

HSE APPROVED SPECIFICATION

Specification DOT-4BW(HSE)

**Welded steel cylinders made of definitely prescribed steels
with electric-arc welded longitudinal seam.**

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1. Type, size and service pressure.

Must be welded type with longitudinal electric-arc welded seam not over 450 kg (1000 pounds) water capacity (nominal); 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.). Cylinders closed by spinning process not authorised. This design specification shall not be used for acetylene service.

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 analyses, witness all tests; report volumetric capacity, tare weight (see report form) and minimum thickness of wall noted.

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	0.046
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%.

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.

4.3. Heads

Material for heads shall be the same as 4.1. of this section or shall be open hearth, electric or basic oxygen carbon steel of uniform quality. Content percent for the following not over: Carbon 0.25, Manganese 0.60, Phosphorous 0.045, Sulphur 0.050.

Heads shall be hemispherical or ellipsoidal in shape with a maximum ratio of 2:1. If low carbon steel is used thickness of such heads shall be determined by using a maximum wall stress of 165 N/mm² (24000 p.s.i.) in formula in 9.1.

5. Identification of material

The material of construction shall be identified by a suitable method.

6. Defects

Material with seams, cracks, laminations or other injurious 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. Heads shall be concave to pressure.

7.2. Circumferential seams.

By electric-arc welding. Joints shall be butt with one member offset (joggle butt) or lap with minimum overlap of at least four times nominal sheet thickness.

7.3. Longitudinal seams in shells.

7.3.1. Longitudinal electric-arc welded seams shall be of the butt welded type. Welds shall be made by a machine process including automatic feed and welding guidance mechanisms. Longitudinal seams shall have complete joint penetration, and shall be free from undercuts, overlaps or abrupt ridges or valleys. Misalignment of mating butt edges shall not exceed 1/6 of nominal sheet thickness or 0.8 mm (0.0312 inch) whichever is less. All joints with nominal sheet thickness up to and including 3.2 mm (0.125 inch) shall be tightly butted. When nominal sheet thickness is greater than 3.2 mm (0.125 inch), the joint shall be gapped with maximum distance equal to one-half the nominal sheet thickness of 0.8 mm (0.0312 inch) whichever is less. Joint design, preparation and fit-up shall be such that the requirements of 7.3.3. are satisfied.

7.3.2. Maximum joint efficiency shall be 1.0 when each seam is radiographed completely. Maximum joint efficiency shall be 0.90 when one cylinder from each lot of 50 consecutively welded cylinders is spot radiographed. In addition, one out of the first five cylinders welded following a shut down of welding operations exceeding four hours shall be spot radiographed. Spot radiographs, when required, shall be made of a finished welded cylinder and shall include the girth weld for 50 mm (2 inches) in both directions from the intersection of the

longitudinal and girth welds and include at least 150 mm (6 inches) of the longitudinal weld. Maximum joint efficiency of 0.75 shall be permissible without radiography,

7.3.3. 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).

In any case the minimum wall thickness shall be such that the wall stress calculated by the formula (see Note 1):

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

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.
- (3) 240 N/mm² (35000 p.s.i.).

NOTE 1: In the formula above quoted

S = wall stress, N/mm² (p.s.i.),
P = service pressure, N/mm² (p.s.i.)
D = outside diameter, mm (inches),
d = inside diameter, mm (inches),
E = joint efficiency of the longitudinal seam (from 7.3.2.).

9.2. 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 or brazing 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 or brazing 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. All openings shall be in the heads or bases.

11.2. Openings in cylinders shall be provided with adequate fittings, bosses, or pads, integral with or securely attached to the cylinder by welding.

11.3. Threads shall comply with the following:

- (1) Threads shall be clean cut and to gauge.
- (2) Taper threads shall be of length not less than as specified for American Standard Taper Pipe threads.
- (3) 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.

11.4. Closure of fittings, boss or pads shall be adequate to prevent leakage.

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

12.1. No person may offer a cylinder charged with a compressed gas for transportation unless the cylinder is equipped with one or more pressure relief devices sized and selected as to type, location, and quantity and tested in accordance with CGA Pamphlet S-1.1. The pressure relief device system must be capable of preventing rupture of the normally charged cylinder when subjected to a fire test conducted in accordance with CGA Pamphlet C-14. Cylinders shall not be shipped with leaking safety devices. Safety relief devices shall be tested for leaks before the charged cylinder is shipped from the cylinder filling plant; it is expressly forbidden to repair leaking fuse plug devices, where leak is through the fusible metal or between the fusible metal and the opening in the plug body, (except by removal of the device and replacement of the fusible metal). Exceptions are as follows:

12.1.1. Except as provided in Notes 1, and 3, safety relief devices are not required on cylinders 305 mm (12 inches) or less in length, exclusive of neck, and 114 mm (4.5 inches) or less in outside diameter.

NOTE 1: Safety relief devices are required on cylinders charged with a liquefied gas for which this part requires a service pressure of 125 bar (1800 p.s.i.) or higher.

NOTE 2: Safety relief devices are required on cylinders charged with nonliquefied gases to a pressure of 125 bar (1800 p.s.i.) or higher at 21°C (70°F).

12.1.2. Safety relief devices are not required on cylinders charged with non-liquefied gas under pressure of 20.7 bar (300 p.s.i.) or less at 21°C (70°F).

12.1.3. Safety relief devices are prohibited on cylinders charged with DOT Division 2, 3 or Division 6.1 materials in Hazard Zone A.

12.1.4. Safety relief devices are prohibited on cylinders charged with fluorine.

12.1.5. Safety relief devices are not required on cylinders charged with methyl mercaptan; with mono-, di-, or trimethylamine, anhydrous; with not over 4.5 kg (10 pounds) of nitrosyl chloride; or with less than 75 kg (165 pounds) of anhydrous ammonia

12.1.6. Safety relief devices, if used, must be in the vapour space of cylinders containing pyrophoric liquids.

12.2. Container valve protection.

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

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

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

12.2.3. 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.

12.2.4. 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.

12.2.6. 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).

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 insure 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.

13.5. One finished cylinder selected at random out of each lot of 500 or less successively produced shall be hydrostatically tested to 4 times service pressure without bursting.

14. Physical tests

14.1. Specimens shall be taken from one cylinder after heat treatment and chosen at random from each lot of 200 or less, as follows:

(1) Body specimen. One specimen shall be taken longitudinally from the body section at least 90 degrees away from the weld.

(2) Head specimen. One specimen shall be taken from either head on a cylinder when both heads are made of the same material; however -

(i) If the two heads are made of differing materials, a specimen shall be taken from each head; and

(ii) If due to welded attachments on the top head there is insufficient surface from which to take a specimen, it may be taken from a representative head of the same heat treatment as the test cylinder.

14.2. 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.

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

- 14.3.1. 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.
- 14.3.2. In using the "extension under load" method, the total strain (or "ex-tension 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.
- 14.3.3. 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.
- 14.3.4. 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 40 percent for 50 mm gauge (2 inch) length or at least 20 percent in other cases, except that these elongation percentages may be reduced numerically by 2 for 50 mm (2 inch) specimens and by 1 in other cases 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 longitudinal seam and shall be prepared and tested in accordance with and shall meet the requirements of CGA Pamphlet C-3.

16.2. Guided bend test. A "root" test specimen shall be cut from the cylinder used for the tensile test specified in section 16.1. Specimens shall be taken across the longitudinal 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 15.

17. Radiographic examination

17.1. Radiographic inspection shall conform to the techniques and acceptability criteria set forth in CGA Pamphlet C-3. When fluoroscopic inspection is used, permanent film records need not be retained.

17.2. Should spot radiographic examination fail to meet the requirements of paragraph (a) of this section, two additional welds from the same lot of 50 cylinders or less shall be examined, and if either of these fail to meet the requirements, each cylinder shall be examined as previously outlined; only those passing are acceptable.

18 Rejected cylinders

18.1. Unless otherwise stated, if a sample cylinder or specimen taken from a lot of cylinders fails the prescribed test, then two additional specimens shall be selected from the same lot and subjected to the prescribed test. If either of these fail the test then the entire lot shall be rejected.

18.2. 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.

19 Marking

19.1. Marking on each cylinder stamped as follows:

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

19.1.2. A serial number.

19.1.3. An Authorised Inspector's official mark.

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

19.1.5. Additional markings are permitted.

19.2. Sequence of marks.

Serial number shall be just below or immediately following the DOT(HSE) 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 in front of or following the serial number, with space between, or symbol and serial number stamped into welded or brazed-on valve spud 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.

19.3. Location of markings.

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

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

- 19.3.2. 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, or by brazing. The brazing rod is to melt at a temperature of 590°C (1100°F). Welding or brazing shall be along all the edges of the plate.
- 19.3.3. On the neck, valve boss, valve protection sleeve, or similar part permanently attached to the top of the cylinder.
- 19.3.4. On the footing permanently attached to the cylinder, provided the water capacity of the cylinder does not exceed 11 kg (25 pounds).

19.4. Size of marks.

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

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 4BW(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 _____ (Manufacturer's name)

(Signed) _____

The material used was type _____

authorised in Table I of Spec. No. 4BW(HSE)

(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

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 outside diameter by mm 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	Burst test (bar) [p.s.i.]	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)

20. 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.