Specification DOT-4L(HSE)

Welded Insulated Cylinders

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1.0 Type, size, service pressure and design service temperature.

1.1 A DOT 4L(HSE) cylinder is a fusion welded insulated cylinder with a water capacity (nominal) not over 454 kg (1000 pounds) and a service pressure of at least 2.76 bar (40 p.s.i.g.) but not greater than 34.5 bar (500 p.s.i.g.) conforming to the following requirements:

1.1.1 For liquefied hydrogen service, the cylinders must be designed to stand on end, with the axis of the cylindrical portion vertical.

1.1.2 The design service temperature is the coldest temperature for which a cylinder is suitable. The required design service temperatures for each cryogenic liquid is as follows:

Cryogenic liquid	Design service temperature
Argon	Minus 196^{o}C (320^{0}F) or colder
Helium	Minus 269^{o}C (452^{0}F) or colder
Hydrogen	Minus 253^{o}C (423^{0}F) or colder
Neon	Minus 246^{o}C (411^{0}F) or colder
Nitrogen	Minus 196^{o}C (320^{0}F) or colder
Oxygen	Minus 196^{o}C (320^{0}F) or colder
LNG	Minus 160^{o}C (256^{0} F) or colder

2.0 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.

3.0 Duties of Inspector

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

3.2 Verify chemical analysis of each ' heat ' (cast) 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 analysis 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 interior; tests; threads; heat treatment. Obtain samples for all tests and check chemical analysis; witness all tests; report volumetric capacity; tare weight 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.

4.0 Material.

4.1 Material used in the construction of this specification must conform to the following:

4.1.1 *Inner containment vessel (cylinder).* Designations and limiting chemical compositions of steel authorised by this specification shall be as shown in Table 1, section 17.1

4.1.2 *Outer jacket.* Steel or aluminium may be used subject to the requirements of section 17.2.

5.0 Identification of Material.

Material must be identified by any suitable method.

6.0. Defects

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

7.0 Manufacture.

Cylinders must be manufactured using equipment and processes adequate to ensure that each cylinder produced conforms to the requirements of this sub-part and to the following requirements:

7.1 Dirt and scale to be removed as necessary to afford proper inspection. No defect is permitted that is likely to weaken the finished cylinder appreciably. A reasonably smooth and uniform surface finish is required. The shell portion must be a reasonably true cylinder.

7.2 The heads must be seamless, concave side to the pressure, hemispherical or ellipsoidal in shape with the major diameter not more than twice the minor diameter. Minimum thickness of heads may not be less than 90 percent of the required thickness of the sidewall. The heads must be reasonably true to shape, have no abrupt shape changes and the skirts must be reasonably true to round.

7.3 The surface of the cylinder must be insulated. The insulating material must be non-combustible. The insulation on non-evacuated jackets must be covered with a steel jacket not less than 1.5 mm (0.060-inch) thick or an aluminium jacket not less than 1.75 mm (0.070 inch) thick, so constructed that moisture cannot come in contact with the insulating material. If a vacuum is maintained in the insulation space, the evacuated jacket must be designed for a minimum collapsing pressure of 2 bar (30 p.s.i.g.) differential whether made of steel or aluminium. The construction must be such that the total heat transfer, from the atmosphere at ambient temperature to the contents of the cylinder, will not exceed 0.0005 Btu per hour, per Fahrenheit degree differential in temperature, per pound of water capacity of the cylinder. For hydrogen, cryogenic liquid service, the total heat transfer, with a temperature differential of 271° C (520° F), may not exceed that required to vent 0.83 m^3 (30 SCF) of hydrogen gas per hour.

7.4 For a cylinder having a design service temperature colder than minus 196 ^{o}C (minus 320 ^{0}F), a calculation of the maximum weight of contents must be made and that weight must be marked on the cylinder.

7.5 Welding procedures and operators must be qualified in accordance with CGA Pamphlet C-3. In addition, an impact test of the weld must be performed in accordance with clause 14.5.4. as part of the qualification of each welding procedure and operator.

8.0 Welding.

Welding of the cylinder must be as follows:

8.1 All seams of the cylinder must be fusion welded. Means must be provided for accomplishing complete penetration of the joint. Only butt or joggle butt joints for the cylinder seams are authorised. All joints in the cylinder must have reasonably true alignment.

8.2 All attachments to the sidewalls and heads of the cylinder must be by fusion welding and must be of a weldable material complying with the impact requirements of clause 14.5.4.3.

8.3 For welding the cylinder, each procedure and operator must be qualified in accordance with the sections of CGA Pamphlet C-3 that apply. In addition, impact tests of the weld must be performed in accordance with clause 14.5.4. as part of the qualification of each welding procedure and operator.

8.4 Brazing, soldering and threading are permitted only for joints not made directly to the cylinder body. Threads must comply with the requirements of clause 11.0.

9.0 Wall Thickness.

The minimum wall thickness of the cylinder must be such that the calculated wall stress at the minimum required test pressure may not exceed the least value of the following:

(a) 310 N/mm^2 (45,000 p.s.i.)

(b) One-half of the minimum tensile strength across the welded seam determined in paragraph 14.5.1.

(c) One-half of the minimum tensile strength of the base metal determined as required in paragraph 14.0.

(d) The yield strength of the base metal determined as required in paragraph 14.0.

(e) Further provided that wall stress for cylinders having longitudinal seams may not exceed 85 per cent of the above value, whichever applies.

(f) Calculation must be made by the following formula:

$S=[P(1.3D^2+ 0.4d^2)]/(D^2 - d^2)$
where:
S=wall stress N/mm^2 (p.s.i.),
P=minimum test pressure prescribed for pressure test, N/mm^2 (p.s.i.),
D=outside diameter, mm (inches),
d=inside diameter , mm (inches).

10.0 Heat Treatment.

Heat treatment is not permitted.

11.0 Openings in Cylinder.

Openings in cylinders must conform to the following:

(a) Openings are permitted in heads only, unless otherwise agreed with the Health and || Safety Executive. They must be circular and may not exceed 76mm (3 inches) in diameter or one third of the cylinder diameter, whichever is less. Each opening in the cylinder must be provided with a fitting, boss or pad, either integral with, or securely attached to, the cylinder body by fusion welding. Attachments to a fitting, boss or pad may be made by welding, brazing, mechanical attachment, or threading.

(b) Threads must comply with the following:
(i) Threads must be clean-cut, even, without checks and cut to gauge.
(ii) Taper threads to be of a length not less than that specified for NPT.
(iii) Straight threads must have at least 4 engaged threads, tight fit and calculated shear strength at least 10 times the test pressure of the cylinder. Gaskets, which prevent leakage and are inert to the hazardous material, are required.

12.0 Safety relief devices and protection for valves, safety devices and other connections.

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 valve may be fitted to a container intended for the conveyance of non-toxic gases.

The material 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

Pressure relief valves should 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.

12.3 Bursting Discs

Bursting discs, if fitted, shall be constructed in accordance with CGA pamphlet S-1.1. and shall be so designed as to ensure that rupture occurs at a pressure not greater than the test pressure of the container.

A bursting disc may be fitted to any container intended for the conveyance of non-toxic gases. The pressure at which the bursting disc is designed to rupture shall, where practicable, be stamped on the bursting disc holder.

12.3 Container Valve Protection

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

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

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

12.3.3 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 he container is dropped onto a flat surface.

12.3.4 By loading the containers compactly in an upright position and securely braced in the motor vehicles, when loaded at the consignor and to be unloaded by the consignee.

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

13.0 Pressure Test.

Each cylinder, before insulating and jacketing, must be examined under a pressure of at least 2 times the service pressure maintained for at least 30 seconds without evidence of leakage,

visible distortion or other defect. The pressure gauge must permit reading to an accuracy of 1 per cent.

14.0 Physical Test.

A physical test must be conducted to determine yield strength, tensile strength and elongation as follows:

14.1 The test is required on 2 specimens selected from material of each heat and in the same condition as that in the completed cylinder.

14.2 Specimens must conform to the following:

14.2.1 A gauge length of 203mm (8 inches) with a width not over 38mm (1½ inches), a gauge length of 51mm (2 inches) with width not over 38mm (1½ inches), or a gauge length at least 24 times thickness [authorised when cylinder wall is not over 1.6mm ($^{1}/_{16}$ inch thick)].

14.2.2 The specimen, exclusive of grip ends, may not be flattened. Grip ends may be flattened to within 25 mm (one inch) of each end of the reduced section.

14.2.3 When size of the 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.

14.2.4 Heating of a specimen for any purpose is not authorised.

14..3 The yield strength in tension must be the stress corresponding to a permanent strain of 0.2 percent of the gauge length or for austenitic steel 1% of the gauge length. The following conditions apply:

14.3.1 The yield strength must be determined by either the "offset" method or the "extension under load" method as prescribed in ASTM Standard E8.

14.3.2 In using the "extension under load" method, the total strain (or "extension under load"), corresponding to the stress at which the 0.2 percent permanent strain occurs may be determined with sufficient accuracy by calculating the elastic expansion of the gauge length under appropriate load and adding thereto 0.2 percent of the gauge length. Elastic extension calculations must be based on the elastic modules of the material used. In the event of controversy, the entire stress-strain diagram must be plotted and the yield strength determined from the 0.2 percent offset.

14.3.3 For the purpose of strain measurement, the initial strain reference must be set while the specimen is under a stress of 82.7 N/mm^2 (12,000 p.s.i.) and the strain indicator reading being set at the calculated corresponding strain.

14..3.4 Cross-head speed of the testing machine may not exceed 3.2 mm/min ($^{1}/_{8}$inch/minute) during yield strength determination.

14.4 Acceptable Results for Physical Tests.

Physical properties must meet the limits specified in clause 17.0, Table 2, for the particular steel in the annealed condition. The specimens must show at least a 20 percent elongation for a 50mm (2 inch) gauge length. Except that the percentage may be reduced numerically by 2 for each 51.7 N/mm^2 (7,500 p.s.i.) increment of tensile strength above 689.5 N/mm^2 (100,000 p.s.i.) to a maximum of 5 such increments. Yield strength and tensile strength must meet the requirements of clause 17.0, Table 2.

14. 5. Test of Welds. Welds must be tested as follows:

14.5.1 *Tensile test.* A specimen must be cut from one cylinder of each lot of 200 or less, or welded test plate. The welded test plate must be of one of the heats in the lot of 200 or less which it represents, the same condition and approximately the same thickness as of the representative cylinder batch. The weld must be made by the same procedures as the major weld on the cylinder. The specimen must be taken across the major seam and must be prepared and tested in accordance with and must 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 fails to meet the requirements, the entire lot represented must be rejected.

14.5.2 *Guided bend test.* A "root" bend test specimen must be cut from the cylinder or welded test plate, used for the tensile test specified in clause 14.5.1 and from any other seam or equivalent welded test plate if the seam is welded by a procedure different from that used for the major seam. Specimens must be taken across the particular seam being tested and must be prepared and tested in accordance with and must meet the requirements of CGA Pamphlet C-3.

14.5.3 *Alternate guided-bend test*. This test may be used and must be as specified in CGA Pamphlet C-3. The specimen must 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, is at least 20 percent, except that this percentage may be reduced for steels having a tensile strength in excess of 689 N/mm^2 (100,000 pounds per square inch), as provided in clause 14.4.

14.5.4 *Impact tests*. One set of three impact test specimens (for each test) must be prepared and tested for determining the impact properties of the deposited weld metal:

(i) As part of the qualification of the welding procedure.
(ii) As part of the qualification of the operators.
(iii) For each "heat" of welding rod or wire used.
(iv) For each 308 metres (1,000 feet) of weld made with the same heat of welding rod or wire.

14.5.4.1 All impact test specimens must be of the Charpy type, keyhole or milled U-notch and must conform in all respects to Figure 3 of ASTM E-23-60T. Each set of impact specimens must be taken across the weld and have the notch located in the weld metal. When the cylinder material thickness is 2.5mm or thicker, impact specimens must be cut from a cylinder or welded test plate used for the tensile or bend test specimens. The dimension along the axis of the notch must be reduced to the largest possible of 10mm, 7.5mm, 5mm or

2.5mm, depending upon cylinder thickness. When the material in the cylinder or welded test plate is not of sufficient thickness to prepare a 2.5mm impact test specimens, 2.5mm specimens must be prepared from a welded test plate made from 1.6mm ($^1/_8$ inch) thick material meeting the requirements specified in section 17.1, Table 2, and having a carbon analysis of .05 minimum, but not necessarily from one of the heats used in the lot of cylinders. The test piece must be welded by the same welding procedure as used on the particular cylinder seam being qualified

14.5.4.2 Impact test specimens must be cooled to the design service temperature. The apparatus for testing the specimens must conform to the requirements of ASTM Standard E-23-60T. The test piece, as well as the handling tongs, must be cooled for a length of time sufficient to reach the service temperature. The temperature of the cooling device must be maintained within a range of plus or minus 2°C (3^0 F). The specimen must be quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than six seconds.

14.5.4.3 The impact properties of each set of impact specimens may not be less than the values in the following table:-

Size of Specimen	Minimum impact value required for avg. of each set of three specimens (Nm)	Minimum impact value permitted on one only of a set of three (Nm)
10mm x 10mm	20.30	13.50
10mm x 7.5mm	17.00	11.50
10mm x 5mm	13.50	9.50
10mm x 2.5mm	6.80	4.70

14.5.4.4 When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, the retest of three additional specimens must be made. The value of each of these retest specimens must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest is authorised.

15.0 Radiographic Examination.

Cylinders must be subject to a radiographic examination as follows:

15.1 The techniques and acceptability of radiographic inspection must conform to the standards set forth in CGA Pamphlet C-3.

15.2 One finished longitudinal seam must be selected at random from each lot of 100 or less successively produced and be radiographed throughout its entire length. Should the radiographic examination fail to meet the requirements of clause 15.1, two additional seams of the same lot must be examined, and if either of these fail to meet the requirements of clause 15.1, only those passing are acceptable.

16.0 Rejected cylinders.

Reheat treatment of rejected cylinders is authorised. Subsequent thereto, cylinders must pass all prescribed tests. Welds may be repaired by suitable methods of fusion welding.

17.0 Authorised materials of construction.

Authorised materials of construction are as follows:

17.1 *Inner containment vessel (cylinder).* Electric furnace steel of uniform quality must be used. Chemical analysis must conform to ASTM A240. Type 304 or 321 Stainless Steel.|| A heat of steel made under Table 1 and Table 2 in this clause 17.0 is acceptable, even though its check chemical analysis is slightly out of the specified range, if it is satisfactory in all other respects, provided the tolerances shown in Table 3 in this clause 17.1 are not exceeded. The following chemical analyses and physical properties are authorised:

TABLE 1 - AUTHORISED MATERIALS

Designation	Chemical analysis, limits in percent	
Carbon [1]	0.08 max	
Manganese	2.00 max	
Phosphorus.....	0.045 max	
Sulphur.....	0.030 max	
Silicon.....	1.00 max	
Nickel.....	8.00 - 13.0	||
Chromium.....	17.00 - 20.00	||
Molybdenum.....	None	
Titanium.....	None	
Columbium.....	None	

[1] The carbon analysis must be reported to the nearest hundredth of one percent.

TABLE 2 - PHYSICAL PROPERTIES

Designation	Physical Properties. (Annealed)
Tensile strength, MPa(p.s.i.) (minimum).....	517 (75,000)

Yield strength, MPa (p.s.i.) (minimum).....	207 (30,000)
Elongation in 51mm (2 inches) (minimum) percent	30.0%
Elongation other permissible gauge lengths (minimum) percent	15.0%

TABLE 3 - CHECK ANALYSIS TOLERANCES

Elements	Limit or minimum of specified range (percent)	Tolerance over the maximum limit or under the minimum limit
Carbon	To 0.030, incl	0.005
	Over 0.030 to 0.20, incl.	0.01
Manganese	To 1.00 incl	0.03
	Over 1.00 to 3.00 incl.	0.04
Phosphorus [1]	To 0.040 incl	0.005
	Over 0.040 to 0.20 incl	0.010
Sulphur	To 0 .40 incl	0.01
Silicon	To 1.00 incl	0.05
Nickel	Over 5.00 to 10.00 incl	0.10
	Over 10.00 to 20.00 inc.	0.15
Chromium	Over 15.00 to 20.00 incl	0.20

[1] Re-phosphorized steels not subject to check analysis for phosphorus.

17.2 *Outer jacket.*

17. 2.1. Non-flammable cryogenic liquids. Cylinders intended for use in the transportation of non-flammable cryogenic liquid must have an outer jacket made of steel or aluminium.

17.2.2. Flammable cryogenic liquids. Cylinders intended for use in the transportation of flammable cryogenic liquid must have an outer jacket made of steel.

18.0 Markings.

Markings must be stamped plainly and permanently on shoulder or top head of jacket or on a permanently attached plate or head protective ring. The cylinders shall be marked as follows:

18.1. DOT-4L (HSE) followed by the service pressure [For example, DOT-4L (HSE) 13.8 bar (200psi)].

18.2. The letters "ST", followed by the design service temperature (for example, ST-253ºC), must be marked on cylinders having a design service temperature of colder than minus 196ºC only. Location to be just below the DOT mark.

18.3 The maximum weight of contents, in kg (for example, "Max. Content 51 kg"), must be marked on cylinders having a design service temperature colder than minus 196ºC only. Location to be near symbol.

18.4. Special orientation instructions must be marked on the cylinder (for example, THIS END UP), if the cylinder is used in an orientation other than vertical with openings at the top of the cylinder.

18.5. If the jacket of the cylinder is constructed of aluminium, the letters "AL" must be marked after the service pressure marking. Example : DOT-4L(HSE) --- AL.

18.6. Except for serial number and jacket material designation, each marking prescribed in this clause 18, must be duplicated on each cylinder by any suitable means.

18.7. The serial number; the authorised Inspection Body's mark and the date of the hydraulic test.

18.8. The size of the marking shall be at least 6mm high.

19.0 Inspector's report.

Each inspector shall prepare a report containing, at a minimum, the applicable information listed in CGA Pamphlet C-11. Any additional information or markings that are required by the specification must be shown on the test report. The signature of the inspector on the report certifies that the processes of manufacture and heat treatment of cylinders were observed and found to be satisfactory.

The inspector's reports must contain information on:

(1) The jacket material and insulation type;
(2) The design service temperature (ºC); and
(3) The impact test results, on a lot basis.

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Appendix 1.
Inspector's Report

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

(Place) _____

(Date) _____

Steel Gas Cylinders
Manufactured for _____ Company

Location at _____
Manufactured by _____
Location at _____
Consigned to _____
Location at _____
Quantity _____
Size _____ mm (inches) outside diameter
by _____ mm (inches) long
Cylinders were pressure tested at_____ N/mm^2 (psi) and found to be satisfactory
Maximum and minimum weight _____
Maximum and minimum volumetric capacity _____
Jacket material _____
Insulation type _____
Marks stamped into the (Location of marking) of the cylinder are:
Specification DOT 4L(HSE)
Serial numbers _____ to _____
Design service temperature____ minus _____ ^{o} C
Maximum weight of content _____ Kgs.
Inspector's marks _____
Identifying symbol (registered)
Test date _____
Tare weight (yes or no)
other marks _____
These cylinders were made the process of _____
The material used was authorised by _____
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 hereto. The heat numbers (were - were not) marked on the material.

Test No	Heat No	Check analysis No	Cylinders represented	Chemical analysis C P S Si Mn Ni Cr Cu Al Zr

All material was inspected and all was accepted was found free from seams, cracks, laminations and other injurious defects.

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

The cylinder walls were measured and the minimum thickness was noted to be ___mm. The outside diameter was determined by a close approximation to be _____mm . The wall stress was calculated to be_____ N/mm^2 .

Pressure tests,tensile tests of material, other tests as prescribed in this specification were made in the presence of the inspector and all cylinders accepted were found to be in compliance with the requirements of this specification.

Records thereof are attached herewith.

Signed: .....