All values	0.15%
Chromium	<1.50%	0.2%
	>1.50%	0.3%
Nickel	All values	0.30%
Molybdenum	All values	0.10%

The combined content of the micro-alloying elements, e.g. V, Nb, Ti, B, Zr shall not exceed 0.15%

The actual content of all deliberately added elements shall conform to the above specification and be reported.

3.2.2.
The following limits, by weight, in Table 2 on sulphur and phosphorus shall not be exceeded in the cast analysis of the material used for the manufacture of gas containers.

TABLE 2

Sulphur	0.010%
Phosphorus	0.015%
Sulphur and Phosphorus	0.020%

3.3

Steelmaker's Certificate

The steelmaker shall supply a certificate stating:

a) the steelmaking process
b) the ladle analysis
c) mechanical test results for yield strength, tensile strength , elongation and the heat treatment details.

These certificates shall be retained by the manufacturer.

3.4
Mechanical properties

The following shall be obtained:

Tensile Strength:	1207 N/mm^2 maximum 1069 N/mm^2 minimum
Yield Strength	962 N/mm^2 minimum
Elongation on 5.65 $\sqrt{S}$ o	12% minimum
Radius of bend test former:	4 x ta maximum (where ta = actual thickness)
Hardness (Brinell):	370 maximum 310 minimum

3.5.
Impact Charpy Tests (See 9.3.1.)

Impact strength (CVN) at -50^{o}C in accordance with the following table :-

Table 3

Test orientation		Transverse		Longitudinal
Cylinder diameter		> 140		< 140
Min design wall thickness (mm)	3 to 5	> 5 to 7.5	> 7.5 to 10	3 to 5
Test temperature 0 C	- 50	-50	-50	-50
Charpy Impact **A** Strength J/cm^2	30	35	40	60

A - Absolute minimum acceptance value of the average of three specimens.

4. CYLINDER DESIGN

4.1 General requirements

Permissible designs according to this Specification are restricted to cylinders having a base of concave or convex shape, head of hemispherical shape, and a single neck opening. (See Figure 1).

4.2 Nomenclature (see Figure 1)

t	=	minimum cylinder wall thickness (mm) - to resist internal pressure and external forces due to normal handling, but excluding any additional thickness for corrosion and other influences.
D_o	=	external diameter of cylinder (mm)
D_i	=	internal diameter of cylinder (mm)
P_1	=	test pressure (bar)
p	=	pressure (bar) developed by gaseous contents at reference temperature
P_f	=	settled filling pressure at 15^o C (bar)
T_k	=	minimum thickness of base at knuckle (mm)
T_c	=	minimum thickness of base in centre region (mm)
L_t	=	minimum length of wall/base transition taper (mm)
T_t	=	minimum thickness at bottom of transition taper (mm)
R_k	=	minimum internal knuckle radius of base (mm)
C	=	minimum concave depth of concave base (mm)
H	=	minimum outside height of domed part of convex base (mm)
D_S	=	diameter of standing circle of concave base (mm)
T_S	=	minimum thickness at junction of shoulder and neck (mm)
T_N	=	minimum thickness of neck (mm)
f_e	=	maximum permissible equivalent stress (N/mm^2) at test pressure
Y	=	minimum specified yield stress (N/mm^2)
T	=	minimum specified tensile strength (N/mm^2)
P_d	=	failure pressure (bar)
a	=	actual minimum wall thickness of cylinder (mm)
I_o	=	flaw length of artificial flaw (mm)
R_o	=	cutter tip radius of milling tool for artificial flaw (mm)
d	=	depth of artificial flaw (mm)

4.3 Maximum developed service pressure (p)

The maximum developed pressure in service (p) shall not exceed 85% of the test pressure P_1. The maximum developed service pressure shall be established from BS 5355 for the intended gaseous content.

4.4 Test pressure (P_1)

The test pressure P_1 shall be the design pressure. The test pressure shall be a minimum of 1.5 times the filling pressure P_f, and shall also comply with the requirements of Clause 4.3.

4.5 Mechanical properties for design

The mechanical properties of the cylinder used for design (and guaranteed by the manufacturer as minimum values) shall be:

$Y = 962\ N/mm^2$
$T = 1069\ N/mm^2$ the corresponding ratio Y/T is 0.90.

4.6 Design stress at test pressure

The design stress at test pressure shall be: $f_e = 0.75Y$

4.7 Thickness of cylindrical body

Thickness t shall be not less than that from Formula *(1)*.

$$t = \frac{0.3\ P_1\ D_o}{7f_e - 0.4\ P_1} \qquad \textit{formula (1)}$$

except that t shall be not less than:

$$t = 2.48\ \sqrt{Di/T} \qquad \textit{formula (2)}$$

When formula *(2)* applies the value of P_1 shall be not less than that obtained from transposed formula *(1)* putting $t = 2.48\ \sqrt{Di/T}$

Note: *Formula (1) is known as the modified Lame-Mises*

4.8 Thickness and profile of base

(1) Minimum thickness T_k through the knuckle standing circle of concave base shall be not less than 2t.

(ii) Minimum thickness T_c through that part of a concave base within the standing circle D_s shall be not less than 2t. For convex base T_c is the minimum thickness through the part of the base contained within the internal knuckle radius R_k which shall not be less than 1.5t.

(iii) For concave bases there shall be a taper transition from side-wall to knuckle of length L_t = 6t minimum, measured from the top of the taper to the point of tangency with the knuckle radius.

(iv) The thickness T_t at the bottom of the taper transition shall be 1.7t minimum for concave bases.

(v) The internal knuckle radius R_k shall not be less than 0.075 D_o.

(vi) The external depth of concave C, measured from the plane through the standing circle to the external centre-base, shall be not less than 0.12 D_o.

(vii) The external height of convex H shall not be less than 0.2 D_o.

4.9 Thickness and profile of convex head (See Figure 1)

(1) The internal surface profile shall be substantially hemispherical.

(ii) Minimum thickness T_s at the junction of the shoulder and the neck-root shall be not less than 1.5t.

4.10 Thickness of neck (See Figure 1)

Thickness of the neck T_n shall be sufficient to withstand valving and pressure-loading without permanent distortion, and in any event shall be not less than t when measured from the outside of the neck to the root of the internal thread.

5. APPROVAL OF DESIGN AND CONSTRUCTION

Before manufacture commences, three copies of detailed design drawings, together with design calculations in accordance with Section 4 of this Specification, and a statement on the method of manufacture (see Section 7), shall be submitted to the Verification Body for approval. Design drawings shall carry an unique identifying number.

No alteration shall be made to the design or method of manufacture after approval, unless such alteration has received prior agreement of the Verification Body.

6. FITTINGS

6.1 Valve Fittings

Valve fittings shall comply with the requirements of BS 341: Part 1, or BS 1319, or other recognised standard as appropriate, in respect of quality and materials.

6.2 Valve protection

Means for attaching valve protection shall be provided on all cylinders having a nominal water capacity greater than 5 litres.

Such means shall not involve welding, brazing or soldering any fitting whatsoever to the cylinder.

7. CYLINDER MANUFACTURING PROCESS

Cylinders shall be made from billets using the process of hot backward extrusion followed by hot drawing, made from tubes using the process of hot spinning or made / from plates using the process of cold deep drawing. /

Closure of the cylinder to form the neck shall be by hot spinning.

8. HEAT TREATMENT

8.1 On completion of the metal forming operations specified in Section 7., each cylinder shall be uniformly heat treated to produce the required mechanical properties.

Quenching shall be in oil or other suitable quenchant, provided the quenching severity produced is similar to that of oils commonly used for this purpose. The cylinder manufacturer shall certify and record the heat treatment process applied to the finished cylinder.
The austenitising temperature once selected and set, shall be controlled within the limits of $\pm$ 10° C. The tempering temperature once selected and set, shall be controlled within the limits of $\pm$ 10° C.

8.2 Steel compositions used for the manufacture of high strength cylinders are likely to possess greater hardenability than ordinary alloy steel cylinder grades such as 5045/1 CM and consequently may be more susceptable to cracking under certain conditions of quenching. Therefore, prior to cylinder production, the manufacturer shall establish, by testing any limiting boundary conditions of quenching outside of which cracking may occur. As part of this testing, the manufacturer shall deliberately explore the boundaries of the quenching process in terms of the steel chemical compositions, within the manufacturers specified range, which promote greatest hardenability, in combination with the conditions of the manufacturers quenching system which gives rise to the greatest quenching rates (such as concentrations of additives in water based quenchants, quenchant degradation, system agitation and quenchant temperature). Examination of the test cylinder for quenchant cracks shall be by Magnetic Particle Inspection. If, as the result of this testing a critical quenching rate for cracking is revealed, the manufacturer shall ensure that in production, controls are set such that a maximum quenching rate, at least 15 ^{0}C per second less than the critical value, is never exceeded.

8.3. The maximum production quenching rate applicable to the specified steel grade, together with the quenching conditions, shall be stated by the manufacturer.

8.4 Regular recorded checks on actual quenching rates shall be made by the manufacturer in relation to the maximum quenching rate.

8.5 The cylinder manufacture shall certify and record the heat treatment process applied to the finished cylinder.

8.6. The austinising temperature once selected and set, shall be controlled within the limits of +/- 10^0C. The tempering temperature once selected and set, shall be controlled within the limits +/- 10^0C.

9. INSPECTIONS AND TESTS

9.1 General

The inspection and testing of cylinders shall be carried out to the satisfaction of the Verification Body, who shall certify that the cylinders comply with the requirements of this Specification.

The purchaser and the Verification Body shall have reasonable access to those parts of the manufacturer's works engaged on the order, for purposes of ensuring that cylinders comply with the requirements of this Specification.

Adequate notification of, and facilities for inspecting and testing shall be provided by the manufacturer to the Verification Body.

9.2 Prototype tests

9.2.1 General Provisions

In addition to production acceptance tests specified in Clauses 9.3 and 9.4, the prototype tests specified in 9.2.2, 9.2.3, 9.2.4 and 9.2.5, are required on all new cylinder designs. A cylinder shall be considered a new design if:

(a) It is manufactured in a different factory.

(b) The shape of base is different (concave or convex).

(c) A change in hydraulic test pressure requires a change in wall thickness. (Where a cylinder is to be used at a lower pressure duty than that for which design approval has been given and prototype testing carried out successfully, it shall not be deemed a new design).

(d) The diameter has changed by more than 5%.

(e) The length of the cylinder has increased by more than 50%. (Cylinders with a length/diameter ratio less than 3 shall not be used as a reference cylinder for any new design with a length/diameter ratio exceeding 3).

The cylinders used for tests 9.2.2, 9.2.3, 9.2.4 and 9.2.5 shall be from the first production batch of the new design, and shall be certified by the manufacturer as being representative of that particular design and manufacturing process.

9.2.2 Dimension check

Longitudinal sections shall be cut from the neck and base of a cylinder of each new design and checked for conformity with the design drawing.

9.2.3 Pressure cycling test

Three cylinders shall be tested. The cylinders shall carry stamp marking in accordance with Section 10. The test shall be carried out using a non-corrosive pressurising fluid. The maximum pressure in the cycle shall either be the design test pressure of the cylinder, or 67% of this value. The minimum test pressure in the cycle shall not exceed 10% of the maximum pressure. The frequency of cycling shall not exceed 15 cycles/minute, and the temperature measured on the outside of the cylinder during the test shall not exceed 50°C.

Acceptance values for the test are:

- 12,000 cycles without failure when the maximum cycle pressure is the design pressure;

or,

- 80,000 cycles without failure when the maximum cycle pressure is 67% of the design test pressure;

Failure shall be construed as leakage from any part of the cylinder other than the neck/pipework joint.

Following attainment of the required number of cycles:

One of the three cylinders shall continue to be pressure cycled to destruction under the same cycle conditions and the number of cycles causing destruction and the mode of failure recorded.

Two of the three cylinders shall be subjected to the hydraulic burst test of 9.2.4.

9.2.4 Hydraulic burst test

Two cylinders which have undergone and attained the acceptance requirements of test 9.2.3 shall be subjected to a hydraulic burst test. The rate of pressurisation shall not exceed 5 bar/second. In the course of the test, the yield pressure, burst pressure, burst mode, and volumetric expansion shall be recorded.

Test acceptance criteria are:

1. The yield pressure shall be equal to or greater than 4/3 times the design test pressure.

2. The burst pressure shall be equal to or greater than 1.6 times the design test pressure.

3. The cylinder shall burst from a point within the sidewall.

4. The cylinder shall remain in one piece after bursting.

9.2.5 Flawed cylinder burst test.

The flawed cylinder burst test is to establish that the failure pressure (P_f) which produces the leak (not a burst) with a flaw of a given size, is greater than a mimimum pressure related to 2/3 x P1 = Ps

9.2.5.1 Flaw geometry

The flaws shall be machined longitudinally, approximately at mid-length of the cylindrical part of the cylinder. The flaws shall be located at minimum wall thickness (t) of the midsection, based on the thickness measurement at four points around the cylinder.
The flaw length l_o shall be the overall length of the cut and shall be equal to:

$$l_o = 1{,}6 \sqrt{D_o \times t}$$

The flaw cutter shall be approximately 12.5 mm thick with an angle of 45° and a tip radius of $0.25 \pm 0{,}025$ mm. The cutter diameter shall be 50 mm for cylinder with diameter D_o less than or equal to 140 mm, 65 to 85 mm for cylinders with D_o greater than 140 mm (a standard CVN cutter is recommended)

Note - The cutter should be sharpened regularly to ensure tip radius meets requirements.

The depth of the flaw shall be adjusted to obtain a leak by hydropressurisation. "Leak" means that the crack will not propagate by more than 10% outside the machined flaw measured on the external surface, i.e. total length not over $1{,}1 \times l_o$.

9.2.5.2 Test procedure.

The test shall be performed by monotonic pressurization or cyclic pressurization as described below:

-Monotonic pressurization to burst

The cylinder shall be pressurized hydrostatically as prescribed in clause 6.1.3 (hydraulic burst test) until pressure is released from the cylinder at the flaw location.

- Cyclic pressurization.

The test shall be performed at pressure Ps x (t/a) as described in clause 6.2.2 (pressure cycling tests) The initial flaw depth shall be at least 0,6 x a.

9.2.5.3 Acceptance criteria.

a) The test result is acceptable only if the following two conditions are simultaneously met:

1) Failure pressure Pf≥ Ps x (t/a)

2) Failure mode is by leak

b) If the failure pressure Pf ≥ Ps x (t/a) causes a leak, a further test may be performed a with less deep flaw γ. In the retest condition a) shall apply

. c) If the failure pressure Pf ≤ Ps x (t/a) causes a burst, a further test may be performed with a deeper flaw γ. In the retest condition a) shall apply.

d) If the failure pressure Pf ≥ Ps x (t/a) causes a burst, the cylinder has failed to meet the test requirements.

9.3 Production sample tests

This category comprises mechanical tests, hydraulic burst tests and dimensional checks other than thickness.

For sampling purposes a 'batch' is defined as a group of containers of the same design, manufactured from the same cast of steel, having undergone the same heat treatment.

9.3.1 Mechanical tests

The following tests shall be carried out on a representative cylinder taken from a batch not exceeding 201 cylinders.

(1) Tensile test

The tensile test specimen shall be made from a strip cut longitudinally from a finished cylinder. The shape and dimensions of the test specimen shall be in

accordance with Clause 6 and Annex C of EN10002-1: Part 1. The cross section shall be a proportion of the wall of the cylinder, the face and back of the test piece comprising the cylinder surfaces as manufactured. The ends only of the test piece may be flattened for gripping purposes.

The tolerance on dimensions for the machined surfaces of the test piece shall be to grade IT9 of BS 4500 : Part 1. The gauge length for test piece and test results shall comply with the requirements specified in Clause 8 of BS EN10002-1: Part 1.

The tensile test shall be carried out as specified in Clause 10 of BS EN10002-1: Part 1. If the thickness of the test piece, as measured over the surface of the cylinder is found to vary, the minimum value shall be taken for calculations.

The tensile testing machine shall be maintained to grade A of BS1610.

The results obtained for yield stress, tensile strength, and elongation shall meet the requirements of Section 3.4 of this Specification.

(2) Bend tests

Cold bend tests shall be made on four strips cut from the cylinder. The strips shall be taken from a ring (or two rings if one is insufficient) cut from the cylinder. The width of the test specimens shall be 25 mm or four times the design thickness of the cylinder (including any corrosion allowance) whichever is the greater.

The test pieces shall not be machined on the surfaces corresponding to the outside and inside of the cylinder, but the cut edges may be rounded off to a radius approximately 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 Section 3.4 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 cylinder 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.

(3) Impact tests

Three longitudinal and three transverse Charpy V-notch specimens shall be prepared and tested at -50°C in accordance with the requirements of BS131: Part 2. Transverse test pieces shall be taken only when cylinder wall thickness and diameter permits. Results of tests shall meet the requirements of Section 3.4 Table 3 of this Specification.

9.3.2 Hydraulic burst test

A hydraulic burst test shall be carried out on a representative cylinder taken from a batch not exceeding 201 cylinders.

The test and acceptance criteria shall be as specified for the prototype burst test in Clause 9.2 of this Specification, but without cycling the cylinder prior to the burst test.

9.3.3 Dimensional checks (other than thickness)

The following dimensional checks shall be carried out at the rate of four cylinders per batch not exceeding 201 cylinders:

(a) Ovality

The difference between maximum and minimum external diameters measured at any cross section on the body of the cylinder shall not exceed 2% of the mean external diameter at that section.

(b) Straightness

The maximum deviation of the cylindrical body of the cylinder from a straight line shall not exceed 3mm per metre length.

(c) Length

The length shall be within the tolerances specified on the design drawing.

(d) Base depth of concavity

The depth of concavity shall be in accordance with that specified on the design drawing.

(e) Height of convexity of base

The height of the convexity of the base shall be in accordance with that specified on the design drawing.

9.4 Production tests on every cylinder

9.4.1 Wall thickness check

The wall thickness of every finished cylinder shall be checked ultrasonically using procedures specified in Appendix II to this Specification. If the wall thickness check is carried out at an earlier stage of production the check on the finished cylinders may be limited to areas where wall thickness reductions have taken place. Wall thickness less than the design minimum thickness specified on the design drawing shall be cause for cylinder rejection.

9.4.2 End thickness check

The base and head thickness of every cylinder shall be checked ultrasonically using procedures specified in Appendix II to this Specification or other equivalent methods approved by the Verification Body (eg mechanical measuring). Base or head thickness less than the design minimum thickness specified on the design drawing shall be cause for cylinder rejection.

9.4.3 Examination for defects

Examination for defects shall be carried out on every finished cylinder using ultrasonic procedures specified in Appendix II to this Specification. A defect of depth exceeding 5% of thickness or exceeding 0.25mm, whichever is the greater, shall be cause for cylinder rejection. However, the defect may be removed and the examination repeated, provided the thickness is rendered not less than that specified on the design drawing.

9.4.4 Hardness test

Each cylinder after final heat treatment shall be subjected to a hardness test employing a spherical indentor in accordance with BS 240: Part 1.

The diameter of the ball and the applied load shall be in accordance with the requirements of the standard and shall be such as not to damage the cylinder.

The indentation shall be placed on the cylindrical portion of the cylinder. The surface of the cylinder 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 specified on the design drawing.

The hardness values, which shall be recorded, shall be in accordance with Clause 3.4.

9.4.5 Hydraulic proof test

Every cylinder shall be subjected to a hydraulic test.

The test pressure shall be determined by the requirements of Clause 4. No pressure greater than 80% of the test pressure shall have been applied to any cylinders before the test.

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 cylinder to be tested.

Pressure gauges shall comply with the requirements of industrial class 1 of BS 1780: Part 2 .

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 cylinder connected to it shall be such as to avoid trapping air in the system.

Note: More than one cylinder 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, when applied to the cylinder(s) it shall not be exceeded by more than 3% or 10 bar, whichever is the lower.

On attaining the test pressure the cylinder(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 cylinder(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 cylinder(s) retested.

The interior of each cylinder shall be thoroughly dried by a suitable method immediately after hydraulic testing. Cylinder shall not be heated above 350°C.

9.4.6 Tightness test.

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

9.4.7 Water capacity check

The water capacity of each cylinder shall be checked and recorded. This shall be done by weighing, by filling the cylinder with a calibrated volume liquid, or by other means approved by the Verification Body, in order to ensure compliance with the required water capacity in the design drawing.

9.4.8 Visual Inspection

After removal of the oxide layer, by shot blasting or equivalent means, each finished cylinder shall be visually inspected, internally and externally, for

flaws, surface condition, surface contour, neck threads, and stamping marks (see Clause 10).

If, in the judgement of the Verification Body a cylinder fails to meet the standards required by this Specification, it shall be rectified or rejected.

9.4.9 Record of tests

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

10. STAMP MARKING OF CYLINDERS

10.1 Information to be marked

Each cylinder that complies with the requirements of this Specification shall be permanently and legibly marked with the following information:

(a) The manufacturer's mark and cylinder serial number.

(b) The test pressure (bar) and date of hydraulic test, indicated by the month and year or by the year with a symbol denoting the quarter of the year, and the identification mark of the person or company who conducted the test.

(c) The identification mark(s) of the Verification Body.

(d) The number of this Specification, ie HSE- SSGC-1.

(e) The design water capacity of the cylinder as specified on the design drawing (L).

(f) The weight of the container, including permanent fittings only (kg).

(g) The settled filling pressure at 15^{o}C (bar).

With the exception of item (c), all of the above markings shall be made by the cylinder manufacturer.

10.2 Position and size of marking

The manufacturer's mark shall be either on the base or head of the cylinder (or both). All other marks shall be on the head.

No permanent marking shall be made on the body of the cylinder, but shall be at areas on the head and base where the thickness of the material is adequate for marking to be carried out.

To verify the adequacy for marking of metal thickness at the cylinder ends, a prototype cylinder shall be sectioned and examined after marking. The marking shall cause no change in contour of the cylinder ends.

The marked characters shall normally be at least 6mm high where space permits. On small cylinders the character height may be reduced, but shall not be less than 3mm.

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APPENDIX 1A

Specimen design certificate for seamless steel gas cylinders

Certificate No ..... Customer ..... Date .....

Manufacturer ..... Specification .....

Order No. (Customer .....
(Manufacturer .....

Gas .....

Serial No(s) (Customer ..... Quantity ordered .....
(Manufacturer .....

Minimum specified yield stress ..... Minimum specified tensile strength .....

Drawing	Test Pressure	Min Thickness		External Diameter	Nominal Length without cap or valve	Water Cap Nominal/min *	Weight		
		Cyl.shell	Base				min.*	max.*	nom.*
	bar	mm	mm	mm	mm	L	kg	kg	kg

*Delete as appropriate

Identification marks stamped on the cylinder shoulder

(a) manufacturer's marks
(b) the number of this Specification
(c) filling pressure at 15ºC
(d) date of hydraulic test
(e) Verification Body's mark(s)
(f) test pressure
(g) customer's mark(s) (if any)
(h) cylinder serial number
(1) weight of cylinder without valve

APPENDIX 1B

Specimen certificate for water capacity, weight and material

Water capacity and weight

Water capacity between ..... and .....L.

Weight between ..... and ..... kg

Material

The cylinder in batch(es) ..... were manufactured from the following cast(s) of steel:

Steelmaker: .....

Cast	Steel	C	Si	Mn	P	S	Cr	Mo	Ni

APPENDIX 1C

Specimen certificate for mechanical tests

Batch No	Steel Code	Test piece dimensions	Upper yield stress or 0.2% proof stress	Tensile strength	Elongation
		mm	N/mm^2	N/mm^2	%
Bend tests satisfactory at					

For and on behalf of the manufacturer

.....

for and on behalf of the Verification Body

.....

APPENDIX 1D

Specimen Acceptance Certificate for Seamless Steel Gas Cylinders

Manufacturer ..... Date .....

Customer ..... Spec

Size ..... Verification Body

Gas ..... Man. order no. .....

Ser. No(s). (Customer .....
(Manufacturer .....

Customer's order no. .....

Batch No(s) .....

We hereby certify that the cylinders produced to design certificate number ..... comply with the following requirements.

Minimum cylindrical shell thickness

The wall thickness of all cylinders 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

Temper at .....°C

Hydraulic pressure tests

Each cylinder has been proof tested to a pressure of ..... bar and found to be satisfactory.

Date of press test.

Ultrasonic test

Each cylinder has been ultrasonically examined on the parallel walls to a 5% standard and found to be satisfactory.

APPENDIX II

Ultrasonic defect detection and thickness measurement

II.1 Defect detection

II.1.1 General

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

Cylinders shall be tested for defects in the parallel walls.

II.1.2 Surface condition

Both the surface and the reflecting surfaces of the cylinder shall be clean and free from any materials that will interfere with the test, eg loose scale.

II.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 II.1.6.

II.1.4 Couplant

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

II.1.5 Calibration standards

II.1.5.1 A calibration standard of a convenient length shall be prepared from a cylinder of similar diameter and wall thickness, material surface finish and metallurgical condition to the cylinder to be inspected. The calibration standard shall be free from discontinuities which may interfere with the detection of the reference notches

II.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 25mm of each other but the pairs of notches on the inner and outer surfaces shall be separated by at least 50mm along the axis of the standard.

The standard notches shall be 25 $\pm$. 0.25 long and their width shall not be more than twice the nominal depth. The notch depth shall be 5% of the minimum wall thickness or 0.25mm, whichever is the greater. The tolerance on depth shall be $\pm$ 10% of the nominal notch depth. 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.

II.1.6 Calibration of equipment

Using the calibration standard specified in II.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 during the inspection of the cylinder.

II.1.7 Frequency

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

II.1.8 Procedure

The cylinder 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 cylinder surface will be described. The speed of rotation and translation shall be constant within $\pm$ 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 cylinder 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 cylinders have been tested. If during this check the presence of the appropriate notch is not indicated, then all cylinders tested subsequent to the last acceptable calibration shall be retested after recalibration has been accomplished.

II.1.9 Assessment of results

Any cylinder 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 than after correction the cylinder shall be re-subjected to ultrasonic defect detection and thickness measurement.

Cylinders continuing to show defect indications at points of minimum design thickness shall be deemed not to comply with the requirements of this specification.

II.2 Thickness measurement

II.2.1 General

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

(a) on the base and head;

(b) on the parallel body; and

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

II.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, eg loose scale.

II.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 $\pm$ 2.5% of the set value.

II.2.4 Couplant

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

II.2.5 Calibration standards

Where possible a calibration standard, of similar diameter, material surface finish and metallurgical condition to the cylinders 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.

II.2.6 Calibration of equipment

Using the calibration standard specified in II.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 cylinder.

II.2.7 Frequency

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

II.2.8 Procedure

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

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

II.2.9 Assessment of results

All cylinders 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 cylinder that is shown to be below the minimum wall thickness shown on the manufacturer's drawing shall be deemed not to comply with the requirements of this specification.

APPENDIX III

Periodic Inspection and Testing

In-service inspection and testing may be carried out in accordance with the basic requirements of British Standard BS5430 : Part 1 "Periodic Inspection testing and maintenance of transportable gas containers for seamless steel containers." The duties concerning the in-service inspection of cylinders is covered under the requirements of *Part 3 of " The Carriage of Dangerous Goods (Classification,Packaging and Labelling) and Use of Transportable Pressure Receptacles Regulations 1996. SI 2092 "*. Because of this high strength, high pressure application, it is noted that it is the duty of the "Owner" of the container in conjunction with the "Competent Person" to establish a suitable scheme for the periodic in-service inspection for this containers and that a more stringent examination scheme may be required.