

ISSUE 1

HSE APPROVED SPECIFICATION

Specification DOT-4BA(HSE)

Welded steel cylinders made of definitely prescribed steels

January 1997

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1. Type, size and service pressure.

1.1. Cylinders may be spherical or cylindrical in shape. Closures made by the spinning process are not authorised.

1.2. Spherical type cylinders must be made from two seamless hemispheres joined by the welding of one circumferential seam.

1.3. Cylindrical type cylinders must be of circumferentially welded construction.

1.4. The capacity of the cylinder must not exceed 454 kg (1000 pounds) water capacity (nominal).

1.5. Service pressure at least 15.51 Bar g (225 p.s.i.g.) and not over 34.48 Bar g (500 p.s.i.g.). Developed pressure of the contents according to BS 5355 must not exceed the test pressure.

2. Certificate of compliance

The Inspection Body approved by the HSE shall certify that the manufacture, inspection and testing of the cylinders was carried out in compliance with the requirements of this specification.

Note: A suitable form of certificate is shown in Appendix 1.

3. Duties of inspector

3.1 Inspect all material and reject any not complying with requirements of this specification.

3.2 Verify chemical analysis of each heat of materials by analysis or by obtaining certified analysis: Provided, that a certificate from the manufacturer thereof, giving sufficient data to indicate compliance with requirements is acceptable when verified by check analyses of samples, taken from one cylinder out of each lot of 200 or less.

3.3. Verify compliance of cylinders with specification requirements including: markings; condition of inside; tests; threads; heat treatment. Obtain samples for all tests, and check chemical analysis, witness all tests; report volumetric capacity, tare weight (see report form) and minimum thickness of wall noted and recorded.

3.4. Furnish complete test reports required by this specification to the maker of the cylinder and, upon request, to the purchaser. The test report shall be retained by the inspector for fifteen years from the original test date of the cylinder.

4. Authorised steel

4.1. Table I

Designation	Chemical composition, percent-ladle analysis		
	Grade 1 ⁽¹⁾	Grade 2 ⁽¹²⁾	Grade 3 ⁽²⁴⁵⁾
Carbon	0.10/0.20	0.24 maximum	0.22 maximum
Manganese	1.10/1.60	0.50/1.00	1.25 maximum
Phosphorus, maximum	0.04	0.04	0.045 ⁽⁶⁾
Sulphur, maximum	0.05	0.05	0.05
Silicon	0.15/0.30	0.30 maximum	
Copper, maximum	0.4		
Niobium		0.01/0.04	
Heat treatment authorised	⁽³⁾	⁽³⁾	⁽³⁾
Maximum stress (N/mm ²)	240	240	240

- 1 Addition of other elements to obtain alloying effect is not authorised.
- 2 Ferritic grain size 6 or finer according to ASTM E112-63
- 3 Any suitable heat treatment in excess of 593°C (1100°F), except that liquid quenching is not permitted.
- 4 Other alloying elements may be added and shall be reported.
- 5 For compositions with a maximum carbon content of 0.15 % of ladle analysis, the maximum limit for manganese on ladle analysis may be 1.4%.
- 6 Rephosphorized Grade 3 steels containing no more than 0.15% phosphorus are permitted if carbon content does not exceed 0.15% and manganese does not exceed 1%.

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4.2. Check analysis tolerance.

[A heat of steel made under any of the above grades, the ladle analysis of which is slightly out of the specified range is acceptable if the check analysis is within the following variation:]

Element	Limit or maximum specified (%)	Tolerance (%) over the maximum limit or under the minimum limit	
		Under minimum limit	Over maximum limit
Carbon	To 0.15 inclusive	0.02	0.03
	Over 0.15 to 0.40 inclusive	0.03	0.04
Manganese	To 0.60 inclusive	0.03	0.03
	Over 0.60 to 1.15 inclusive	0.04	0.04
	Over 1.15 to 2.50 inclusive	0.05	0.05
Phosphorus ⁷	All ranges		0.01
Sulphur	All ranges		0.01
Silicon	To 0.30 inclusive	0.02	0.03
	Over 0.30 to 1.00 inclusive	0.05	0.05
Copper	To 1.0 inclusive	0.03	0.03
	Over 1.00 to 2.00 inclusive	0.05	0.05
Nickel	To 1.0 inclusive	0.03	0.03
	Over 1.00 to 2.00 inclusive	0.05	0.05
Chromium	To 0.90 inclusive	0.03	0.03
	Over 0.90 to 2.10 inclusive	0.05	0.05
Molybdenum	To 0.20 inclusive	0.01	0.01
	Over 0.20 to 0.40 inclusive	0.02	0.02
Zirconium	All ranges	0.01	0.05
Niobium	To 0.04 inclusive	0.005	0.01
Aluminium	Over 0.10 to 0.20 inclusive	0.04	0.04
	Over 0.20 to 0.30 inclusive	0.05	0.05

⁷ Rephosphorized steel not subject to check analysis for phosphorus.

5. Identification of material

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(a) Any suitable method except that plates and billets for hot drawn cylinders shall be marked with the heat number.

6. Defects

Material with seams, cracks, laminations or other detrimental defects, not authorised.

7. Manufacture

7.1. By suitable appliances and methods; dirt and scale to be removed as necessary to afford proper inspection; no defect acceptable that is likely to weaken the finished cylinder appreciably; reasonably smooth and uniform surface required. Exposed bottom welds on cylinders over 460 mm (18 inches) long shall be protected by footrings. Minimum thickness of heads shall be not less than 90 percent of the required thickness of the side wall.

7.2. Circumferential seams are by welding.

7.3. Longitudinal seams in heads not permitted.

7.4. Welding procedures and operators shall be qualified in accordance with CGA Pamphlet C-3.

8. Welding of attachments

The attachment to the tops and bottoms only of cylinders by welding of neckrings, footrings, handles, bosses, pads and valve protection rings is authorised provided that such attachments and the portion of the container to which they are attached are made of weldable steel, the carbon content of which shall not exceed 0.25 percent.

9. Wall thickness

9.1. For outside diameters over 150 mm (6 inches) the minimum wall thickness shall be 2 mm (0.078 inch).

9.2. In any case the minimum wall thickness shall be such that the calculated wall stress at minimum test pressure shall not exceed the lesser value of any of the following:

- (1) The value shown in Table I, for the particular material under consideration.
- (2) One-half of the minimum tensile strength of the material determined as required in section 14.

The measured wall thickness shall not include galvanising or other protective coating.

9.3. Cylinders that are cylindrical in shape must have the wall stress calculated by the formula:

$$S = [P (1.3D^2 + 0.4d^2)] / (D^2 - d^2)$$

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S = wall stress, N/mm² (p.s.i.),

P = minimum test pressure prescribed for water jacket test, N/mm² (p.s.i.)

D = outside diameter, mm (inches),

d = inside diameter, mm (inches),

9.4. Cylinders that are spherical in shape must have the wall stress calculated by the formula:

$$S=PD/4tE$$

Where:

S = wall stress N/mm² (p.s.i.),

P = minimum test pressure prescribed for water jacket test;N/mm² (p.s.i.),

D = outside diameter mm (inches),

t = minimum wall thickness mm (inches),

E= 0.85 (provides 85 per cent weld efficiency factor which must be applied in the girth weld area and heat affected zones which zone shall extend a distance of 6 times wall thickness from centre line of weld);

E = 1.0 (for all other areas).

9.5. For a cylinder with a wall thickness less than 2.5 mm (0.1 inch), the ratio of tangential length to outside diameter shall not exceed 4:1.

10. Heat treatment

10.1. Each cylinder shall be uniformly and properly heat treated prior to test by the applicable method shown in **Table 1**. Heat treatment shall be accomplished after all forming and welding operations.

10.2. Heat treatment is not required after welding weldable low carbon parts to attachments of similar material which have been previously welded to the top or bottom of cylinders and properly heat treated, provided such subsequent welding does not produce a temperature in excess of 205°C (400°F) in any part of the top or bottom material.

11. Openings in cylinders

11.1. Any opening must be placed on other than a cylindrical surface.

11.2. Each opening in a spherical type cylinder must be provided with a fitting, boss, or pad of weldable steel securely attached to the container by fusion welding.

11.3. Each opening in a cylindrical type cylinder must be provided with a fitting, boss, or pad, securely attached to container by welding.

11.4. If threads are used, they must comply with the following:

(a) Threads must be clean-cut, even, without checks and tapped to gauge.

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(b) Taper threads to be of length not less than as specified for American Standard taper pipe threads.

(c) Straight threads, having at least 4 engaged threads, to have tight fit and calculated shear strength at least 10 times the test pressure of the cylinder; gaskets required, adequate to prevent leakage.

12. Safety relief devices and protection for valves, safety devices and other connections, if applied

12.1. General Requirements

No pressure relief device shall be fitted to a container intended for the conveyance of toxic gases, but a pressure relief device may be fitted to a container intended for the conveyance of non-toxic gases.

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

All pressure relief devices shall be so designed and fitted as to ensure that the cooling effect of the contents of the container during discharge shall not prevent the effective operation of the devices.

The outlets from all pressure relief devices shall be so sited that free discharge from the devices is not impaired.

The outlets from all pressure relief devices shall be so designed and constructed as to prevent the collection of moisture or other foreign matter that could adversely affect the performance of the devices.

12.2. Pressure Relief Valves

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. Discharge from the pressure relief valve shall be obtained at a pressure not greater than the test pressure of the container, except in the case of liquefiable petroleum gas containers for service in the UK.

Where liquefiable petroleum gas containers for service in the UK are fitted with pressure relief valves they shall be set as follows:

- (a) Propane: 26 bar;
- (b) Butane: 21 bar.

12.3. Bursting discs

Bursting discs if fitted, shall be constructed in accordance with BS 2915 and shall be so designed as to ensure that rupture occurs at a pressure not greater than the test pressure of the container except in the case of containers for halons and nitrogen.

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Note. A bursting disc may be fitted to any container intended for the conveyance of non-toxic and non-flammable gases. The pressure at which the 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 disc shall be resistant to vacuum or be fitted with a vacuum support.

12.4. Container valve protection.

Containers charged with flammable, corrosive, or noxious gases, shall have their valves protected by one of the following methods.

12.4.1. By equipping the containers with securely attached metal caps of sufficient strength to protect the valves from damage during transit.

12.4.2. By boxing or crating the containers so as to give proper protection to the valves.

12.4.3. By so constructing the containers that the valve is recessed into the container or otherwise protected so that it will not be subjected to a blow when the container is dropped on a flat surface.

12.4.4. By loading the containers compactly in an upright position and securely bracing in cars or motor vehicles, when loaded by the consignor and to be unloaded by the consignee.

12.4.6. By equipping with valves strong enough to avoid damage during transit for containers containing non liquefied gas under pressure not exceeding 20.7 bar (300 p.s.i.) at 21°C (70°F).

12.5. The protective collar or neck ring must provide protection for the valve and any other fittings against accidental functioning and damage.

13. Hydrostatic test

13.1. By water jacket, or other suitable method, operated so as to obtain accurate data. Pressure gauge must permit readings to accuracy of 1 percent. Expansion gauge shall permit readings of total volumetric expansion to accuracy either of 1 percent or 0.1 cubic centimetre.

13.2. Pressure must be maintained for 30 seconds and sufficiently longer to ensure complete expansion. Any internal pressure applied after heat treatment and previous to the official test shall not exceed 90 percent of the test pressure.

13.3. Permanent volumetric expansion shall not exceed 10 percent of the total volumetric expansion at test pressure.

13.4. Cylinders shall be tested as follows:

13.4.1. At least 1 cylinder selected at random out of each lot of 200 or less shall be tested as outlined in paragraphs 13.1., 13.2., and 13.3. of this section to at least two times service pressure.

13.4.2. All cylinders not tested as outlined in paragraph 13.4.1. of this section shall be examined under pressure of at least two times service pressure and show no defect.

14. Physical tests

14.1. Prototype Fatigue Test

Each new design to this specification shall comply with 14.2.

For the purpose of this specification, a container shall be considered a new design when one of the following applies:

- (a) it is manufactured at a different factory;
- (b) it is manufactured by a different process;
- (c) it is given a different heat treatment;
- (d) the base profile and base thickness have changed relative to the container diameter and calculated wall thickness
- (e) the specified minimum yield stress has changed by more than 50 N/mm²;
- (f) the length of the container has increased by more than 50%;
- (g) the diameter has changed by more than 5%;
- (h) a change in hydraulic test pressure has caused a change in wall thickness (a container used for a duty requiring a lower test pressure than that for which the design approval has been given shall not be deemed to be of a new design).

14.2. Pressure Cycling Test

Three cylinders from the first batch or production run made to a new design shall be submitted to the pressure cycling tests. The containers shall be certified by the manufacturer to be representative of his design and manufacturing procedure.

The tests shall be carried out using a non-corrosive fluid with a range of pressure equivalent to either the test pressure or the charging 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.

The containers shall be considered to have passed the test if they satisfactory complete, without any sign of leakage, either;

12000 cycles over a range equivalent to 0.9 x test pressure; or
80000 cycles over a range equivalent to 0.6 x test pressure.

14.3. Fracture Mechanics Assessment.

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As an alternative to the prototype fatigue test, as specified in 14.2., a fracture mechanics assessment may be made to illustrate that defect growth due to fatigue will not reduce the integrity of the cylinder. Once material properties have been found it should be demonstrated that the maximum allowable defect size will not grow to the Critical Crack Size in 100 000 cycles of filling, emptying and testing.

14.4. Mechanical Tests.

14.4.1. To determine yield strength, tensile strength, elongation, and reduction of area of material. Required on 2 specimens cut from one cylinder or part thereof having passed the hydrostatic test and heat treated as required, taken at random out of each lot of 200 or less. Physical test for spheres required on 2 specimens cut from flat representative sample plate of the same heat taken at random from the steel used to produce the sphere. This flat steel from which 2 specimens are to be cut must receive the same heat treatment as the spheres themselves. Sample plates to be taken for each lot of 200 or less spheres.

14.4.2. Specimens shall be: Gauge length 200 mm (8 inches) with width not over 38 mm (1.5 inches); or gauge length 50 mm (2 inches) with width not over 38 mm (1.5 inches), provided, that gauge length at least 24 times thickness with width not over 6 times thickness is authorised when cylinder wall is not over 4.8 mm (0.1875 inches) thick. The specimen exclusive of grip ends, shall not be flattened. Grip ends may be flattened to within 25.4mm (1 inch) of each end of the reduced section. When size of cylinder does not permit securing straight specimens, the specimens may be taken in any location or direction and may be straightened or flattened cold, by pressure only, not by blows; when specimens are so taken and prepared, the inspector's report must show in connection with record of physical tests detailed information in regard to such specimens. Heating of specimens for any purpose is not authorised.

14.4.3. The yield strength in tension shall be the stress corresponding to a permanent strain of 0.2 percent of the gauge length.

14.4.4. The yield strength shall be determined by either the "off-set" method or the "extension under load" method as prescribed in ASTM Standard E8-78.

14.4.5. In using the "extension under load" method, the total strain (or "extension under load"), corresponding to the stress at which the 0.2 % permanent strain occurs may be determined with sufficient accuracy by calculating the elastic extension of the gauge length under appropriate load and adding thereto 0.2 percent of the gauge length. Elastic extension calculations shall be based on an elastic modulus of 206.8×10^9 N/m² (30×10^6 p.s.i.). In the event of controversy, the entire stress-strain diagram shall be plotted and the yield strength determined from the 0.2% offset.

14.4.6. For the purpose of strain measurement, the initial strain reference shall be set while the specimen is under a stress of 83 N/mm² (12000 p.s.i.), the strain indicator reading being set at the calculated corresponding strain.

14.4.7. Cross-head speed of the testing machine shall not exceed 3.2 mm (0.125 inch) per minute during yield strength determination.

15. Elongation

Physical test specimens shall show at least 20 percent except that these elongation percentages may be reduced numerically by 1 for each 52 N/mm² (7500 p.s.i.) increment of tensile strength above 345 N/mm² (50000 p.s.i.) to a maximum of four increments.

16. Test of welds

16.1. Tensile test.

A specimen shall be cut from one cylinder of each lot of 200 or less. The specimen shall be taken across the major seam and shall be prepared and tested in accordance with and shall meet the requirements of CGA Pamphlet C-3.

Should this specimen fail to meet the requirements, specimens may be taken from two additional cylinders or welded test plates from the same lot and tested. If either of the latter specimens fail to meet the requirements, the entire lot represented shall be rejected.

16.2. Guided bend test.

A "root bend" test specimen shall be cut from the cylinder used for the tensile test specified in section 16.1. Specimens shall be taken across the major seam and shall be prepared and tested in accordance with and shall meet the requirements of CGA Pamphlet C-3.

16.3. Alternate guided bend test.

This test may be used and shall be as required by CGA Pamphlet C-3. The specimen shall be bent until the elongation at the outer surface, adjacent to the root of the weld, between the lightly scribed gauge lines a. to b., shall be at least 20 percent, except that this percentage may be reduced for steels having a tensile strength in excess of 345 N/mm² (50000 p.s.i.), as provided in clause 15.

17 Rejected cylinders

Reheat treatment authorised; subsequent thereto, acceptable cylinders shall pass all prescribed tests. Repair of welded seams by welding is authorised provided that all defective metal be cut away and joint be rewelded as prescribed for original welded joints.

18 Marking

18.1. Marking on each cylinder stamped as follows:

18.1.1. DOT-4BA(HSE) followed by the service pressure (for example, DOT-4BA(HSE) 20.7 bar [300 p.s.i.] etc.).

18.1.2. A serial number and identification of the maker.

18.1.3. An Authorised Inspection Body's official mark.

18.1.4. Date of test (for example, 12-94 for December 1994).

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18.1.5. Additional markings are permitted.

18.2. Sequence of marks.

Serial number shall be just below or immediately following the DOT(HSE-MT) marks; inspector's official mark shall be near the serial number. Date of test shall be so placed that dates of subsequent test can easily be added. Symbol preceding or following the serial number, with space between, or symbol and serial number stamped into welded or brazed-on valve boss directly above the DOT(HSE) mark located on head of cylinder are also authorised. Other variations in sequence of marks authorised only when necessitated by lack of space.

18.3. Location of markings.

Markings shall be stamped plainly and permanently in the following locations on the cylinder:

18.3.1. On shoulders and top heads when they are not less than 2.2 mm (0.087 inch) thick.

18.3.2. On a metal plate attached to the top of the cylinder or permanent part thereof: sufficient space shall be left on the plate to provide for stamping at least six retest dates; the plate must be at least 1.6 mm (0.0625 inch) thick and shall be attached by welding, along all the edges of the plate.

18.3.3. On the neck, valve boss, valve protection sleeve, or similar part permanently attached to the top of the cylinder.

18.3.4. On the footing permanently attached to the cylinder, provided the water capacity of the cylinder does not exceed 11 kg (25 pounds).

18.4. Size of marks.

Space permitting, at least 6 mm (0.25 inch) high.

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APPENDIX 1.

Inspector's report

(a) Required to be clear, legible and in following form:

(Place) _____
(Date) _____

Steel gas cylinders

Manufactured for _____ Company
Location at _____
Manufactured by _____ Company
Location at _____
Consigned to _____ Company
Location at _____
Quantity _____
Size _____ mm (inches) outside diameter
by _____ mm (inches) long

Marks stamped into the (location of marking) of the cylinder are:

Specification DOT 4BA(HSE)
Serial numbers _____ to _____ inclusive
Inspector's mark _____
Identifying symbol (registered) _____
Test date _____
Tare weights (yes or no) _____
Other marks _____

These cylinders were made by process of

The material used was type _____ authorised in Table I of Spec. No. 4BA(HSE)

The material used was identified by the following _____ (heat-purchase order) _____ numbers.

The material used was verified as to chemical analysis and record thereof is attached. The heat numbers _____ (were--were not) marked on the material.

All material was inspected and all that was accepted was found free from seams, cracks, laminations, and other defects which would reduce the integrity of the material.

The compliance of the cylinders with specification requirements was verified including markings, condition of inside, tests, threads etc. All cylinders with defects which reduced the integrity were rejected. The process of manufacture and heat treatment were supervised and found to be efficient and satisfactory.

The cylinder walls were measured and the minimum thickness noted was _____ mm (inch).

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The outside diameter was determined by a close approximation to be ____ mm (inch). The wall stress was calculated to be ____ N/mm² (pounds per square inch) under an internal pressure of _____ bar (pounds per square inch).

Hydrostatic tests, tensile tests of material and other tests as prescribed in specification DOT-4BA (HSE) were made in the presence of the inspector and all cylinders accepted were found to be in compliance with the requirements of that specification. Records thereof are attached.

Each cylinder _____ (has-has not) been equipped with safety devices as follows:-
_____.

I hereby certify that all of these cylinders proved satisfactory in every way and comply with the requirements of this specification.

(Manufacturer's name)

(Signed) _____
(Inspector)

By: _____

(Place)
(Date)

RECORD OF CHEMICAL ANALYSIS OF STEEL FOR CYLINDERS

Numbered to inclusive
Size mm (inch) outside diameter by mm (inch) long
Made by Company
For Company

Test No.	Heat No.	Check analysis No.	Cylinders represented (serial No.s)	Chemical analysis													
				C	P	S	Si	Mn	Ni	Cr	Mo	Cu	Al	Zr			

Steel was manufactured by Company.
The original of the certified mill test reports are in files of the manufacturer.
Note: Any omission of analyses by heats, if authorised, must be accounted for by notation hereon reading "The prescribed certificate of the manufacturer of material has been secured, found satisfactory, and placed on file", or by attaching a copy of the certificate.

Chemical analyses were made by: (Place)
(Date)

RECORD OF PHYSICAL TESTS OF MATERIAL FOR CYLINDERS

Numbered to inclusive
 Size mm (inch) outside diameter by mm (inch) long
 Made by Company
 For Company

Test No.	Cylinders represented by test (serial No.s)	Yield strength (N/mm ²) [p.s.i.]	Tensile strength (N/mm ²) [p.s.i.]	Elongation (percent)	Reduction of area (percent)	Weld tensile test	Weld bend test
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(Signed)
 (Place)
 (Date)

RECORD OF HYDROSTATIC TESTS ON CYLINDERS

Numbered to inclusive
 Size mm (inch) outside diameter by mm (inch) long
 Made by Company
 For Company

Serial No.s of cylinders tested arranged numerically	Actual test pressure (bar) [p.s.i.]	Total expansion (cubic centimetres) ¹	Permanent expansion (cubic centimetres) ¹	Percent ratio of permanent expansion to total expansion ¹	Tare weight (kg) ² [pounds]	Volumetric capacity ³
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NOTE 1: When specifications require test for only one out of each lot of 200 or less cylinders, the check on the others must be indicated by a notation hereon reading, "Each cylinder was subjected to a pressure of ## bar (p.s.i.) and showed no defect".

¹ If the tests are made by a method involving the measurement of the amount of liquid forced into the cylinder by the test pressure, then the basic data, on which the calculations are made, such as the pump factors, temperature of liquid, coefficient of compressibility of liquid, etc., must also be given.

² Do not include removable cap but state whether with or without valve. These weights must be accurate to a tolerance of 1 percent.

³ Report approximate maximum and minimum volumetric capacity for the lot.

Signed)

19. Report retention

The makers of cylinders under this specification must retain the test reports required by this specification for fifteen years from the original test date of the cylinder.