HSE
Health & Safety Executive

HSE APPROVED SPECIFICATION

SPECIFICATION FOR LARGE SEAMLESS STEEL (897 to 1069N/mm^2) TRANSPORTABLE GAS CONTAINERS

SPECIFICATION NUMBER CP1-3T

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CONTENTS

1. SCOPE

2. CERTIFICATE OF COMPLIANCE

3. REFERENCES

4. PERMITTED STEEL

5. IDENTIFICATION OF MATERIAL

6. DEFECTS

7. NECK FOLDS

8. MANUFACTURE

9. WELDING OR BRAZING

10 WALL THICKNESS

11. HEAT TREATMENT

12. THREADED OPENINGS

13. RELIEF DEVICES

14. HYDROSTATIC TESTING

15. DIMENSIONAL TOLERANCES

16. MECHANICAL TESTING

17. ULTRASONIC INSPECTION

18. MARKING

APPENDIX 1.

INSPECTORS REPORT

1. SCOPE

This specification details the requirements for the material, design, construction and testing of seamless steel cylinders not less than 450 kg water capacity and service pressure not less than 125 Bar and not over 266 Bar.

These cylinders are permitted for the following non-liquified gases: air, argon, boron triflouride, carbon monoxide, ethane, ethylene, helium, methane, neon, nitrogen, and oxygen. Not to be used for compressed natural gas (CNG).

2. CERTIFICATE OF COMPLIANCE

The approved Inspection Body 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. REFERENCES

BS5045 PART 1 - Specification for seamless steel gas containers above 0.5 litre water capacity.
ASTM Standard E8 - American Society for Testing and Materials (tensile testing).
ASTM Standard A-370 - American Society for Testing and Materials (Charpy impact testing).
A-388-67 - Ultrasonic Inspection
DOT 3T - Seamless Steel Cylinders
CGA-C-1 - Compressed Gas Association Hydrostatic Testing.

4. PERMITTED STEEL

Open-hearth, basic oxygen, or electric steel of uniform quality. The following chemical analysis is permitted:

DESIGNATION	**DOT 178.45, REF: ASTM A372 TYPE VIII.**
Carbon	0.35/0.50
Manganese	0.75/1.05
Phosphorus	0.025 Max.
Sulphur	0.025 Max.
Silicon	0.15/0.35
Chromium	0.80/1.15
Molybdenum	0.15/0.25

5. IDENTIFICATION OF MATERIAL

The material of construction shall be identified by a suitable method, plates and billets for hot-drawn cylinders shall be marked with the heat number.

6. DEFECTS

Materials with seams, cracks, laminations, or other injurious defects, are not permitted.

7. NECK FOLDS

After forging the container ends, the internal surface of the neck and shoulder shall be visually inspected for folds and cracks using appropriate means. e.g. endoscope, introscope, mirror. The surface shall be free from cracks.
Folds that are clearly visible as depressions which have rounded peaks and roots shall not be deemed to constitute defects, but those which have sharp profiles, or whose shape cannot definitely be identified, particularly those that are only discernible as a crack or a line of oxide on the container surface and extend into the threaded portion, are not acceptable and shall be removed.

8. MANUFACTURE

Dirt and scale shall be removed as necessary to afford proper inspection. No fissures or other defects acceptable that the likely to weaken the finished cylinder and the surface finish shall be reasonably smooth and uniform. If not originally free from such defects, the surface may be machined or otherwise treated to eliminate these defects.

9. WELDING OR BRAZING

Welding or brazing for any purpose whatsoever is prohibited.

10. DESIGN

10.1 Cylinders shall meet the following design conditions:
Assuming the cylinder to be supported horizontally at its two ends only and to be uniformly loaded over its entire length consisting of the weight per unit length of the straight cylindrical portion filled with water and compressed to the specified test pressure; the sum of two times the maximum tensile stress in the bottom fibres due to bending (NOTE 1), plus that in the same fibres (longitudinal stress) (NOTE 2), due to hydrostatic test shall not exceed 80 percent of the minimum yield strength of the steel at such maximum stress. Wall thickness shall be increased when necessary to meet the requirement.

NOTE 1: To calculate the maximum tensile stress due to bending, the following formula shall be used:

$$S = \frac{MC}{I}$$

NOTE 2: To calculate the maximum longitudinal tensile stress due to hydrostatic test pressure, the following formula shall be used:

$$S = \frac{A_1 P}{10\ A_2}$$

Where: S = tensile stress - N/mm^2
M = bending moment - $(Wl^2)/8$
W = weight N per mm length of cylinder filled with water
l = length of cylinder - mm
c = radius, D/2 of cylinder - mm
I = moment of inertia - $0.04909\ (D^4 - d^4)\ mm^4$
D = outside diameter - mm
d = inside diameter - mm
A_1 = internal area in cross section of cylinder-mm^2

A_2 = area of metal in cross section of cylinder-mm^2
P = hydrostatic test pressure - bar

10.2 The minimum wall shall be such that the wall stress at the minimum specified test pressure shall not exceed 67 percent of the minimum tensile strength of the steel as determined from the physical tests required in paragraph 16 and shall not be over $624N/mm^2$

10.3 Calculation shall be by the formula:

$$S = [P/10 (1.3D^2 + 0.4 d^2)] / (D^2 - d^2)$$

where S = wall stress in N/mm^2
P = minimum test pressure prescribed for water jacket test - bar
D = outside diameter in mm
d = inside diameter in mm

11. HEAT TREATMENT

11.1 The completed cylinders must be uniformly and properly heat treated prior to tests. Heat treatment of cylinders of the permitted analyses shall be as follows:

11.1.1 All cylinders must be quenched by oil, or other suitable medium.

11.1.2 The steel temperature on quenching shall be that recommended for the steel analysis but in no case shall exceed 954°C.

11.1.3 All steels shall be tempered at a temperature most suitable for that steel.

11.1.4 The minimum tempering temperature shall be not less than 538°C.

11.1.5 All cylinders, if water quenched or quenched with a liquid producing a cooling rate in excess of 80 percent of the cooling rate of water, must be inspected by the magnetic particle, dye penetrant or ultrasonic method to detect the presence of quenching cracks. Cylinders found to have cracks must have cracks removed to sound metal by mechanical means. Such cylinders will be acceptable if the repaired area is subsequently examined to assure no defect, and it is determined that design thickness requirements are met.

12. THREADED OPENINGS

12.1 All threads are required to be clean cut, even, without cutting tool marks and to gauge.

12.2 Taper threads, when used, are to be of length not less than as specified for American Standard taper pipe threads.

12.3 Straight threads having at least 6 engaged threads are permitted and shall have a tight fit. The calculated shear strength shall be at least 10 times the test pressure of the cylinder.

13. PRESSURE RELIEF DEVICES

Cylinders shall be protected from over pressurisation in accordance with the requirements of 13.4 of BS.5045: Part 1.

14. HYDROSTATIC TEST

14.1 The hydrostatic test shall be by the water jacket method and operated so as to obtain accurate data. Pressure gauge must permit reading to accuracy of 1 percent. The calibrated expansion gauge must permit reading of total expansion to accuracy either of 1 percent or 0.1ml.

14.2 Pressure must be maintained for at least 30 seconds and sufficiently longer to ensure complete expansion. Any internal pressure applied after heat treatment and previous to the official test must not exceed the maximum operating pressure. If, due to failure of the test apparatus, the test pressure cannot be maintained, the test may be repeated at a pressure increased by 10 percent or 7 bar, whichever is the lower.

14.3 Permanent volumetric expansion must not exceed 10 percent of total volumetric expansion at test pressure.

14.4 Each cylinder must be tested to at least 5/3 times service pressure. The test apparatus and method of testing shall be in accordance with the Compressed Gas Association (CGA) pamphlet C-1.

15. DIMENSIONAL TOLERANCES

15.1 Outside diameter

The tolerance on the nominal outside diameter shall be $\pm$ 1% ; this shall be verified at the quarter and mid-length locations on the container.

15.2 Thickness

At no point shall the container shell thickness be less than the minimum thickness resulting from the calculation in 10.3.

15.3 Eccentricity

The minimum calculated thickness shall be guaranteed, the values of the minimum and maximum thickness measured in any cross-section of the container shall not differ by more than 12.5% from the mean value of these two thickness; this shall be verified at least at the quarter and mid-length locations on the containers.

15.4 Out of Roundness

The difference between the maximum and minimum outside diameter in the same cross-section shall not exceed 2% from the mean value of these diameters measured at least at the quarter and mid length locations on the container.

15.5 Straightness

The total deflection of the container cylindrical shell generated with respect to their length shall not exceed 3mm per metre.

15.6 Length

The tolerance on the overall length of the container shall be ± 1.5% or ± 50mm, whichever is the greater.

15.7 **Water Capacity**

The tolerance on the water capacity shall be ± 2.5%.

15.8 **Mass**

The mass tolerance of any individual container shall be ± 10%. If the containers are intended to constitute a battery, the tolerance on the shipment mean mass shall be ± 5% of the nominal unit design mass.

16. **MECHANICAL TEST**

16.1 **Specimens**

16.1.1 When the cylinders are heat treated in a non-continuous furnace, two tension specimens and three impact test specimens must be tested from one of the cylinders or a test ring from each batch. The batch size represented by these tests may not exceed 200 cylinders.

16.1.2 When the cylinders are heat treated in a continuous furnace, two tension specimens and three impact test specimens must be tested from one of the cylinders or a test ring from each four hours of production or less. However, in no case may a batch based on this production period exceed 200 cylinders.

16.1.3 Each specimen for the tension test and impact must be taken from the sidewall of a cylinder or from a ring which has been heat treated with the finished cylinder of which the specimen must be representative. The axis of the specimen must be parallel to the axis of the cylinder. Each cylinder or ring specimen for test must be of the same diameter, thickness, and metal as the finished cylinder they represent. A test ring must be at least 600mm long with ends covered during the heat treatment process so as to simulate the heat treatment process of the finished cylinder it represents.

16.1.4 A test cylinder or test ring need represent only one of the heats in a furnace batch provided the other casts in the batch have previously been tested and have passed the tests and that such tests do not represent more than 200 cylinders from any one cast.

16.1.5 For the purposes of these requirements, the term "batch" indicates a quantity of one or more containers of similar size, design and material specification heat treated under the same conditions of temperature and duration in the same production run (ie without stopping the furnace).

16.2 **Tensile Tests**

16.2.1 The tests shall determine tensile strength, yield strength and elongation.

16.2.2 Rectangular specimens shall be: Gauge length 50mm with width not over 33mm. The specimen, exclusive of grip ends, must not be flattened. Grip ends may be flattened to within 25mm of each end of the reduced section. When the 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.

16.2.3 Round specimens shall be machined, having the maximum diameter practicable.

16.2.4 When round specimens are so taken and prepared, the inspection report must show, in connection with the record of physical tests, detailed information in regard to such specimens. Heating of specimen for any purpose is not authorised.

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

16.2.6 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 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 $207 \times 10^3 N/mm^2$. In the event of controversy, the entire stress-strain diagram shall be plotted and the yield strength determined from the 0.2 percent offset.

16.2.7 For the purposes of strain measurement, when using the extension under load method, the initial strain shall be set while the specimen is under a stress of $83N/mm^2$, the strain indicator reading shall be set at the calculated corresponding strain.

16.2.8 Cross-head speed of the testing machine shall not exceed 3mm per minute during yield strength determination.

16.3 **Tensile Test Results**

16.3.1 The ultimate tensile strength determined in accordance with 16.2 shall not exceed $1069N/mm^2$.

16.3.2 The elongation, measured in accordance with 16.2.2 and 16.2.3. must be at least 16 percent at 50mm gauge length.

16.4 **Hardness Testing**

16.4.1 After the final heat treatment, each cylinder must be hardness tested on the cylindrical surface. A minimum of four readings shall be taken, two at each end of the cylinder, located 180^o apart. The hardness shall not exceed HB 331. When the result of a hardness test exceeds the maximum permitted, two or more retests may be made, however, the hardness number obtained in each retest may not exceed the maximum permitted.

16.4.2 When the test results do not conform to the requirements specified, the cylinders represented by the tests may be reheat treated and the tests repeated.

16.5 **Impact Tests**

16.5.1 Each impact specimen shall be Charpy V-notch type size 10 x 10mm taken in accordance with ASTM Standard A370. Where only a reduced size specimen can be obtained, it shall be the largest standard subsize obtainable, but not smaller than 10 x 5.0 mm.

16.6 **Impact Test Results**

16.6.1 The Charpy V-notch impact properties for the three impact specimens which shall be tested at -50^{0}C may not be less than the values shown below:

Size of Specimen (mm)	Average value for acceptance 3 specimens	Minimum value 1 specimen only of the three
10.0 x 10.0.....	34 Joules.....	27 Joules.....
10.0 x 7.5.....	28 Joules.....	23 Joules.....
10.0 x 5.0.....	23 Joules.....	19 Joules.....

17. **ULTRASONIC INSPECTION**

17.1 After the hydrostatic test, the cylindrical section of each cylinder shall be examined in accordance with ASTM Standard A-388-67 using the angle beam technique. The equipment used must be calibrated to detect a notch equal to five percent of the design minimum wall thickness. Any discontinuity indication greater than that produced by the five percent notch shall be cause for rejection of the cylinder unless the discontinuity is repaired, minimum design wall thickness is verified by ultrasonic measurement and the area is re-inspected using the angle beam technique.

18. **MARKING**

18.1 Each container which complies with the requirements of this specification shall be permanently and legibly marked with the following:

(a) CPI-3T followed by the settled pressure in bar at 15^{o}C.

(b) Container serial number.

(c) Manufactures mark or registration number.

(d) The identification mark(s) of the Inspection Body.

(e) HYDRAULIC TEST PRESSURE in bar. The date of the hydrostatic test so placed that dates of subsequent tests can be easily added.

(f) The design water capacity as specified in the design drawing.

(g) The weight of the container (Kgs).

18.2 The marks shall be at least 6mm in height.

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APPENDIX 1.

INSPECTION REPORT.

Manufacturing Location _____

Consigned to _____

Address _____

Quantity _____

Size _____ mm outside diameter by _____mm long.

Marks Stamped into the shoulder of the cylinder are:

Specification _____

Serial numbers _____ to _____ inclusive

Inspection Body's mark _____

___

Identifying symbol (registered) _____

Test date _____

Tare weights _____

Other marks (if any) _____

These cylinders were made by process of _____

_____

The cylinders were heated treated by the process of _____

_____

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.

All material, such as seamless tubing, was inspected and each cylinder was inspected both before and after closing the ends; all that was accepted was found free from seams, cracks, laminations, and other defects which might prove injurious to the strength of the cylinder. The processes of manufacture and heat treatment of cylinders were supervised and found to be efficient and satisfactory. The cylinder walls were measured and the minimum thickness noted was _____ mm. The outside diameter was determined by a close approximation to be _____ mm. The wall stress was calculated to be _____ N/mm^2 under an internal pressure _____ bar.

Hydrostatic tests, charpy tests, tensile tests of material, and other tests, as prescribed in specification No. CPI-3T were made in the presence of the inspector and all material and cylinders accepted were found to be in compliance with the requirements of that specification. Records thereof are attached hereto. I hereby certify that all of these cylinders proved satisfactory in every way and comply with the requirements of specification No. CPI-3T.

(Signed) _____

Inspection Body.

(Place) _____

(Date) _____