CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

Document Name: ISO 7866: Gas Cylinders--Refillable Seamless Aluminum Alloy Gas Cylinders--Design, Construction and Testing

CFR Section(s): 49 CFR 178.71(h)

Standards Body: International Organization for Standardization

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

INTERNATIONAL STANDARD

ISO 7866

First edition
1999-06-15

Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing

Bouteilles à gaz — Bouteilles sans soudure en alliage d'aluminium destinées à être rechargées — Conception, construction et essais

Reference number
ISO 7866:1999(E)

Contents

Page

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7866 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Annexes A and B form a normative part of this International Standard. Annexes C and D are for information only.

Introduction

The purpose of this International Standard is to provide a specification for the design, manufacture, inspection and testing of a seamless aluminium cylinder for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

This International Standard aims to eliminate the concern about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards. This International Standard should not be construed as reflecting on the suitability of the practices of any nation or region.

Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable seamless aluminium alloy gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases for worldwide use (normally up to + 65 °C).

NOTE If so desired, cylinders of water capacity less than 0,5 l may be manufactured and certified to this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6506:1981[1], *Metallic materials — Hardness test — Brinell test.*

ISO 6508:1986[2], *Metallic materials — Hardness test — Rockwell test (scales A - B - C - D - E -F - G - H - K).*

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature.*

ISO 7438:1985, *Metallic materials — Bend test.*

ISO 7539-6:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens.*

ISO 11114-1:1997, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials.*

ISO 13341:1997, *Transportable gas cylinders — Fitting of valves to gas cylinders.*

ISO 13769[3], *Gas cylinders — Stamp marking.*

---

[1] To be withdrawn and replaced by ISO 6506-1, ISO 6506-2 and ISO 6506-3.

[2] To be withdrawn and replaced by ISO 6508-1, ISO 6508-2 and ISO 6508-3.

[3] To be published.

3 Terms and definitions

For the purpose of this International Standard the following terms and definitions apply.

3.1
yield stress
value corresponding to the 0,2 % proof stress (non-proportional elongation), $R_{p0,2}$

3.2
solution heat treatment
thermal treatment which consists of heating the products to a suitable temperature and holding at that temperature long enough to allow constituents to enter into solid solution

3.3
quenching
controlled rapid cooling in a suitable medium to retain the solute phase in solid solution

3.4
artificial ageing
heat treatment process in which the solute phase is precipitated to give an increased yield stress and tensile strength

3.5
batch
quantity of up to 200 cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness and design, made successively from the same cast of aluminium alloy and subjected to the same heat treatment for the same duration of time

NOTE The lengths of the cylinders in a batch may vary by up to 12 %.

3.6
design stress factor (F)(variable)
ratio of equivalent wall stress at test pressure (p_h) to the guaranteed minimum yield stress (R_e)

3.7
IAA
registration record of international alloy designations and chemical composition limits for wrought aluminium and wrought aluminium alloys as published by the Aluminum Association[4)]

4 Symbols

a Calculated minimum thickness, in millimetres, of the cylindrical shell (see Figure 1)

a' Guaranteed minimum thickness, in millimetres, of the cylindrical shell

A Percentage elongation

b Guaranteed minimum thickness, in millimetres, at the centre of a convex base (see Figure 1)

D Nominal outside diameter, in millimetres, of the cylinder (see Figure 1)

D_f Diameter, in millimetres, of former (see Figure 5)

E Modulus of elasticity in MPa

F Design stress factor (variable) (see 3.6)

---

4) Aluminum Association Inc., 900, 19th Street N.W., Washington D.C., 20006-2168, USA.

H Outside height, in millimetres, of domed part (convex head or base end) (see Figure 1)

L_o Original gauge length, in millimetres, as defined in ISO 6892 (see Figure 4)

n Ratio of the diameter of the bend test former to the actual thickness of the test piece (t)

p_b Actual burst pressure, in bar[5] above atmospheric pressure

p_h Hydraulic test pressure, in bar, above atmospheric pressure

p_y Observed pressure when cylinder starts yielding during hydraulic bursting test, in bar, above atmospheric pressure

r Inside knuckle radius, in millimetres (see Figure 1)

r_i Inside crown radius, in millimetres (see Figure 1)

R_e Minimum guaranteed value of yield stress (see 3.1), in MPa

R_{ea} Actual value of the yield stress, in MPa, as determined by the tensile test specified in 10.2

R_g Minimum guaranteed value of tensile strength, in MPa

R_m Actual value of the tensile strength, in MPa, as determined by the tensile test specified in 10.2

S_o Original cross-sectional area of tensile test piece, in square millimetres, in accordance with ISO 6892

t Actual thickness of the test specimen, in millimetres

t_m Average cylinder wall thickness, in millimetres, at the position of test (see Table 2)

u Ratio of the distance between knife edges to the average cylinder wall thickness t_m at the position of test

w Width, in millimetres, of the tensile test piece (see Figure 4)

5 Inspection and testing

Evaluation of conformity is required to be performed in accordance with the relevant regulations of the country(ies) where the cylinders are used.

In order to ensure that the cylinders are in compliance with this International Standard they shall be subject to inspection and testing in accordance with clauses 9, 10 and 11 by an authorized inspection body (hereafter referred to as "the inspector") recognized in the countries of use. The inspector shall be competent for inspection of cylinders.

6 Materials

6.1 General requirements

6.1.1 The chemical composition limits for alloys for the fabrication of gas cylinders shall be as specified in Table 1.

---

5) 1 bar = 10^5 Pa = 10^5 N/m^2.

Table 1 — Chemical composition of materials

Group	Type of alloy (IAA registered designation)	Marking code reference		Chemical composition (% m/m)														Remarks
				Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb	Others Each	Others Total	Al	
1	6351A	A	min.	0,70	—	—	0,40	0,4	—	—	—	—	—	—	—	—	Remainder	Special precautions shall be taken for this alloy to prevent coarse grain structure in the neck of the cylinder
			max.	1,30	0,5	0,10	0,80	0,8	—	—	0,20	0,20	—	0,003	0,05	0,15		
	6082A	B	min.	0,70	—	—	0,40	0,6	—	—	—	—	—	—	—	—	Remainder	Special precautions shall be taken for this alloy to prevent coarse grain structure in the neck of the cylinder
			max.	1,30	0,5	0,10	1,00	1,2	0,25	—	0,20	0,10	—	0,003	0,05	0,15		
	6061A	C	min.	0,40	—	0,15	—	0,8	0,04	—	—	—	—	—	—	—	Remainder	
			max.	0,80	0,7	0,40	0,15	1,2	0,35	—	0,25	0,15	—	0,003	0,05	0,15		
2	5283A	D	min.	—	—	—	0,50	4,5	—	—	—	—	—	—	—	—	Remainder	
			max.	0,30	0,3	0,03	1,00	5,1	0,05	0,03	0,10	0,03	0,05	0,003	0,05	0,15		
3	7060	G	min.	—	—	1,80	—	1,3	0,15	—	6,10	—	—	—	—	—	Remainder	
			max.	0,15	0,2	2,60	0,20	2,1	0,25	—	7,50	0,05	0,05	0,003	0,05	0,15		

NOTE 1 The above materials are used extensively throughout the world in preference to the alloy compositions quoted in ISO 209-1. They are included in this standard quoting the IAA registered designations, but making reference to ISO 209-1 where it is considered applicable.

NOTE 2 When contamination is suspected, e.g. because of melting non-virgin material, the bismuth content shall be shown to not exceed 0,03 % (m/m).

NOTE Other aluminium alloy(s) may be used to produce gas cylinders provided that they satisfy the requirements of the corrosion resistance tests defined in annex A, meet all other requirements of this International Standard and are approved by the relevant statutory authorities of the countries in which the cylinders are to be used. Such new alloys may be used provided they have been used for the manufacture of either at least 20 000 cylinders in satisfactory service for two years, or at least 5 000 cylinders manufactured from not less than ten casts of aluminium and in satisfactory service for two years. Evidence of this satisfactory service is to be submitted to ISO for discussion by the appropriate Technical Committee. Once accepted by this committee, the new alloy will be added to Table 1 and the standard revised or amended. At this stage, cylinders manufactured from this alloy may be marked in accordance with this International Standard. Satisfactory service is defined as having no failures in service.

6.1.2 The cylinder manufacturer shall identify the cylinders with the particular casts of the alloy from which they are made, and shall obtain and provide certificates of the analyses of the casts used. If check analyses are required, they shall be carried out either on test pieces taken from material in the form supplied by the producer of the aluminium alloy or from finished cylinders.

6.1.3 Grades of aluminium alloy used for cylinder manufacture shall be compatible with the intended gas service, e.g. corrosive gases, embrittling gases (see ISO 11114-1).

6.2 Thermal treatments

6.2.1 Heat treatable alloys (see Table 1, groups 1 and 3)

The manufacturer shall specify on the type approval documentation, the solution heat treatment and artificial ageing temperatures and the minimum times for which the cylinders have been held at those temperatures. The medium used for quenching after solution heat treatment shall be identified.

6.2.2 Non-heat treated alloys (see Table 1, group 2)

The manufacturer shall specify on the type approval documentation, the type of metal-forming operation carried out (extrusion, drawing, ironing, head forming, etc).

Unless the alloy is subjected to a temperature in excess of 400 °C during the forming process, a stabilizing heat treatment shall be carried out at a temperature above 220 °C, and the temperature and time at temperature shall be identified by the manufacturer.

6.2.3 Control of specified heat treatment

During the heat treatment the manufacturer shall comply with the specified temperature for the solution, artificial ageing and stabilizing treatments within a range of 20 °C.

6.3 Testing requirements

The material of the finished cylinders shall satisfy the requirements of clauses 9, 10 and 11.

6.4 Failure to meet test requirements

6.4.1 In the event of failure to meet test requirements, retesting or re-heat treatment and retesting shall be carried out as follows:

a) If there is evidence of a fault in carrying out a test, or an error of measurement, a second test shall be performed, on the same cylinder if possible. If the result of this test is satisfactory, the first test shall be ignored.

b) If the test has been carried out in a satisfactory manner and the failure is in a test representing the prototype or batch cylinders, the procedure detailed in either 6.4.2 or 6.4.3 shall be followed.

c) If the test has been carried out in a satisfactory manner and the failure is in a test applied to every cylinder then only those cylinders which fail the test require retesting or re-heat treatment and retesting. If the failure is due to the heat treatment applied, then the failed cylinders shall be subject to the procedure in 6.4.3. If the failure is due to a cause other than the heat treatment applied, all defective cylinders shall be rejected.

6.4.2 Two further cylinders selected at random from the same batch shall be subjected to the tests specified in 10.1.2.a) and 10.1.2.b). If both cylinders meet the specified requirements, the batch shall be accepted. Should either cylinder fail to meet the specified requirements, the batch shall

a) be rejected or

b) be treated in accordance with 6.4.3.

6.4.3 The batch of cylinders shall be reheat treated and two further cylinders shall be tested in accordance with 10.1.2.a) and 10.1.2.b). If both cylinders meet the specified requirements, the batch shall be accepted. Should either cylinder fail to meet the specified requirements, the batch shall be rejected.

6.4.4 Where it can be established that the heat treatment was at fault, the cylinders may be re-solution treated and artificially aged, or alternatively additional time at the ageing treatment temperature may be given. Cylinders that have been subject to re-heat treatment may only be presented to the inspector once more for testing.

7 Design

7.1 General requirements

7.1.1 The calculation of the wall thickness of the pressure-containing parts shall be related to the yield stress (R_e) of the material.

7.1.2 For calculation purposes, the value of the yield stress (R_e) is limited to a maximum of 0,90 R_g for aluminium alloys.

7.1.3 The internal pressure upon which the calculation of wall-thickness is based shall be the hydraulic test pressure (p_h).

7.2 Calculation of cylindrical-shell thickness

The guaranteed minimum thickness of the cylindrical shell (a') shall not be less than the thickness calculated using equations (1) and (2), and additionally condition (3) shall be satisfied:

$$a = \frac{D}{2}\left(1 - \sqrt{\frac{10FR_e - \sqrt{3}\,p_h}{10FR_e}}\right) \qquad (1)$$

Where the value of F is the lesser of $\dfrac{0{,}65}{R_e / R_g}$ or 0,85

R_e/R_g shall not exceed 0,90.

NOTE Regional international agreements may limit the magnitude of the 'F' factor used for design.

The wall thickness shall also satisfy the formula

$$a > \frac{D}{100} + 1\text{mm} \qquad (2)$$

with an absolute minimum of 1,5 mm

The burst ratio shall be satisfied by test

$$p_b/p_h \geqslant 1{,}6 \qquad (3)$$

NOTE It is generally assumed that p_h = 1,5 × service pressure for permanent gases for cylinders designed and manufactured to this Internatioinal Standard.

7.3 Design of convex ends (heads and bases)

7.3.1 The thickness and shape of the base and head of the cylinders shall be such as to meet the requirements of the tests laid down in 10.4 (hydraulic bursting test) and 9.2.3 (pressure cycling test).

In order to achieve satisfactory stress distribution, the cylinder wall thickness shall increase progressively in the transition zone between the cylindrical shell and the ends, particularly the base, e.g. typical shapes of convex heads and base ends are shown in Figure 1.

7.3.2 The thickness at the centre of a convex end shall be not less than the minimum wall thickness of the cylindrical part.

The base shall have a hemispherical, torispherical or semi-ellipsoidal profile.

7.3.3 The inside crown radius r_i should be not greater than 1,2 $\times$ the inside diameter of the shell, and the knuckle radius r should be not less than 10 % of the inside diameter of the shell.

Where these conditions are not fulfilled, the cylinder manufacturer shall prove by the prototype tests as required in 9.1 that the design is satisfactory.

7.4 Neck design

7.4.1 The external diameter and thickness of the formed neck end of the cylinder shall be adequate for the torque applied in fitting the valve to the cylinder. The torque may vary according to the diameter of thread, the form and the sealant used in fitting the valve. The torques specified in ISO 13341 shall not be exceeded, since this would result in permanent damage to the cylinder.

7.4.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of the wall in the cylinder neck that will prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without support of an attachment, such as a neck ring.

7.5 Foot-rings

When a foot-ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder. The shape should preferably be cylindrical and shall give the cylinder sufficient stability. The foot-ring shall be secured to the cylinder by a method other than welding, brazing or soldering. in order to prevent ingress of water, any gaps which may form water traps shall be sealed by a method other than welding or brazing.

7.6 Neck-rings

When a neck-ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder, and shall be securely attached by a method other than welding, brazing or soldering.

The manufacturer shall ensure that the axial load to remove the neck-ring is greater than 10 $\times$ the weight of the empty cylinder and that the minimum torque to rotate the neck ring is 100 Nm.

7.7 Design

A fully dimensioned drawing shall be prepared which includes the specification of the material and makes reference to this International Standard.

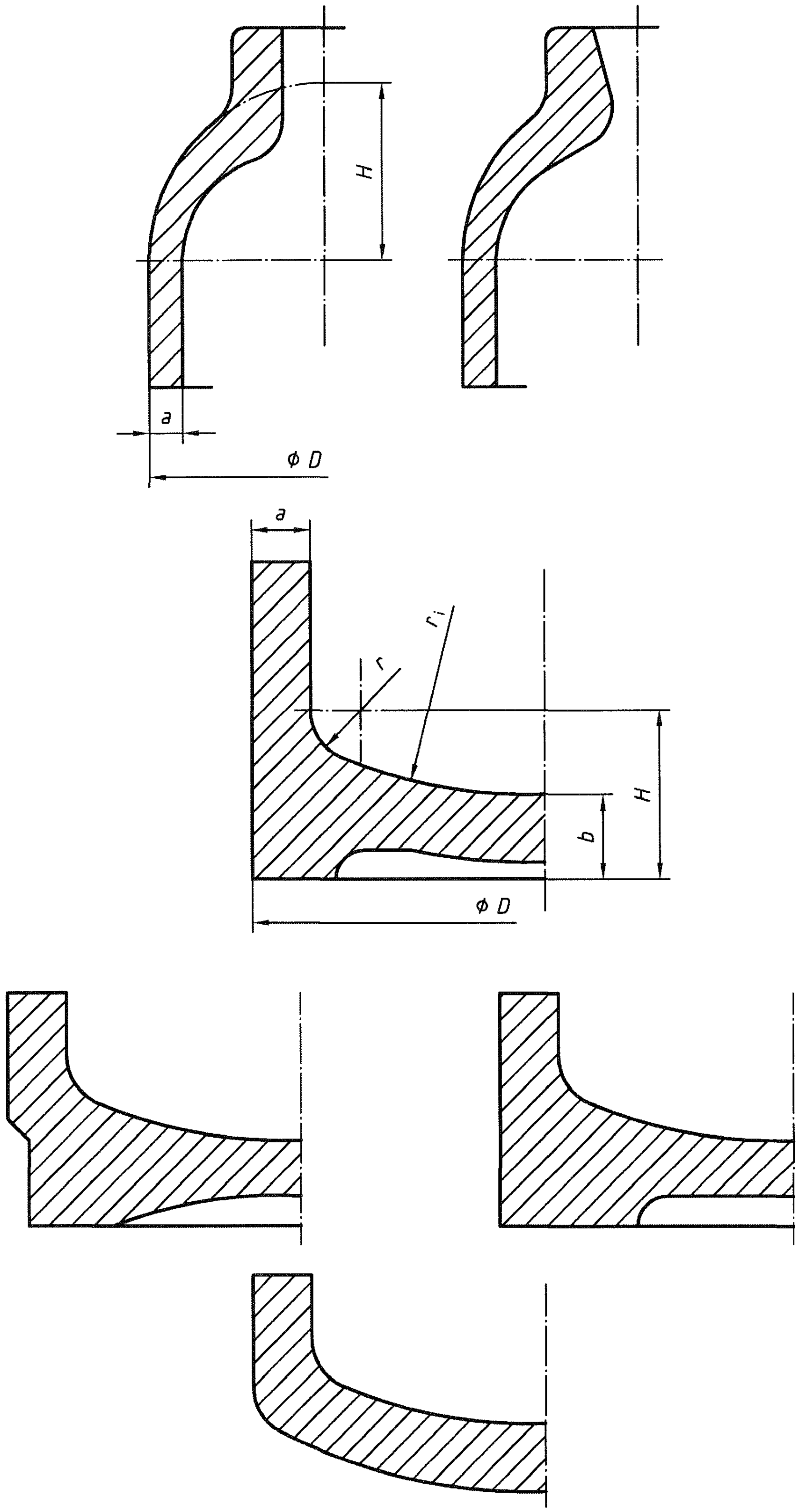


Figure 1 — Typical convex ends

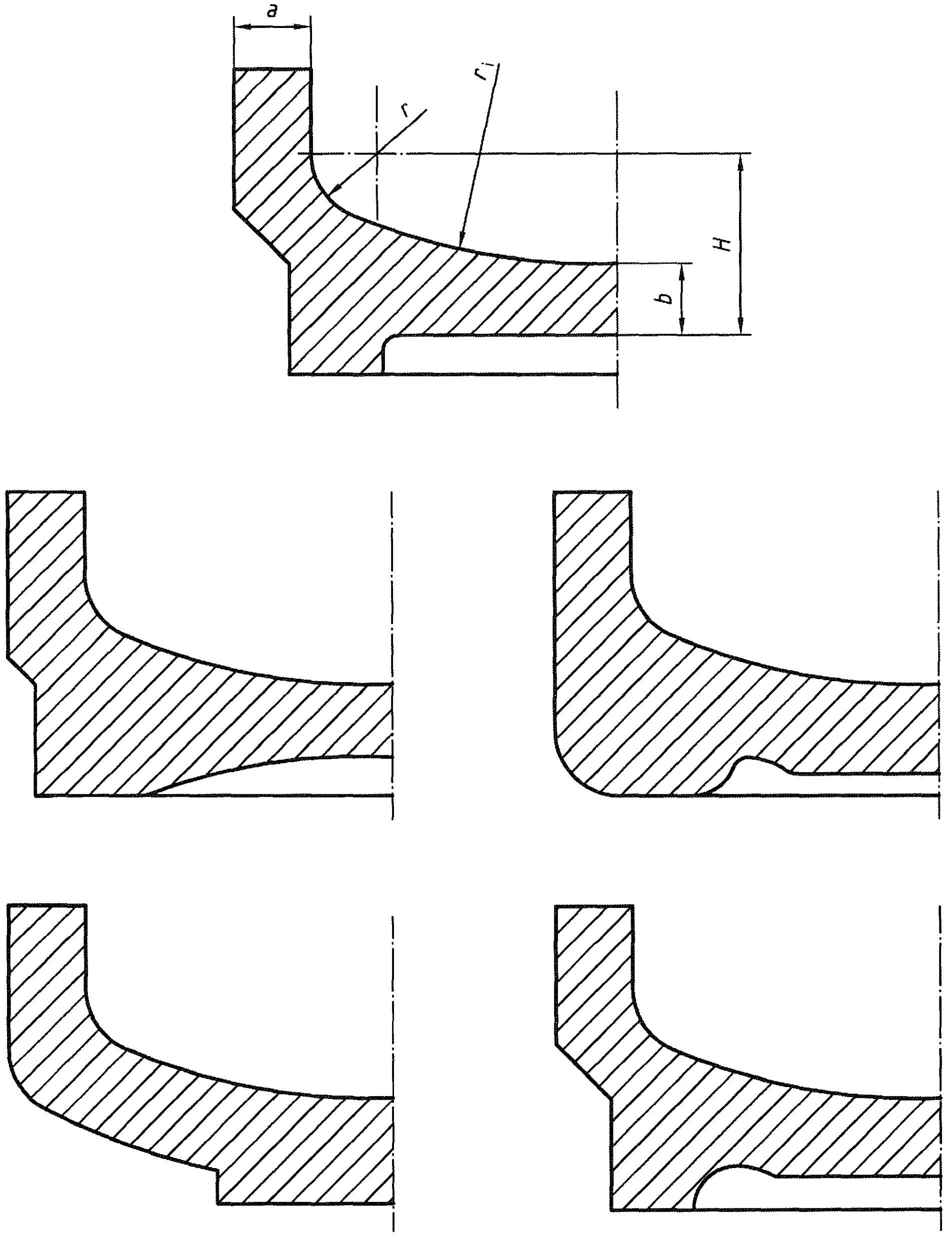


Figure 1 — Typical convex ends (concluded)

8 Construction and workmanship

8.1 General

The cylinder shall be produced by

a) cold or hot extrusion from cast (see 8.3) or extruded or rolled billet;

b) cold or hot extrusion, followed by cold drawing from cast (see 8.3) or extruded or rolled billet;

c) cupping, flow forming, spinning and cold drawing sheet or plate;

d) open necking at both ends of an extruded or cold-drawn tube (see Figure 2).

Plugging to correct manufacturing defects is not permitted.

8.2 End forming

The ends shall be formed by an appropriate method, e.g. forging, swaging and spinning. Prior to and/or after the closing-in operation, all significant remnants of the as-cast structure shall be removed from the open end(s) area(s).

Where heat has to be applied to form the cylinder's neck/shoulder, it shall be ensured that a uniform heat distribution is achieved prior to the forming operation e.g. by means of induction heating. This approach shall be used independent of the method employed for the manufacture of the shell.

Regardless of the method used for the closing-in operation, the tools used for the head forming process shall facilitate metal flow and result in smooth surfaces of the cylinder, especially in the neck/shoulder areas. There shall be no sudden contour changes or significant folds, (see 11.6), which may act as stress raisers during the cylinder's eventual service conditions.

8.3 Wall thickness

Each cylinder shall be examined, before the closing-in operations, for thickness and for external and internal surface defects. The wall thickness at any point shall be not less than the minimum thickness specified.

8.4 Surface defects

The internal and external surfaces of the finished cylinder shall be free from defects which would adversely affect the safe working of the cylinder.

The wall thickness of any dressed areas shall not be less than that of the minimum thickness specified.

8.5 Neck threads

The internal neck threads shall conform to the design specification to permit the use of a corresponding valve thus minimising neck stresses following the valve torquing operation. Particular care shall be taken to ensure that neck threads are accurately cut, are of full form and free from any sharp profiles e.g. burrs.

8.6 Out-of-roundness

The out-of-roundness of the cylindrical shell, i.e. the difference between the maximum and minimum outside diameters in the same cross-section, shall not exceed 2 % of the mean of these diameters.

8.7 Exposure to heat

Any exposure to heat after the heat treatment or stabilization treatment shall not modify the characteristics of the aluminium alloy used.

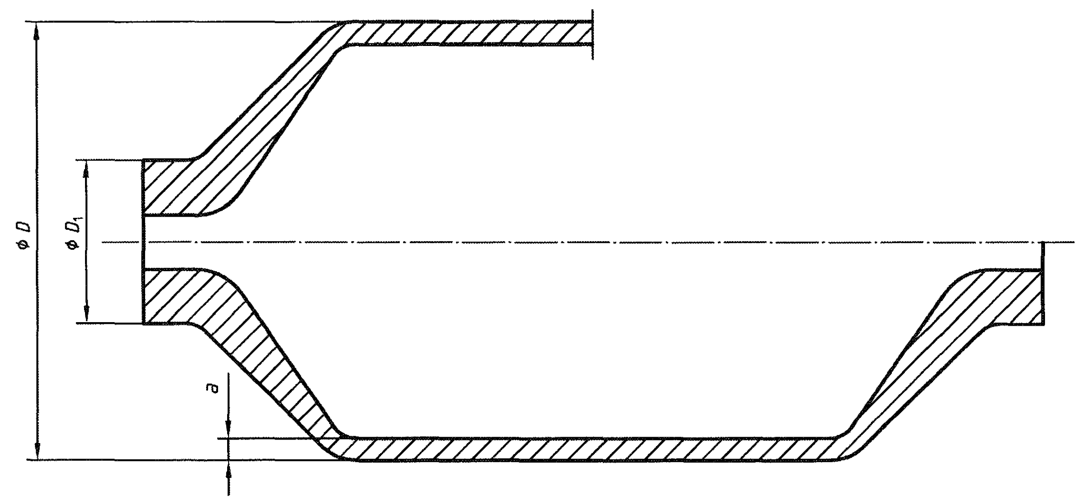


Figure 2 — Necked ends from tube

9 Type approval procedure

9.1 General requirements

A technical specification of each new design of cylinder (or cylinder family as defined in f) below) including design drawing, design calculations, alloy details and heat treatment, shall be submitted by the manufacturer to the inspector. The type approval tests detailed in 9.2 shall be carried out on each new design under the supervision of the inspector.

A cylinder shall be considered to be of a new design compared with an existing approved design, when:

a) it is manufactured in a different factory; or

b) it is manufactured by a different process (see 8.1); or

c) it is manufactured from an alloy of different composition limits from that used in the original prototype tests; or

d) it is given a different heat treatment that is outside the temperature ranges specified in 6.2.3 and/or for times shorter than those used for the original type approval less 10 %; or

e) the base profile and the base thickness have changed relative to the cylinder diameter and calculated minimum wall thickness; or

f) the overall length of the cylinder has increased by more than 50 % (cylinders with a length/diameter ratio less than three shall not be used as reference cylinders for any new design with this ratio greater than three); or

g) the nominal outside diameter has changed; or

h) the design wall thickness has changed; or

i) the hydraulic test pressure has been increased (where a cylinder is to be used for lower-pressure duty than that for which design approval has been given, it shall not be deemed to be a new design); or

j) the guaranteed minimum yield stress (R_e) and/or the guaranteed minimum tensile strength (R_g) have changed.

9.2 Prototype tests

9.2.1 General

A minimum of 50 cylinders which are guaranteed by the manufacturer to be representative of the new design heat treated no more than the minimum times + 10 % required in 6.2, shall be made available for prototype testing. However, if the total number of cylinders required is less than 50, enough cylinders shall be made to complete the prototype tests required, in addition to the production quantity, but in this case the approval validity is limited to this particular production batch.

9.2.2 Inspection

In the course of the type approval process, the inspector shall select the necessary cylinders for testing and

a) verify that:

- the design conforms to the requirements of clause 7;
- the thicknesses of the walls and ends on two of the cylinders taken for tests meet the requirements of 7.3 and 7.4, the measurements being taken on three transverse sections of the cylindrical part and over the whole of a longitudinal section of the base and the head;
- the requirements of clause 6 (Materials) are complied with;
- the requirements of 7.5, 7.6 and 8.2 to 8.6 inclusive are complied with for all cylinders selected by the inspector;
- the material meets the requirements of the intercrystalline and stress corrosion tests specified in annex A;
- the sustained load cracking test has been completed satisfactorily in accordance with annex B.

b) supervise the following tests on the cylinders selected:

- the tests specified in 10.1.2 a) (mechanical testing) on two cylinders, the test pieces being identifiable with the batch;
- the tests specified in 10.1.2 b) (hydraulic burst test) on two cylinders, the cylinders bearing representative stamp markings;
- the tests specified in 9.2.3 (pressure cycling test) on three cylinders, the cylinders bearing representative stamp markings.

9.2.3 Pressure cycling test

This test shall be carried out with a non-corrosive liquid subjecting the cylinders to successive reversals at an upper cyclic pressure which is equal to the hydraulic test pressure (p_h). The cylinders shall withstand 12 000 cycles without failure.

For cylinders with hydraulic test pressure (p_h) > 450 bar, the upper cyclic pressure may be reduced to two-thirds of the test pressure. In this case the cylinders shall withstand 80 000 cycles without failure.

The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure, but with an absolute maximum of 30 bar.

The cylinder shall actually experience the maximum and minimum cyclic pressures during the test.

The frequency of reversals of pressure shall not exceed 0,25 Hz (15 cycles/min.) The temperature measured on the outside surface of the cylinder shall not exceed 50 °C during the test.

After the test the cylinder bases shall be sectioned in order to measure the thickness and to ensure that this thickness is sufficiently close to the minimum thickness prescribed in the design and shall be within the usual production tolerances. In no case shall the actual base thickness exceed that specified on the drawing by more than 15 %.

The test shall be considered satisfactory if the cylinder attains the required number of cycles without developing a leak.

9.3 Type approval certificate

If the results of the checks according to 9.2 are satisfactory, the inspector shall issue a type approval certificate, a typical example of which is given in annex C.

10 Batch tests

10.1 General requirements

10.1.1 All tests for checking the quality of the gas cylinder shall be carried out on material from finished cylinders.

For the purpose of batch testing, the manufacturer shall provide the inspector with:

— the type approval certificate;

— the certificates stating the cast analyses of the alloy supplied for the construction of the cylinders;

— a list of the cylinders, stating serial numbers and stamp markings as required;

— confirmation that threads have been checked properly in accordance with gauging requirements. The gauges to be used shall be specified (e.g. ISO 11191).

10.1.2 During batch testing the inspector shall:

— ascertain that the type approval certificate has been obtained and that the cylinders conform to it;

— check whether the requirements set out in clauses 6, 7 and 8 have been met and in particular check by an external and, if physically possible, internal visual examination of the cylinders whether their construction and the checks carried out by the manufacturer in accordance with 7.5, 7.6 and 8.2 to 8.6 are satisfactory. The visual examination shall cover at least 10 % of the cylinders submitted;

— verify that the results of the tests specified in 10.1.2 a) (mechanical testing) and 10.1.2 b) (hydraulic burst tests) are satisfactory. Where alternative tests are permitted, the purchaser and manufacturer shall agree which tests are to be carried out;

— check whether the information supplied by the manufacturer and referred to in 10.1.1 is correct;

— assess the results of hardness testing specified in 11.3.

The following tests shall be carried out on each batch of cylinders:

a) On one cylinder:

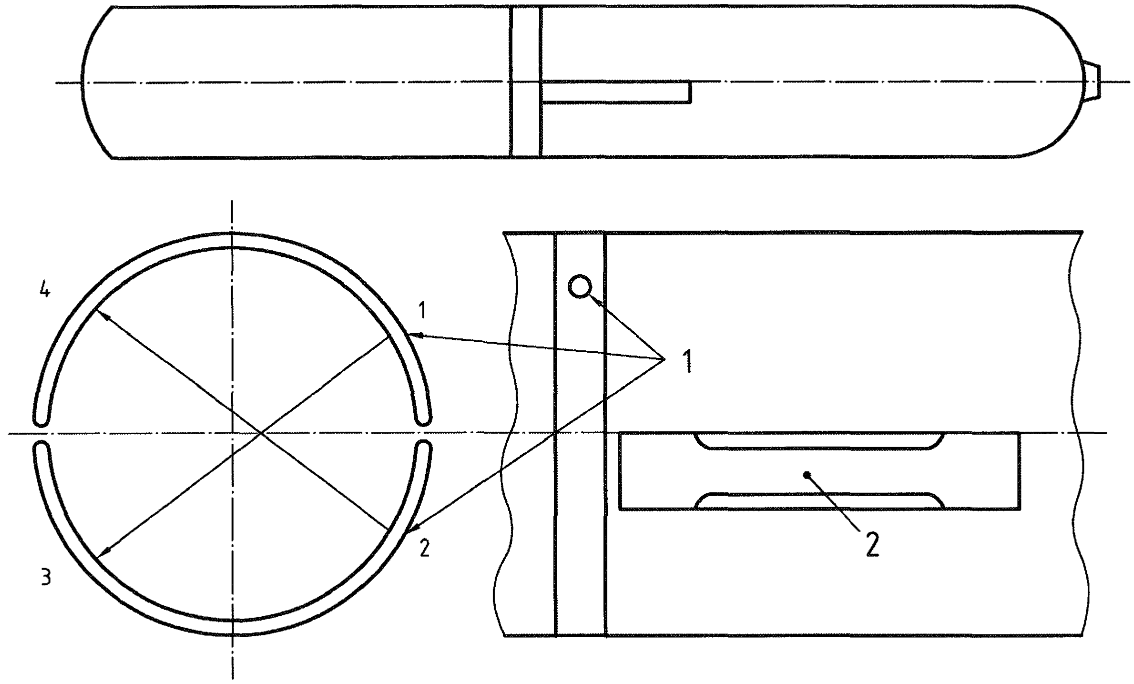
   1) one tensile test in the longitudinal direction (see 10.2);

   2) two bend tests in a circumferential direction (see 10.3), or a flattening test (see 10.4).

   For the locations of test pieces, see Figure 3.

b) On a second cylinder:

   One hydraulic bursting test (see 10.5).



Key

1 Bend test pieces
2 Tensile test piece

Figure 3 — Location of test pieces

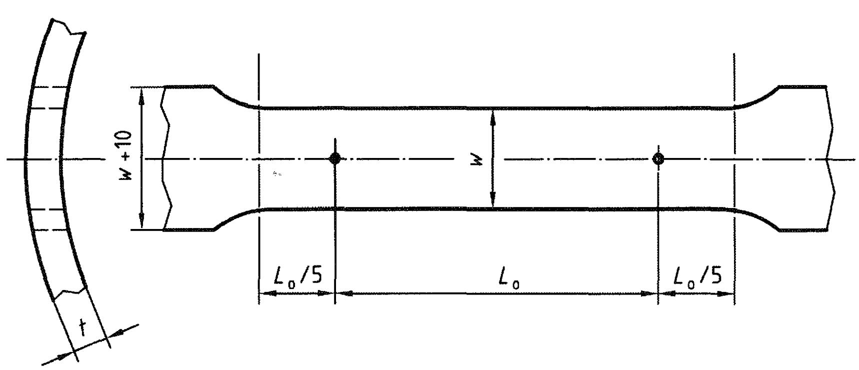
10.2 Tensile test

10.2.1 The tensile test shall be carried out in accordance with ISO 6892 on a test piece which is shaped in accordance with Figure 4 and with a gauge length $L_0 = 5{,}65\sqrt{S_0}$.

The two faces of the test piece representing the inside and the outside surfaces of the cylinder shall not be machined.

10.2.2 The percentage elongation, A, shall be not less than 12 %.

Dimensions in millimetres



Test piece when $t \geqslant 3$ mm
$W \leqslant 4t$
$W < D/8$

Figure 4 — Tensile test pieces

10.3 Bend test and flattening test

10.3.1 Bend test

10.3.1.1 The bend test shall be carried out in accordance with ISO 7438 on two test pieces obtained by cutting either one or two rings of width 25 mm or 3 t whichever is the greater, into four equal parts. The two test pieces shall be taken from the parts that were 180° apart. Each test piece shall be of sufficient length to permit the bend test to be carried out correctly. Only the edges of each strip may be machined.

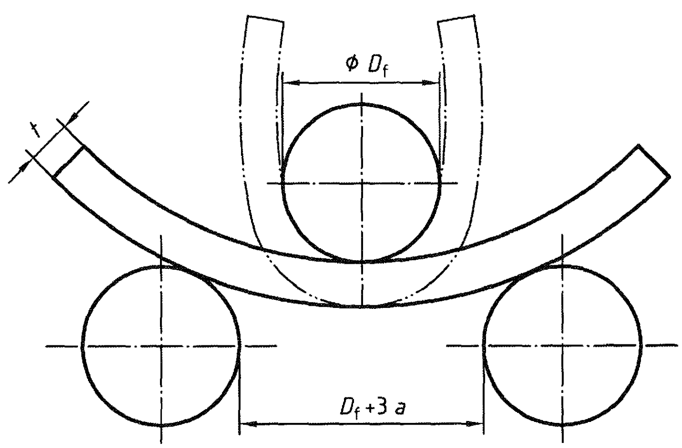
10.3.1.2 The test piece shall not crack when bent inwards around the former until the inside surfaces are no further apart than the diameter of the former (see Figure 5).

10.3.1.3 The diameter of the former (D_f) shall be established from Table 2.

For the actual tensile strength (R_m) given in table 2, $D_f = n \times$ test piece thickness (t).

Table 2 — Bend test and flattening test requirements

Actual tensile strength, R_m MPa	Bend test and flattening test value of n	Flattening test value of u[a]
$R_m \leqslant 325$	6	10
$325 < R_m \leqslant 440$	7	12
$R_m > 440$	8	15
[a] Distance between knife edges = $u \times t_m$ where t_m is the average cylinder wall thickness at the position of test.		



a = Calculated minimum thickness

Figure 5 — Illustration of bend test

10.3.2 Flattening test

10.3.2.1 The flattening test shall be performed on one cylinder selected from each batch after heat treatment.

10.3.2.2 The test cylinder shall be flattened between wedge shaped knife edges with a 60° included angle. The maximum radius of the knife edges shall be established from Table 2.

For the actual tensile strength (R_m) given in Table 2, maximum radius = $n \times t_m$.

The length of the knife edges shall not be less than width of the flattened cylinder. The longitudinal axis of the cylinder shall be at approximately 90° to the knife edges.

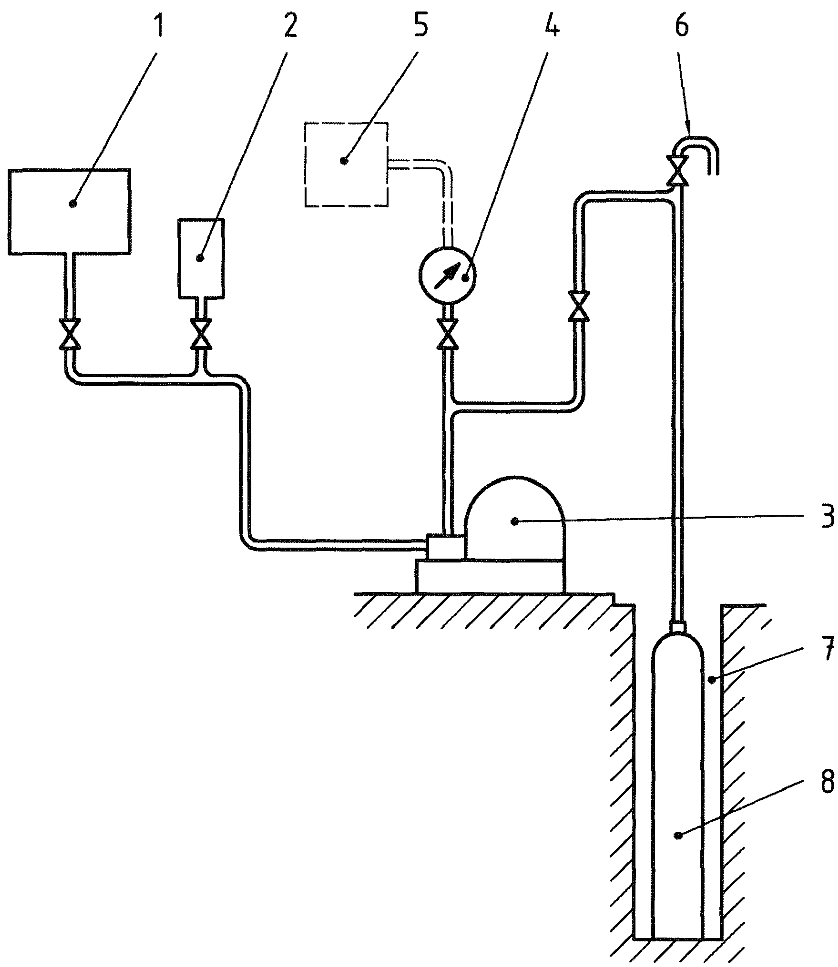
10.3.2.3 The test cylinder shall be flattened until the distance between the knife edges is in accordance with Table 2. The flattened cylinder shall remain visually uncracked.

10.4 Hydraulic bursting test

10.4.1 Test installation

The test equipment shall be capable of operation in accordance with the test conditions specified in 10.4.2 and of accurately producing the information required by 10.4.3.

A typical hydraulic bursting test installation is illustrated in Figure 6.



Key

1 Test fluid reservior
2 Tank for measurement of test fluid (the feed tank may be used as a measuring tank)
3 Pump
4 Pressure gauge
5 Pressure/volumetric expansion curve recorder
6 Vent or air release valve
7 Test well
8 Cylinder

Figure 6 — Typical hydraulic bursting test installation

10.4.2 Test conditions

As the cylinder and test equipment are being filled with water, care shall be taken to ensure that no air is trapped in the circuit, by operating the hydraulic pump until water is discharged from the vent or air-release valve.

During the test, pressurization shall be carried out in two successive stages:

a) the first stage: the pressure shall be increased at a rate of not more than 5 bar/s up to a pressure value corresponding to the initiation of plastic deformation;

b) the second stage: the pump discharge rate shall be maintained at as constant a level as is possible until the cylinder bursts.

10.4.3 Interpretation of test

10.4.3.1 The interpretation of the burst test shall involve:

a) examination of pressure/time curve or pressure/volume-of-water-used curve, to permit determination of the pressure at which plastic deformation of the cylinder commences, together with the bursting pressure and volumetric expansion of the cylinder during the test;

b) examination of the burst tear and of the shape of its edges.

10.4.3.2 For the results of a bursting test to be considered satisfactory, the following requirements shall be met.

a) The observed yield pressure p_y shall be equal to or greater than $1/F \times$ the test pressure, i.e:

$$p_y \geqslant \frac{1}{F} \times p_h$$

b) The actual burst pressure p_b shall be greater than or equal to 1,6 $\times$ the test pressure, i.e:

$$p_b \geqslant 1{,}6\ p_h$$

10.4.3.3 The cylinder shall remain in one piece and shall not fragment.

10.4.3.4 The main tear shall not be of a brittle type, i.e. the edges of the fracture shall not be radial but shall be sloping in relation to a diametral plane. The tear shall not reveal a significant defect in the metal.

10.4.3.5 The fracture shall be acceptable only if it conforms to one of the following descriptions:

a) for cylinders of actual wall thickness 13 mm or less:

- the greater part of the fracture shall be unmistakably longitudinal except for cylinders where the ratio of length to outside diameter is less than 3:1;
- the fracture shall be without branching;
- the fracture shall not extend more than 90° around the circumference on either side of its main part (see Figure 7);
- the fracture shall not extend into those parts of the cylinder of thickness more than 1,5 $\times$ the maximum thickness measured halfway up the cylinder. For cylinders with convex bases, the fracture shall not reach the centre of the cylinder base.

b) For cylinders of actual wall thickness over 13 mm the greater part of the fracture shall be longitudinal.

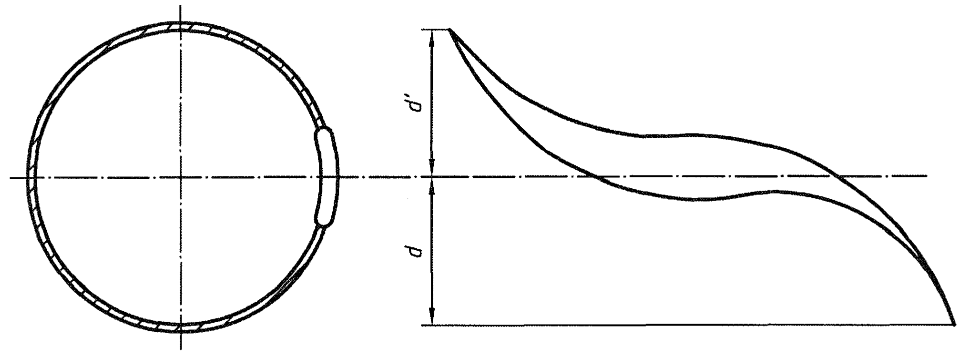


Figure 7 — Illustration of circumferential development of fracture

11 Tests on every cylinder

11.1 General

During production, the tests as required in 8.3 shall be carried out on all cylinders.

Following final heat treatment (see 6.2), all cylinders, except those selected for testing under clause 10, shall be subjected to the following tests:

— a hydraulic proof pressure test in accordance with 11.2.1 or a hydraulic volumetric expansion test in accordance with 11.2.2; the purchaser and manufacturer shall agree which of these alternatives shall be carried out;

— a hardness test in accordance with 11.3;

— a leak test in accordance with 11.4;

— a water capacity check in accordance with 11.5;

— an examination for neck folds in accordance with 11.6.

11.2 Hydraulic test

11.2.1 Proof pressure test

The water pressure in the cylinder shall be increased at a controlled rate until the test pressure, p_h, is reached.

The cylinder shall remain under pressure p_h for at least 30 s to establish that the pressure does not fall and that there are no leaks.

11.2.2 Volumetric expansion test

The water pressure in the cylinder shall be increased at a controlled rate until the test pressure, p_h,is reached.

The cylinder shall remain under pressure p_h for at least 30 s and the total volumetric expansion measured. The pressure shall then be released, and the volumetric expansion re-measured.

The cylinder shall be rejected if it shows a permanent expansion (i.e. volumetric expansion after the pressure has been released) in excess of 5 % of the total volumetric expansion measured at the test pressure, p_h.

The total and permanent expansion readings shall be recorded, together with the corresponding serial number of each cylinder tested, so that the elastic expansion (i.e. total expansion less permanent expansion) under the test pressure can be established for each cylinder.

11.3 Hardness test

A hardness test in accordance with ISO 6506 (Brinell), ISO 6508 (Rockwell B) or other equivalent methods shall be carried out by the manufacturer. The hardness values thus determined shall be within the limits specified by the cylinder manufacturer for the material and manufacturing route, dependent upon the final treatment used for the production of the cylinder. The values may be expressed in Brinell, Rockwell B or other equivalent units.

By agreement with the inspector the hardness test may be replaced by a combined hardness/conductivity test.

11.4 Leakage test

The manufacturer shall employ such manufacturing techniques and apply such tests as will demonstrate to the satisfaction of the inspector that the cylinders do not leak.

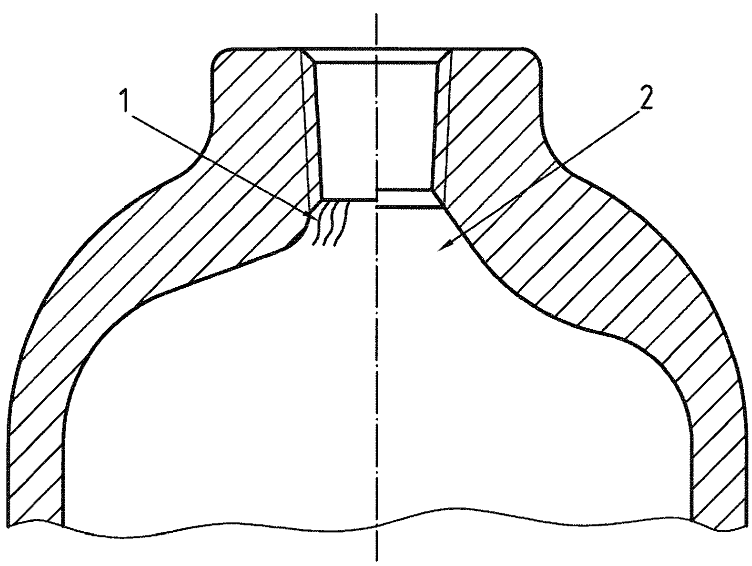
11.5 Capacity check

The manufacturer shall verify that the water capacity conforms to the design drawing.

11.6 Examination for neck folds

Each cylinder shall be examined for neck folds by a suitable means (e.g. introscope, tactile, ultrasonic etc). Folds that are visible as lines running into the threaded portion as shown on the left hand side of Figure 8 shall be removed by a machining operation until the lines are no longer visible.

After the machining operation the thickness of the machined area and the thread's characteristics shall be at least those required to pass all necessary testing. The whole internal shoulder area shall be re-inspected to verify that folding or its lines have been removed.



Key

1 Folds
2 Machined away

Figure 8 — Example of cylinder neck folds before and after machining

12 Certification

Each satisfactory batch of cylinders shall be covered by a certificate signed by the inspecting authority's representative to the effect that the cylinders meet the requirements of this International Standard in all respects. An example of a suitably worded certificate is given in annex D.

Copies of the certificate shall be issued to the manufacturer. The original certificate shall be retained by the inspector and the copies by the manufacturer in accordance with the regulations of the relevant statutory authority.

13 Marking

Each cylinder shall be stamped on the shoulder or on a reinforced part of the cylinder or on a permanently fixed collar or neck ring, in accordance with ISO 13769 or the relevant marking requirements of the countries of use.

Annex A
(normative)

Corrosion tests

A.1 Tests for assessing susceptibility to intercrystalline corrosion

A.1.1 Principle

The method described below consists of simultaneously immersing the specimens taken from the finished cylinder under test in a corrosive solution and examining them after a specified etching time in order to detect any signs of intercrystalline corrosion and determine the nature and degree of such corrosion. The propagation of intercrystalline corrosion is determined metallographically on polished surfaces cut transversely to the etched surface.

A.1.2 Taking specimens

Specimens are taken from the head, body and base of the cylinder (see Figure A.1) so that the tests with the solution as defined in A.1.4.1 can be carried out on metal from three parts of the cylinder.

Each specimen shall be of the general shape and the dimensions indicated in Figure A.2.

The faces a_1-a_2-a_3-a_4, b_1-b_2-b_3-b_4, a_1-a_2-b_2-b_1 and a_4-a_3-b_3-b_4 are all sawn with a band saw and then carefully trimmed with a fine file. The surfaces a_1-a_4-b_4-b_1 and a_2-a_3-b_3-b_2 which correspond respectively to the inner and outer faces of the cylinder are left in their rough state.

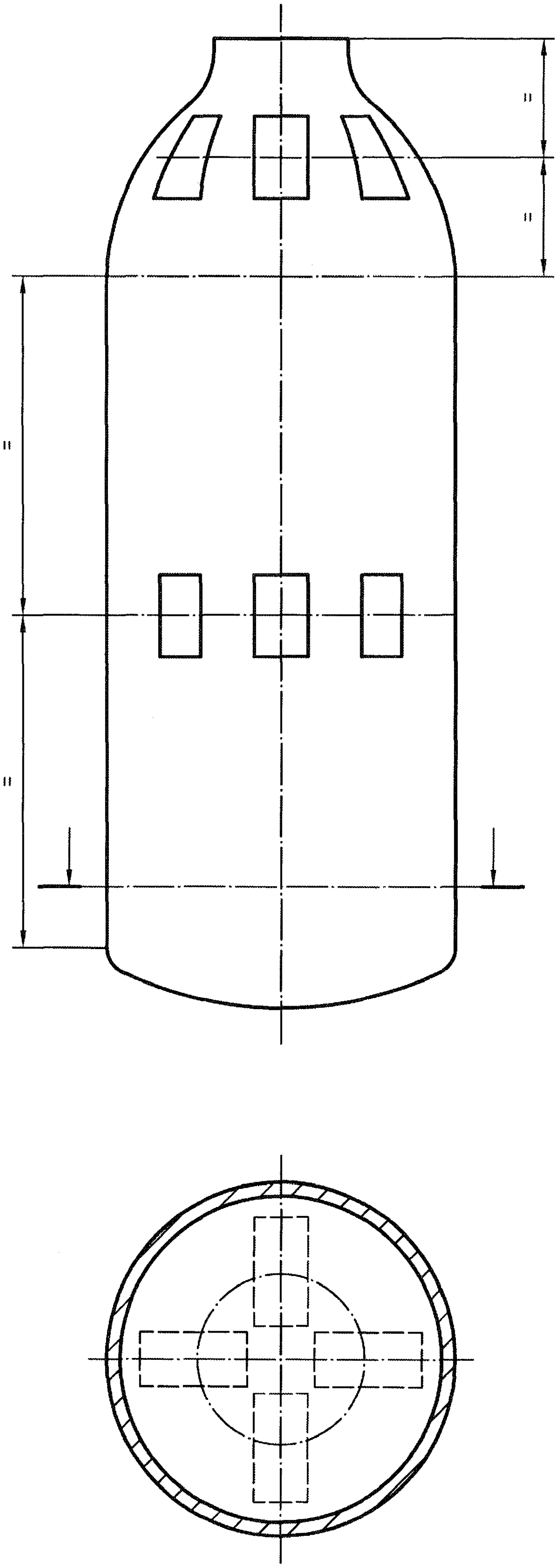
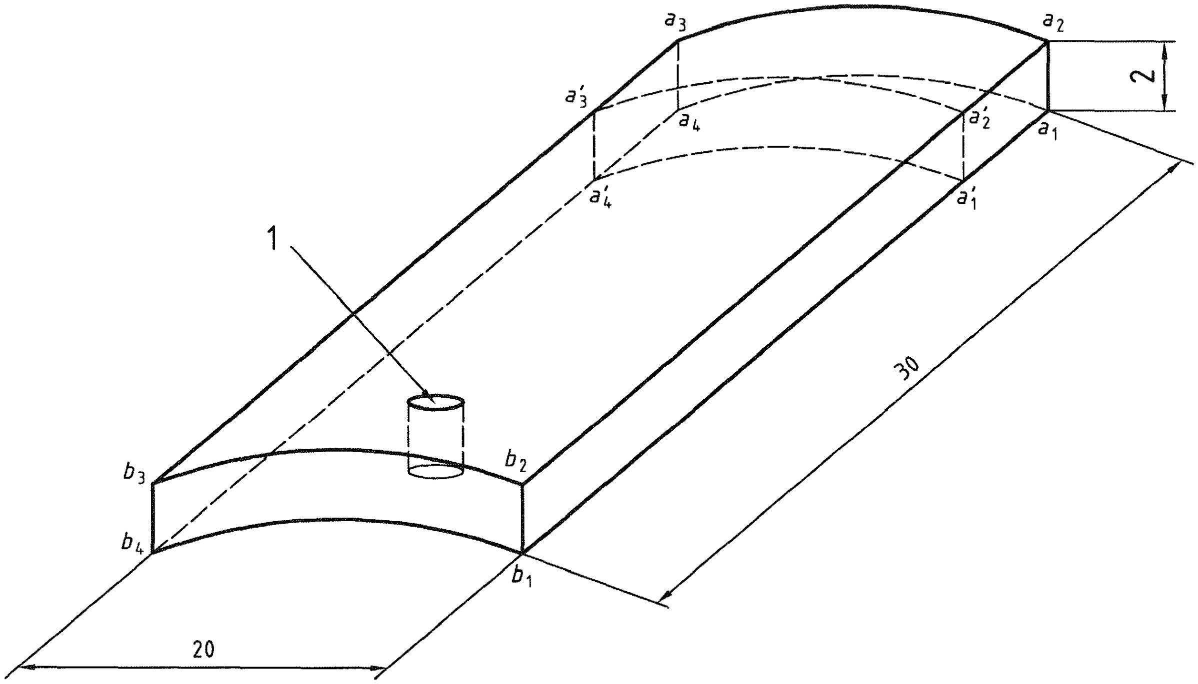


Figure A.1 — Location of specimens

Dimensions in millimetres
± 10 %



Key

1 Hole ∅ 3 mm
2 Thickness of cylinder

Figure A.2 — Specimen shape and dimensions

A.1.3 Preparation of surface before corrosive etching

A.1.3.1 Reagents

A.1.3.1.1 Nitric acid, HNO_3, analytical grade, density 1,33 g/cm^3

A.1.3.1.2 Hydrofluoric acid, HF, analytical grade, density 1,14 g/cm^3 (at 40 %)

A.1.3.1.3 Deionized or distilled water

A.1.3.2 Method

Prepare the following solution in a beaker:

HNO_3 (A.1.3.1.1):	63 cm^3
HF (A.1.3.1.2):	6 cm^3
H_2O (A.1.3.1.3):	931 cm^3

Bring the solution to a temperature of 95 °C.

Treat each specimen, suspended on a wire made of aluminium or another inert material, in this solution for 1 min.

Wash in running water and then in deionized or distilled water (A.1.3.1.3).

Immerse the specimen in nitric acid (A.1.3.1.1) for 1 min at room temperature to remove any copper deposit which may have formed.

Rinse in deionized or distilled water.

To prevent oxidation of specimens they should be plunged, as soon as they have been prepared, into the corrosion bath intended for them (see A.1.4.1).

A.1.4 Performance of test

A.1.4.1 Corrosive solution

The corrosive solution to be used contains 57 g/l of sodium chloride and 3 g/l of hydrogen peroxide.

A.1.4.2 Preparation of the corrosive solution

A.1.4.2.1 Reagents

A.1.4.2.1.1 Sodium chloride, NaCl, crystallized, analytical grade

A.1.4.2.1.2 Hydrogen peroxide, H_2O_2, 100 to 110 volume

A.1.4.2.1.3 Potassium permanganate, $KMnO_4$, analytical grade

A.1.4.2.1.4 Sulfuric acid, H_2SO_4, analytical grade, density 1,83 g/cm^3

A.1.4.2.1.5 Deionized or distilled water

A.1.4.2.2 Titration of hydrogen peroxide

Since hydrogen peroxide is not very stable, it is essential to check its titre before use. To do this take 10 cm^3 of hydrogen peroxide (A.1.4.2.1.2) using a pipette and dilute to 1 000 cm^3 (in a gauged flask) with deionized or distilled water (A.1.4.2.1.5) thus obtaining a hydrogen peroxide solution which will be called C. Using a pipette, place in a conical flask:

— 10 cm^3 of the hydrogen peroxide solution C;

— 2 cm^3 approximately of sulfuric acid (A.1.4.2.1.4).

A solution of permanganate at 1,859 g/l (A.1.4.2.1.3) is used for the titration. The permanganate itself acts as an indicator.

A.1.4.2.3 Explanation of titration

The reaction of the permanganate on the hydrogen peroxide in a sulfuric medium is expressed as:

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

which gives the equivalence: 316 g $KMnO_4$ = 170 g H_2O_2.

Therefore one gram of pure hydrogen peroxide reacts with 1,859 g of permanganate, hence the use of a 1,859 g/l solution of permanganate, which saturates, volume for volume, one gram per litre of hydrogen peroxide. Since the hydrogen peroxide was diluted 100 × to begin with, the 10 cm^3 of the test sample represents 0,1 cm^3 of the original hydrogen peroxide.

By multiplying by ten the number of cubic centimetres of permanganate solution used for the titration, the titre T of the original hydrogen peroxide in g/l is obtained.

A.1.4.2.4 Preparation of the solution

Method for 10 litres:

Dissolve 570 g of sodium chloride (A.1.4.2.1.1) in deionized or distilled water (A.1.4.2.1.5) to obtain a total volume of about nine litres. Add the quantity of hydrogen peroxide (A.1.4.2.1.2) calculated below. Mix and then make up the volume to ten litres with deionized or distilled water.

Calculate the volume of hydrogen peroxide to be put into the solution as follows:

Quantity of pure hydrogen peroxide required: 30 g

If the hydrogen peroxide contains T grams of H_2O_2 per litre, the volume required, expressed in cubic centimetres, will be:

$$\frac{1\,000 \times 30}{T}$$

A.1.4.3 Etching conditions

A.1.4.3.1 The corrosive solution is placed in a crystallizer (or possibly a large beaker), itself placed in a water bath. The water bath is stirred with a magnetic stirrer and the temperature is regulated with a contact thermometer.

The specimen is either suspended in the corrosive solution by a wire made of aluminium (or other inert material) or placed in the solution so that it rests only on the corners, the second method being preferable. The etching time is six hours and the temperature fixed at 30 °C ± 1 °C. Care shall be taken to ensure the quantity of reagent is at least 10 cm^3 per cm^2 of specimen surface

After etching, the specimen is washed in water, immersed for about 30 s in 50 % dilute nitric acid, washed again in water and dried using compressed air.

A.1.4.3.2 A number of specimens may be etched at the same time provided that they are of the same type of alloy and that they are not in contact. The minimum quantity of reagent per unit of specimen surface area shall be adhered to.

A.1.5 Preparation of specimens for examination

A.1.5.1 Apparatus

A.1.5.1.1 Casting dishes, external diameter 40 mm, height 27 mm, wall thickness 2,5 mm

A.1.5.1.2 Epoxy casting resin plus hardener, or equivalent system

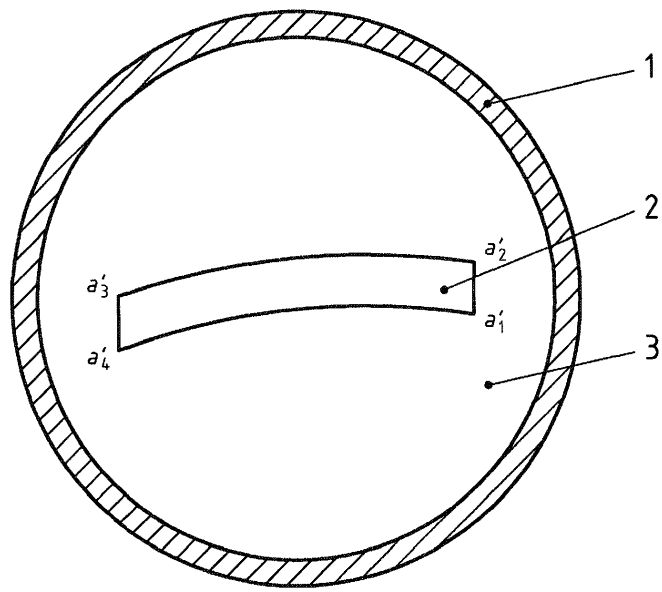
A.1.5.2 Method

Each specimen is placed vertically in a casting dish (A.1.5.1.1) so that it rests on face a_1-a_2-a_3-a_4. Around it is poured a mixture of the epoxy resin and hardener (or equivalent) in the appropriate proportion.

A certain amount of material is removed from face a_1-a_2-a_3-a_4 preferably by lathe, so that,the section a'_1-a'_2-a'_3-a'_4 when examined under the microscope, cannot show corrosion from face a_1-a_2-a_3-a_4. The distance between faces a_1-a_2-a_3-a_4 and a'_1-a'_2-a'_3-a'_4, i.e. the thickness removed by the lathe, shall be at least 2 mm (see Figures A.2 and A.3).

Alternatively, prepare a section by sawing through plane a'_1-a'_2-a'_3-a'_4 (see Figure A.2) to remove a specimen between 5 mm and 10 mm thick (i.e. such that the distance from a'_1 to a_1 is between 5 mm and 10 mm). Mount this specimen in a thermosetting or thermoplastic mounting compound with face a'_1-a'_2-a'_3-a'_4 exposed to allow mechanical polishing.

The section for examination is polished mechanically with abrasive paper, a diamond compound and/or magnesia polishing compound.



Key

1 Casting mould
2 Test piece
3 Epoxy resin and hardener

Figure A.3 — Specimen in casting dish

A.1.6 Micrographic examination of specimens

The examination is intended to assess the degree of penetration of intercrystallization corrosion into each of the two faces which make up the outer and inner surfaces of the cylinder.

The section is first examined at low magnification (e.g. × 40) in order to locate the most corroded areas, and then at a higher magnification, usually about × 300, in order to assess the nature and extent of the corrosion.

A.1.7 Interpretation of micrographic examination

a) For alloys with an equiaxed crystal structure the depth of corrosion shall not exceed the greater of the following two values:

— three grains in the direction perpendicular to the face examined;

— 2 mm.

But in no case shall the depth exceed 0,3 mm.

However, it is permissible for these values to be exceeded locally provided that they are not exceeded in more than four fields of examination at × 300 magnification.

b) For alloys with a crystal structure oriented in one direction through cold working, the depth of corrosion into each of the two faces which make up the internal and external surfaces of the cylinder shall not exceed 0,1 mm.

A.2 Tests for assessing susceptibility to stress corrosion

A.2.1 Principle

The method described below consists of the subjection to stress of rings cut from the cylindrical part of the cylinder, their immersion in brine for a specified period, followed by removal of the brine and exposure to the air for a longer period and repetition of this cycle for 30 d. If there are no cracks after the period of 30 d, the alloy can be considered suitable for the manufacture of gas cylinders.

A.2.2 Tests specimens

Six rings with a width of four times the actual wall thickness or 25 mm, whichever is the greater, are cut from the cylindrical part of the cylinder (see Figure A.4). The specimens shall have a 60 ° cut-out and be subjected to stress by means of a threaded bolt and two nuts (see Figure A.5).

Neither inner nor outer surfaces of the specimens shall be machined.

Dimensions in millimetres

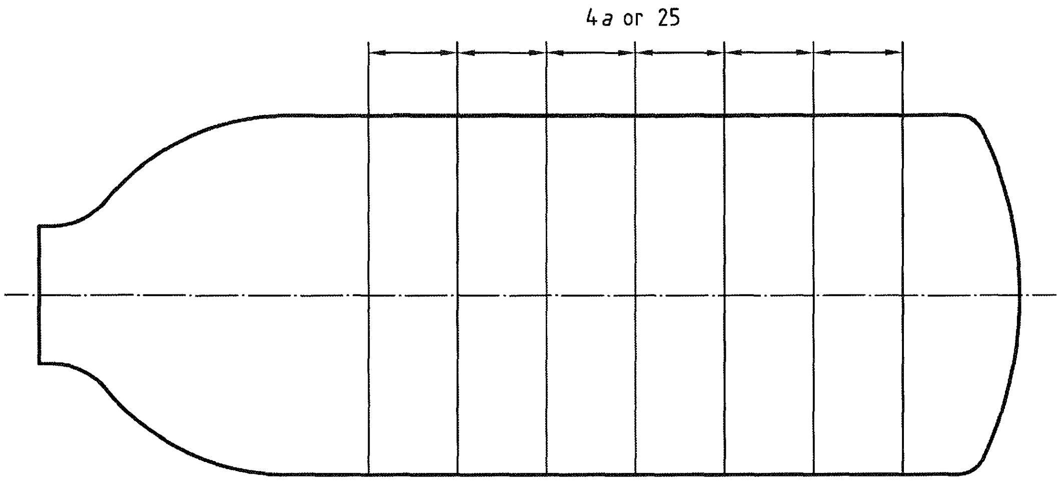


Figure A.4 — Specimen ring locations

A.2.3 Surface preparation before corrosion test

All traces of grease, oil and adhesive used with stress gauges (see A.2.4.2.4) shall be removed with a suitable solvent.

A.2.4 Performance of the test

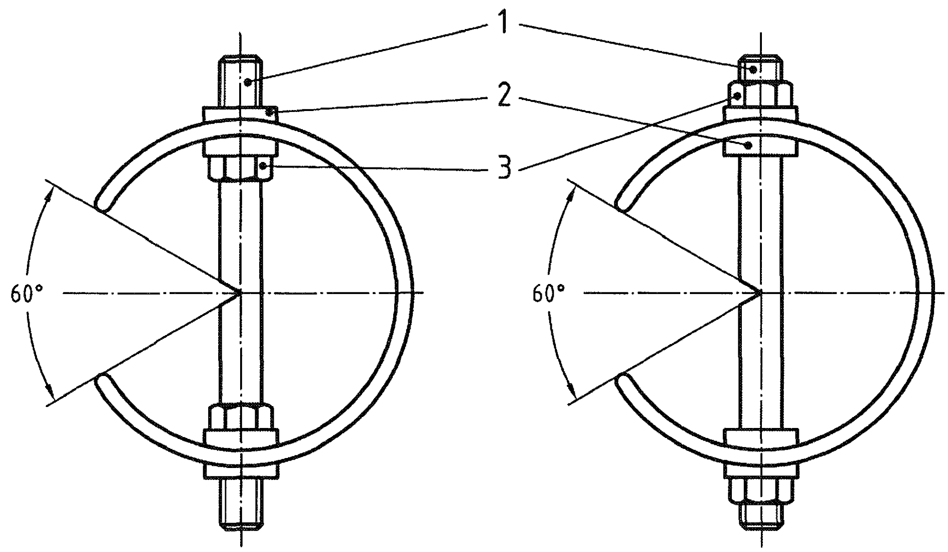
A.2.4.1 Preparation of corrosive solution

The brine is prepared by dissolving 3,5 parts ± 0,1 parts (*m*/*m*) of sodium chloride in 96,5 parts (*m*/*m*) of water.

The pH of the freshly prepared solution shall be in the range 6,4 to 7,2. The pH may be corrected only by using dilute hydrochloric acid or dilute sodium hydroxide.

The solution shall not be topped up by adding the salt solution described in A.2.4.1.1 but only by adding distilled water up to the initial level in the vessel. Topping up may be carried out daily if required.

The solution shall be completely replaced every week.



a) Stressed internally

b) Stressed externally

Key

1 Threaded bar
2 Insulating bush
3 Nut

Figure A.5 — Stressed specimens

A.2.4.2 Applying the stress to the rings

Three of the rings shall be compressed so that the outer surface is under tension. The other three rings shall be expanded so that the inner surface is under tension.

The rings shall be stressed to a maximum as given by:

$$R_e \times F$$

where

R_e is the guaranteed minimum yield stress in MPa;

F is the design stress factor (variable).

The actual stress may be measured by electric stress gauges.

The diameter of the ring to achieve the required stress may be calculated using the following equation:

$$D' = D \pm \frac{\pi R(D - t)^2}{4EtZ}$$

where

D' is the diameter of the ring when compressed (or expanded), in millimetres;

D is the outside diameter of the cylinder, in millimetres;

t is the cylinder wall thickness, in millimetres;

$R = FR_e$ in MPa

E is the modulus of elasticity, in MPa = 70 MPa approximately

Z is a correction factor (see Figure A.6)

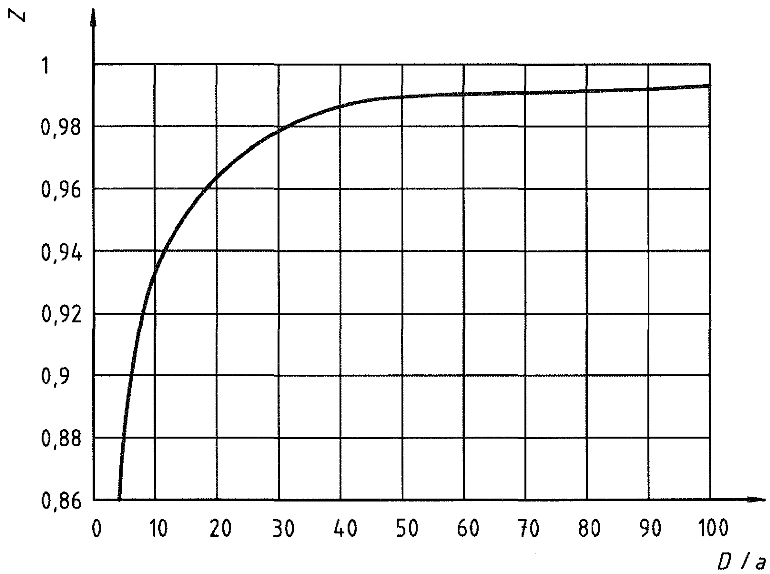


Figure A.6 — Correction factor Z plotted against D/a

It is essential for the nuts and bolts be electrically insulated from the rings and protected from corrosion by the solution.

The six rings shall be completely immersed in the salt solution for 10 min. They are then removed from the solution and exposed to the air for 50 min.

This cycle shall be repeated for 30 d or until a ring breaks, whichever happens first

The specimens shall be visually inspected for any cracks.

A.2.5 Interpretation of results

The alloy shall be considered acceptable for the manufacture of gas cylinders if none of the rings subjected to stress develops any cracks visible to the naked eye, or visible at low-magnification (× 10 to × 30), at the end of the 30 d test period.

A.2.6 Possible metallographic examination

A.2.6.1 In the event of doubt about the presence of cracks (e.g line of pitting), uncertainty may be removed by means of an additional metallographic examination of a section taken perpendicular to the axis of the ring in the suspect area. A comparison is made of the form (inter- or trans-crystalline) and depth of penetration of the corrosion on the faces of the ring subject to tensile and compressive stress.

A.2.6.2 The alloy shall be considered acceptable if the corrosion on each face of the ring is similar. If, however, the face of the ring under tension reveals inter-crystalline cracks which are clearly deeper than those in the face under compression, the ring shall be considered to have failed the test.

A.2.7 Reports

The test report shall contain at least the following information.

a) the name of the alloy and/or its standard number;

b) the composition limits of the alloy;

c) the actual analysis of the cast from which the cylinders were manufactured;

d) the actual mechanical properties of the alloy, together with the minimum mechanical property requirements;

e) the result of the test.

Annex B
(normative)

Test method to determined sustained-load-cracking resistance of aluminium alloy cylinders

B.1 Principle

A fatigue precracked specimen is loaded by a constant load or constant displacement method to a stress-intensity K_{IAPP} equal to a defined value. The specimen is kept in the loaded condition for a specified time and temperature. After the test period, the specimen is examined to assess whether the initial fatigue crack did or did not grow.

If the test specimen exhibits less than or equal to a specified amount of crack growth, then the material is characterized as suitable for gas cylinders with respect to the sustained-load-cracking resistance requirement.

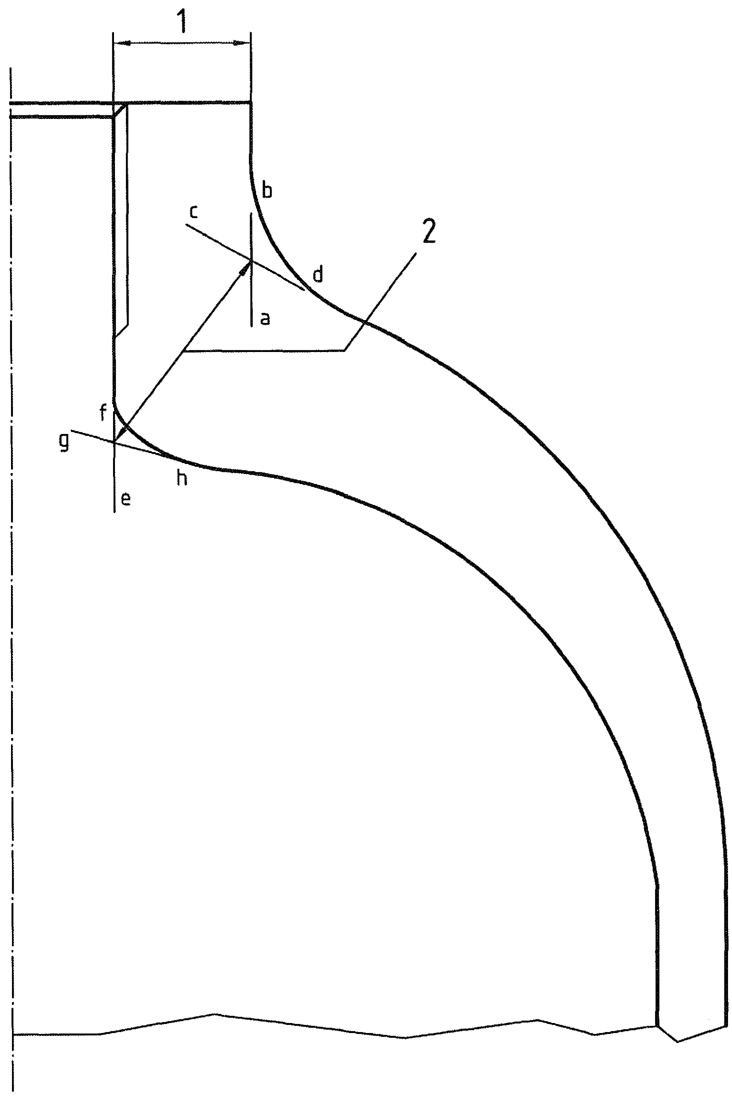
B.2 General

This method covers determination of sustained-load-cracking resistance for aluminum alloy cylinders.

Following the initial qualification for resistance to sustained-load-cracking, this procedure shall only be repeated if any of the conditions a), b), c) or d) listed in 9.1 apply.

Testing shall be conducted using applicable rules in accordance with ISO 7539-6:1989 and the additional rules specified in this document. Rules provided in ISO 7539-6:1989 on corrosive environment need not be satisfied.

Cylinders with nominal neck and shoulder wall thickness $\leqslant$ 7 mm are exempt from the sustained-load-cracking tests. The inspector shall ensure that the neck/shoulder wall thickness of the actual cylinders reasonably represents the quoted nominal figure. Figure B.1 illustrates the neck and shoulder thickness



NOTE ab, cd, ef and gh are tangents initiating at intersecting surfaces

Key

1 Nominal neck thickness
2 Nominal shoulder thickness

Figure B.1 — Illustration of neck and shoulder thickness

B.3 Terms and symbols

The terms and symbols given in ISO 7539-6:1989 as well as the following apply to this annex.

SLC Sustained-load-cracking

K_{IAPP} Applied elastic stress-intensity, in megapascals per square metre

V Crack-mouth opening displacement (CMOD), in millimetres, defined as the mode 1 (also called opening-mode) component of crack displacement due to elastic and plastic deformation, measured at the location on a crack surface that has the greatest elastic displacement per unit load.

E Modulus of elasticity, in megapascals

R_{eSLC} Average of measured yield stress of two specimens from the test cylinder representing the SLC test specimens' location at room temperature, in megapascals. For location of specimens refer to B.4.3.

B.4 Specimen configurations and number of tests

B.4.1 Any one or a combination of specimen geometries of the following listed specimens shall be used for the tests:

— Compact tension test (CTS) specimen, figure 2b, ISO 7539-6:1989;

— Double cantilever beam (DCB) specimen, figure 2c, ISO 7539-6:1989;

— T-type wedge opening (T-WOL) specimen, figure 2d, ISO 7539-6:1989;

— C-shaped specimen, figure 2e, ISO 7539-6:1989.

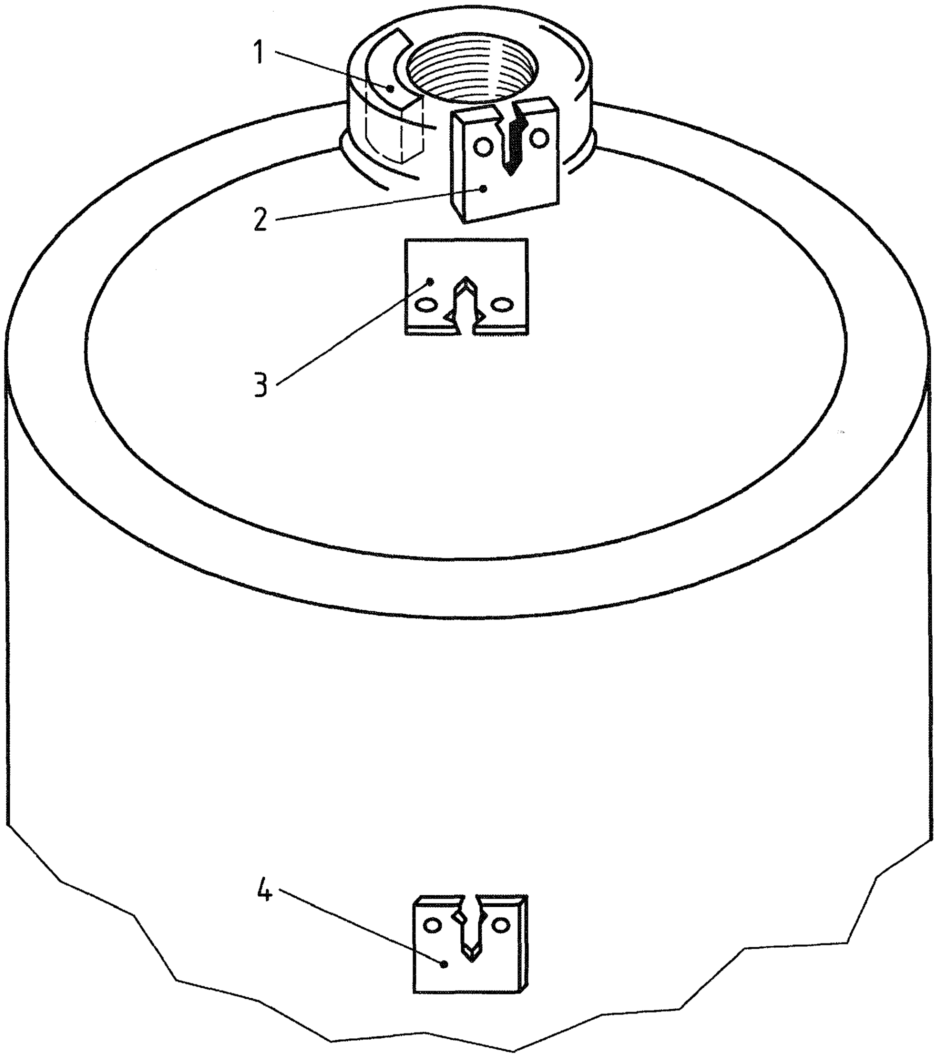
B.4.2 Specimen orientation shall be Y-X or Y-Z as shown in Figure B.2.

B.4.3 At least three specimens from the cylinder wall and if possible three specimens from the shoulder and three specimens from the neck shall be tested. At each location the three specimens shall be taken as close to each other as possible. One specimen from each location shall be used for SLC testing and two from each location for tensile testing (see Figure B.2).

B.4.4 Flattening of specimen blanks is not allowed.

B.4.5 If test specimen thickness cannot be obtained from the specified location or locations to meet the validity requirements given in B.6.7, then the thickest possible specimen shall be tested. The specimen shall be taken when the mechanical properties have been fully developed in the cylinder but before any external machining of the neck/shoulder area.

B.4.6 When it is impossible to obtain full size tensile specimens, small size specimens in accordance with ISO 6892 are permitted for determination of yield stress.



Key

1 Neck specimen Y – Z

2 Neck specimen Y – X

3 Shoulder specimen Y – X
NOTE Specimen should be taken as close as possible to neck. Notch direction should be toward neck as shown.

4 Cylinder wall specimen Y – X

Figure B.2 — Orientation of neck, shoulder and cylinder wall specimens

B.5 Fatigue precracking

All rules provided in clause 6 of ISO 7539-6:1989 shall be met, except in 6.4 where the fatigue crack length (a, mm) requirement should be satisfied by the following equation:

$$a \geqslant 1{,}27 \left(\frac{K_{\mathrm{IAPP}}}{R_{\mathrm{eSLC}}} \right)^2 \times 1000$$

B.6 Specimen testing procedure

B.6.1 All rules of Clause 7 of ISO 7539-6:1989 shall be satisfied, except that the rules in the following listed subclauses need not be satisfied:

7.1.2, 7.1.3, 7.1.4, 7.1.5, 7.2.1, 7.2.2, 7.2.4, 7.2.5

B.6.2 Load the fatigue precracked specimens to a stress-intensity K_{IAPP} determined from the following equation:

$$K_{\mathrm{IAPP}} = 0{,}056\ R_{\mathrm{eSLC}}$$

Specimens shall be loaded by a suitable constant displacement or constant load method.

B.6.3 For specimens loaded by a constant displacement method, the loading shall be determined by either the non-monitored load method or the monitored load method and shall meet the following requirements.

a) For the non monitored load method:

1) at the end of the test, record the crack mouth opening displacement (CMOD) before unloading;

2) unload the specimen;

3) reload the specimen up to the measured CMOD in a device suitable for load measurement, record the load and use this load in the K_{IAPP} calculations. This calculated K_{IAPP} shall be equal to or greater than the calculated K_{IAPP} value from B.6.2.

b) For the monitored load method:

1) the final load at the end of the test period shall be applied in the K_{IAPP} calculations;

2) this calculated K_{IAPP} shall be equal to or greater than the calculated K_{IAPP} value from clause B.6.2.

B.6.4 Testing using the constant displacement method:

a) for testing of CTS specimens at a constant displacement loading, use the following equations to determine V (see B.10.1 for further information):

$$V = \frac{K_{\mathrm{IAPP}}\,(\sqrt{W})}{(0{,}032)\,(E)\,(f(x))\,(\sqrt{B / B_{\mathrm{N}}})}$$

$$f(x) = \frac{2{,}24\,(1{,}72 - 0{,}9x + x^2)\,(\sqrt{1-x})}{(9{,}85 - 0{,}17x + 11x^2)}$$

$$x = \frac{a}{W}$$

b) for testing of C-shaped specimens at a constant displacement loading, use the following equations (see B.10.2 for further information):

For specimens with $X/W = 0$

$$V = \frac{(K_{\mathrm{IAPP}})\,(\sqrt{W})\,(P_1)\,[0{,}43\,(1 - r_1 / r_2) + Q_1]}{(0{,}032)\,(E)\,(Y)}$$

For specimens with $X/W = 0{,}5$

$$V = \frac{(K_{IAPP})(\sqrt{W})(P_2)[0{,}45(1 - r_1 / r_2) + Q_2]}{(0{,}032)(E)(Y)}$$

where

Y = see ISO 7539-6:1989, figure 5e;

$P_1 = (1 + a/W) / (1 - a/W)^2$;

$Q_1 = 0{,}542 + 13{,}137\,(a/W) - 12{,}316\,(a/W)^2 + 6{,}576\,(a/W)^3$;

$P_2 = (2 + a/W) / (1 - a/W)^2$;

$Q_2 = 0{,}399 + 12{,}63\,(a/W) - 9{,}838\,(a/W)^2 + 4{,}66\,(a/W)^3$.

c) the stress-intensity factor equations provided in ISO 7539-6:1989 shall be used in testing of DCB and T-WOL specimens in the constant displacement test method.

B.6.5 Testing using the constant loading method:

a) for testing DCB specimens at a constant load, the following equation shall be used (see B.10.3 for further information):

$$K_{IAPP} = \left[\frac{P_a}{BH^{3/2}}\right]\left[3{,}46 + \frac{2{,}38H}{a}\right]$$

The above equation shall satisfy the following validity requirements.

$2 \leqslant a/H \leqslant 10$

$W \geqslant a + 2H$

b) for testing of CTS, T-WOL and C-shaped specimens at a constant load, the stress-intensity factor equations provided in ISO 7539-6:1989 shall be used.

B.6.6 The loaded specimens shall be tested for 90 days at room temperature.

B.6.7 The validity equation provided in 7.3.6(e) of ISO 7539-6:1989 shall be replaced by the following equation. All specimens shall meet the validity requirements except as exempted in B.4.5.

$$a,\ B,\ B_n,\ (W - a) \geqslant 1{,}27 \left(\frac{K_{IAPP}}{R_{eSLC}}\right)^2 (1000)$$

B.6.8 If the additional test referred to in B.7.4 is required then repeat the entire procedure using only constant load conditions as described in B.6.5 for a period of 180 d at room temperature.

B.7 Crack growth examination

B.7.1 After the specified test period, unload the specimen, fatigue the specimen at maximum stress intensity not exceeding 0,6 K_{IAPP} till the crack advances by at least one millimetre. After fatigue cracking, break open the specimen.

B.7.2 Measure the distance between the two pre- and post-fatigue cracks using a scanning electron microscope (SEM). Measurements shall be taken perpendicular to the pre- and post-fatigue cracks at 25 % B, 50 % B and 75 % B locations. Calculate the average of these three values.

B.7.3 If the average measured distance between the two fatigue cracks does not exceed 0,16 mm, the specimen passes the test. If all specimens pass, the alloy/process is qualified (see also clause B.8).

B.7.4 If the average measured values from B.7.3 exceed 0,16 mm, the alloy/process may be qualified if, when subjected to the test described in B.6.8, the average measured distance between the two fatigue cracks does not exceed 0,3 mm. B.7.1 and B.7.2 shall also apply.

B.8 Cylinder thickness qualification

If the validity requirements of B.6.7 are not met, then the material is suitable up to the maximum thickness of the cylinder location from where the specimens were taken provided the specimens meet the other requirements of this test method. The material is suitable for all thicknesses if the specimens meet the validity requirements of B.6.7 and the other requirements of this test method.

B.9 Report

The information described in ISO 7539-6:1989 clause 8 /with the exception of 8.5) shall be reported. The report shall indicate if the validity criteria are met or not and shall include an SEM micrograph as mentioned in B.7.2. The report shall be kept on file permanently as a record that the cylinder alloy/process has been tested and found acceptable.

B.10 Bibliography

B.10.1 ASTM E1221-88, *Standard Test Method for Determining Plane-Strain Crack Arrest Fracture Toughness* K_{IA} *of Ferritic Steels*, paragraph 9.2.1.

B.10.2 ASTM E399-90, *Test Method for Plane-Strain Fracture Toughness Testing of Metallic Materials*, Paragraph A5.5.5.

B.10.3 H. Tada, P. Paris, G. Irwin, *The Stress Analysis of Cracks Handbook*, 2nd Edition, Pg. 2.36, 1985, Paris Production Inc., St. Louis, Missouri, 63105, USA.

Annex C
(informative)

Typical type approval certificate

This annex provides an example of a suitable form of a type approval certificate. Other formats are also acceptable.

TYPE APPROVAL CERTIFICATE

....

Issued by (Authorized inspection authority)

....

applying ISO-Standard...

concerning

SEAMLESS ALUMINIUM GAS CYLINDERS

Approval No. .... Date ....

Type of cylinder: ....

(Description of the family of cylinders (Drawing No.) which has received type approval)

p_h................................ bar D_{min} .... mm D_{max} .... mm a'........................... mm

Shape of base.. b.. mm

L_{min} .... mm L_{max} .... mm V_{min}................................ L V_{max} L

Material and Heat treatment: ....

Material and Characteristics: Material:.......................... R_e:................................... MPa R_g:..................MPa

Manufacturer or agent...

(Name and address of manufacturer or its agent)

....

....

All information may be obtained from ....

(Name and address of approving body)

....

....

Date .... Place ....

....

(Signature of Inspector)

Annex D
(informative)

Acceptance certificate

This annex provides an example of a suitable form of acceptance certificate. Other formats are also acceptable.

ACCEPTANCE CERTIFICATE

Acceptance Certificate for Seamless steel cylinders No........

A consignment of ...... cylinders consisting of .... test batches have been inspected and tested for .... according to ISO 7866

(designation or type of gas) ....

Manufacturer's Nos: .... to ....

Owner's Nos.: (2): .... to ....

Manufacturer: .... Manuf. Order No: ....

Address: ....

Country: .... Date: ....

Owner/Customer (1): .... Purchase Order No: ....

Address: ....

Country: .... Date: ....

TECHNICAL DATA

Water capacity:	nominal (1) minimal (1)	L L	Nominal length (without cap and without valve)	mm
Test pressure p_h:		bar	Outside diameter D:	mm
Working pressure (1) 15° C - p15:		bar	Min. wall thickness a:	mm
Max. filling charge (1)		kg	Drawing No.	

Material:

Specified analysis (3):	Si %	Fe %	Cu %	Mn %	Mg %	Cr %	Ni %	Zn %	Ti %	Zr %	Pb %	Others
max.												
min.												

Heat Treatment (1):

Stamp Markings (3):

....

Date The Manufacturer

(1) Delete as applicable
(2) If required by customer
(3) To be quoted or drawing to be attached

ACCEPTANCE TESTS

1. Measurements taken on one representative cylinder of the batch (1)

Test No. or Batch No. or Cylinder No.	Covering serial Nos. .... to	Water capacity L	Mass empty kg	Min. measured thickness (mm) wall	 base

2. Mechanical tests (1)

		Tensile test			Hardness	Bend or flattening test
Test No.	Cast No.	Yield stress R_{ea} MPa	Tensile strength R_m MPa	Elongation A %	HB	180° without cracking
Min. values:						

This is to certify that the cylinders covered by this Acceptance Certificate have passed the hydraulic pressure test and all the other tests as required in clause 10 and 11 of ISO 7866:1999 and they are in full accordance with this ISO Standard.

Special remarks: ....

....

....

On behalf of: ....

....

....
Date

....
(Signature of Inspector)

(1) Need not be filled in if test reports are attached.

Bibliography

[1] ISO 209-1:1989, *Wrought aluminium and aluminium alloys — Chemical composition and forms of products — Part 1: Chemical composition.*

[2] ISO 10920:1997, *Gas cylinders — 25E taper thread for connection of valves to gas cylinders — Specification.*

[3] ISO 11191:1997, *Gas cylinders — 25E taper thread for connection of valves to gas cylinders — Inspection gauges.*

ICS 23.020.30

Price based on 41 pages