

Transportable gas cylinders — Specification for the design and construction of refillable transportable welded aluminium alloy gas cylinders

The European Standard EN 12862:2000 has the status of a
British Standard

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National foreword

This British Standard is the official English language version of EN 12862:2000. It supersedes BS 5045-5:1986 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PVE/3, Gas containers, to Subcommittee PVE/3/3, Transportable gas containers — Cylinder design and construction and testing at time of manufacture, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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Summary of pages

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Transportable gas cylinders - Specification for the design and construction of refillable transportable welded aluminium alloy gas cylinders

Bouteilles à gaz transportables – Spécification pour la conception et la construction des bouteilles à gaz rechargeables transportables soudées en alliage d'aluminium

Ortsbewegliche Gasflaschen – Gestaltung und Konstruktion von wiederbefüllbaren ortsbeweglichen geschweißten Gasflaschen aus Aluminiumlegierung

This European Standard was approved by CEN on 8 April 2000.

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 23, Transportable gas cylinders, the Secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2000, and conflicting national standards shall be withdrawn at the latest by November 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This European Standard has been submitted for reference into the RID and/or the technical annexes of the ADR. Therefore in this context the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present standard are normative only when the standards themselves are referred to in the RID and/or the technical annexes of the ADR.

This standard is primarily for industrial gases other than LPG but may also be applied for LPG. However for dedicated LPG cylinders, see prEN 13110:1997 - *Transportable refillable welded aluminium cylinders for LPG - Design and construction* prepared by CEN/TC 286 - *Liquefied petroleum gas equipment and accessories*.

Introduction

The purpose of this standard is to provide a specification for the design, manufacture, inspection and approval of refillable transportable welded aluminium alloy gas cylinders. The specifications given are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and control during manufacture, of cylinders in common use in the countries of the CEN members.

1 Scope

This standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable transportable welded aluminium alloy gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases.

This standard includes requirements for spherical cylinders.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 287-2	Approval testing of welders – Fusion welding – Part 2 Aluminium and aluminium alloys
EN 288-4:1992	Specification and approval of welding procedures for metallic materials - Part 4: Welding procedure tests for the arc welding of aluminium and its alloys
EN 910:1996	Destructive tests on welds in metallic materials - Bend tests
EN 962:1996	Transportable gas cylinders - Valve protection caps and valve guards for industrial and medical gas cylinders - Design, construction and tests
EN 970	Non-destructive examination of welds - Visual examinations
EN 1089-1:1996	Transportable gas cylinders - Gas cylinder identification (excluding LPG) - Part 1: Stampmarking
EN 1435	Non-destructive examination of welds - Radiographic examination of welded joints
EN 10002-1	Metallic materials - Tensile testing - Part 1: Method of test
EN 10003-1	Metallic materials - Brinell hardness test - Part 1: Test Method
EN 30042:1994	Arc-welded joints in aluminium and its weldable alloys - Guidance on quality levels for imperfections (ISO 10042:1992)

EN ISO 7539-6:1995	Corrosion of metals and alloys - Stress corrosion testing - Preparation and use of pre-cracked specimens (ISO 7539-6:1989)
EN ISO 11114-1:1997	Transportable gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 1: Metallic materials (ISO 11114-1:1997)
EN ISO 13341:1997	Transportable gas cylinders - Fitting of valves to gas cylinders (ISO 13341:1997)
EURONORM 6:1955	Bend test for steel
EURONORM 12:1955	Bend test for steel sheet and strip less than 3 mm thick

3 Definitions and symbols

For the purposes of this standard the following definitions and symbols apply.

3.1 Definitions

3.1.1 yield stress: Value corresponding to the 0,2 % proof stress (non proportional elongation), $R_{p0,2}$.

3.1.2 solution heat treatment: A thermal treatment which consists of heating the products to a suitable temperature, holding at that temperature long enough to allow constituents to enter into solid solution and cooling rapidly enough to hold the constituents in solution.

3.1.3 quenching: Controlled rapid cooling in a suitable medium to retain the solute phase in solid solution.

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

3.1.5 batch: A 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 and subjected to the same heat treatment for the same duration of time. The lengths of the cylinders in the heat treatment batch may vary by up to 12 %.

3.1.6 design stress factor (F) (variable): The ratio of equivalent wall stress at test pressure (p_h) to guaranteed minimum yield stress (R_e).

3.2 Symbols

A	Percentage elongation, determined by the tensile test 7.2.3
a	Calculated minimum thickness, in millimetres, of the cylindrical or spherical shell
a'	Guaranteed minimum thickness, in millimetres, of the cylindrical spherical shell
b	Guaranteed minimum thickness, in millimetres, at the centre of a convex base
D_o	Nominal outside diameter, in millimetres, of the cylinder, spherical cylinder or domed end (see figure 2)
D_i	Nominal inside diameter, in millimetres, of the cylinder, spherical cylinder or domed end (see figure 2)
d	Diameter of former, in millimetres (see figure 4)
F	Design stress factor (variable) (see 3.1.6)
h_i	Internal height, in millimetres, of semi-ellipsoidal or torispherical domed end (convex head or base end) (see figure 2)
h_e	Variable used in the determination of shape factor, K (see 5.3.1)
h_o	External height, in millimetres, of a semi-ellipsoidal or torispherical domed end (convex head or base end) (see figure 2 and note below)
K	Shape factor for a semi-ellipsoidal or torispherical domed end, obtained according to the values h_e/D_o and a/D_o , with interpolation where necessary, (see figure 1)
L_o	Original gauge length, in millimetres, according to EN 10002-1
n	The ratio of the diameter of the bend test former to actual thickness of test piece (t)
p_b	Measured burst pressure, in bar ¹⁾ above atmospheric pressure
p_h	Hydraulic test pressure, in bar ¹⁾ above atmospheric pressure
p_{lc}	Lower cyclic pressure, in bar ¹⁾ above atmospheric pressure
p_y	Observed yield pressure which produces a permanent volumetric expansion of 0,2 %, in bar ¹⁾ above atmospheric pressure
R_e	Minimum guaranteed value of yield stress (see 3.1.1), in megapascals, for the finished cylinder

¹⁾ 1 bar = 10⁵ Pa = 10⁵ N/m²

R_{ea}	Actual value of yield stress, in megapascals, determined by the tensile test 7.2.3.
R_{g}	Minimum guaranteed value of tensile strength, in megapascals, for the finished cylinder
R_{m}	Actual value of tensile strength, in megapascals, determined by the tensile test 7.2.3
r_{i}	Internal knuckle radius, in millimetres, of torispherical end [see figure 2c)]
r_{i}'	Internal radius, in millimetres, of dishing of torispherical end [see figure 2c)]
r_{o}	External knuckle radius, in millimetres, of torispherical end [see figure 2c)]
r_{o}'	External radius, in millimetres, of dishing of torispherical end [see figure 2c)]
s_{f}	Straight flange length, in millimetres, for semi-ellipsoidal and torispherical domed ends [see figure 2b) and 2c)]
S_{o}	Original cross-sectional area of tensile test piece, in square millimetres, according to EN 10002-1
t	Actual thickness of test specimen, in millimetres
t_{e}	Calculated minimum thickness, in millimetres, of a domed end
w	Width, in millimetres, of tensile test piece
V_{exp}	Volumetric expansion attained at burst, expressed as a percentage of the initial volume (see 7.3)
Z	Stress reduction factor (see 5.2.1)

4 Materials

4.1 General provisions

4.1.1 Aluminium alloys may be used to produce gas cylinders provided that they satisfy the requirements of the corrosion resistance tests defined in annex A, and meet all other requirements of this standard including annex B.

The alloys most commonly used for the fabrication of gas cylinders are those given in table 1.

4.1.2 After the completion of all welding (including that of the attachments) and before the hydraulic test each cylinder shall be heat treated as required to meet the design criteria.

4.2 Heat Treatment

4.2.1 *Heat treatable alloys*

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

4.2.2 *Non-heat treatable alloys*

The manufacturer shall specify on the prototype testing 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 treatment shall be carried out and the temperature and time at temperature shall be identified by the manufacturer.

4.2.3 *Control of specified heat treatment*

During the heat treatment, the manufacturer shall comply with the specified temperatures and durations, within the following ranges:

a) Temperatures:

Solution temperature:	maximum range 20 °C;
Artificial ageing temperature:	maximum range 20 °C;
Stabilizing temperature:	maximum range 20 °C.

b) Durations

Time cylinders actually spend at temperature during treatments:	
All treatments:	maximum range 20 %.

4.3 Gas/material compatibility

Gas/material compatibility shall be verified as specified in EN ISO 11114-1:1997.

Table 1 - Chemical composition of aluminium alloys

Type of alloy AA ¹⁾ registered designation	Type ²⁾		Chemical composition - weight %											
			Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Others		Aluminium
												Each	Total	
6082	A	min	0,7	-	-	0,40	0,60	-	-	-	-	-	-	Remainder
		max	1,3	0,50	0,10	1,0	1,2	0,25	0,20	0,10	0,0030	0,05	0,15	
-	B	min	1,2	-	-	0,8	1,0	-	-	-	-	-	-	Remainder
		max	1,6	0,5	0,1	1,0	1,4	0,1	0,2	0,2	0,0030	0,05	0,15	
6063	C	max	0,2	-	-	-	0,4	-	-	-	-	-	-	Remainder
		min	0,7	0,5	0,1	0,3	0,9	0,1	0,2	0,2	0,0030	0,05	0,15	
¹⁾ AA is the Aluminum Association Inc., 900 19th Street N.W., Washington D.C., 20006-2168, USA.														
²⁾ Type A and Type B may be used for the body and Type C for the non pressure containing part.														

5 Design

5.1 General provisions

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

5.1.2 For calculation purposes the value of the yield stress (R_e) is limited to a maximum of $0,85 R_g$ for aluminium alloys.

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

5.1.4 For dissolved gases, the manufacturing process of the porous mass can modify the characteristics of the aluminium alloy used. This shall be considered when designing the shell.

5.2 Calculation of wall thickness

5.2.1 *Wall thickness of cylindrical shell*

The guaranteed minimum thickness of the cylindrical shell (a') shall not be less than the thickness calculated using the equation:

$$a = \frac{D_o}{2} \left(1 - \sqrt{\frac{10 F Z R_e - \sqrt{3} \times p_h}{10 F Z R_e}} \right)$$

where: the value of F is the lesser of $\frac{0,65}{(R_e / R_g)}$ or 0,77;

the value of Z is dependent on the amount of non-destructive examination (NDE) and type of cylinder and shall be as specified in table 2.

R_e/R_g shall be limited to 0,85.

The manufacturer may choose between 100 % NDE of welds or spot checks as defined as follows:

- for circumferential welds (including of bung or boss) 25 mm on each side of the weld overlap shall be examined;
- for longitudinal welds 100 mm beyond intersection of the circumferential/longitudinal weld and 25 mm on each side of the circumferential weld shall be examined.

Table 2 - Stress reduction factor Z

Cylinder Type		High Pressure ($p_h > 60$ bar)	Low Pressure ($p_h \leq 60$ bar)
		Stress reduction factor Z	
Without longitudinal welds	100 % of welds NDE tested	0,95	1,00
	Welds spot checked	0,90	0,95
With longitudinal welds	100 % of welds NDE tested	0,90	0,95
	Welds spot checked	0,85	0,90

The calculated minimum thickness shall also satisfy the equation:

$$a \geq \frac{D_o}{200} + 1,5 \text{ mm}$$

When choosing the guaranteed value of the wall thickness of the cylindrical shell (a'), the manufacturer shall take into account all the test requirements for prototype and production testing, particularly the burst test requirements of 7.3.2.2.

The burst ratio (p_b/p_h) shall be determined by test and shall be as follows:

- for low pressure cylinders ($p_h \leq 60$ bar), burst ratio $> 2,0$;
- for high pressure cylinders ($p_h > 60$ bar), burst ratio $\geq 1,6$.

5.2.2 Wall thickness of spherical cylinder

The thickness of the wall shall not be less than the values given by the following equations:

- 1) $a = (p_h D_i) / (40 F Z R_e - 4,5 p_h)$
- 2) $a = (p_h D_o) / (40 F Z R_e - 2,5 p_h)$
- 3) $a = 2,48 \sqrt{D_i / R_g}$

where the values of F and Z shall be as defined in 5.2.1.

5.3 Design of ends (heads and bases)

5.3.1 Thickness of domed ends

The minimum thickness of a hemispherical domed end shall be equal to the minimum thickness of the cylindrical shell a .

The minimum thickness of a semi-ellipsoidal or torispherical domed end shall be the greater of:

- a) the thickness of the cylindrical wall; or
- b) the value calculated from equation:

$$t_e = aK$$

where K shall be as determined from figure 1.

For a semi-ellipsoidal end, $h_e = h_o$

For a torispherical end, h_e is the lesser of h_o , $\frac{D_o^2}{4r_o'}$ or $\sqrt{\left(\frac{D_o r_o}{2}\right)}$

NOTE The external height of a torispherical domed end (h_o), can be determined from:

$$h_o = r_o' - \sqrt{\left\{\left(r_o' - \frac{D_o}{2}\right) \times \left(r_o' + \frac{D_o}{2} - 2r_o\right)\right\}}$$

5.3.2 Limitations of shape (see figure 2)

The shape of the ends shall be subject to the following limitations.

- a) For a torispherical end, r_i' shall not be greater than D_o .
- b) For a torispherical end, r_i shall be not less than $0,1 D_i$ and not less than three times the actual thickness of the end as manufactured.
- c) For a semi-ellipsoidal end the ratio h_o/D_o shall be not less than 0,192.
- d) s_f shall be not less than $0,3 \sqrt{(D_o t_e)}$.

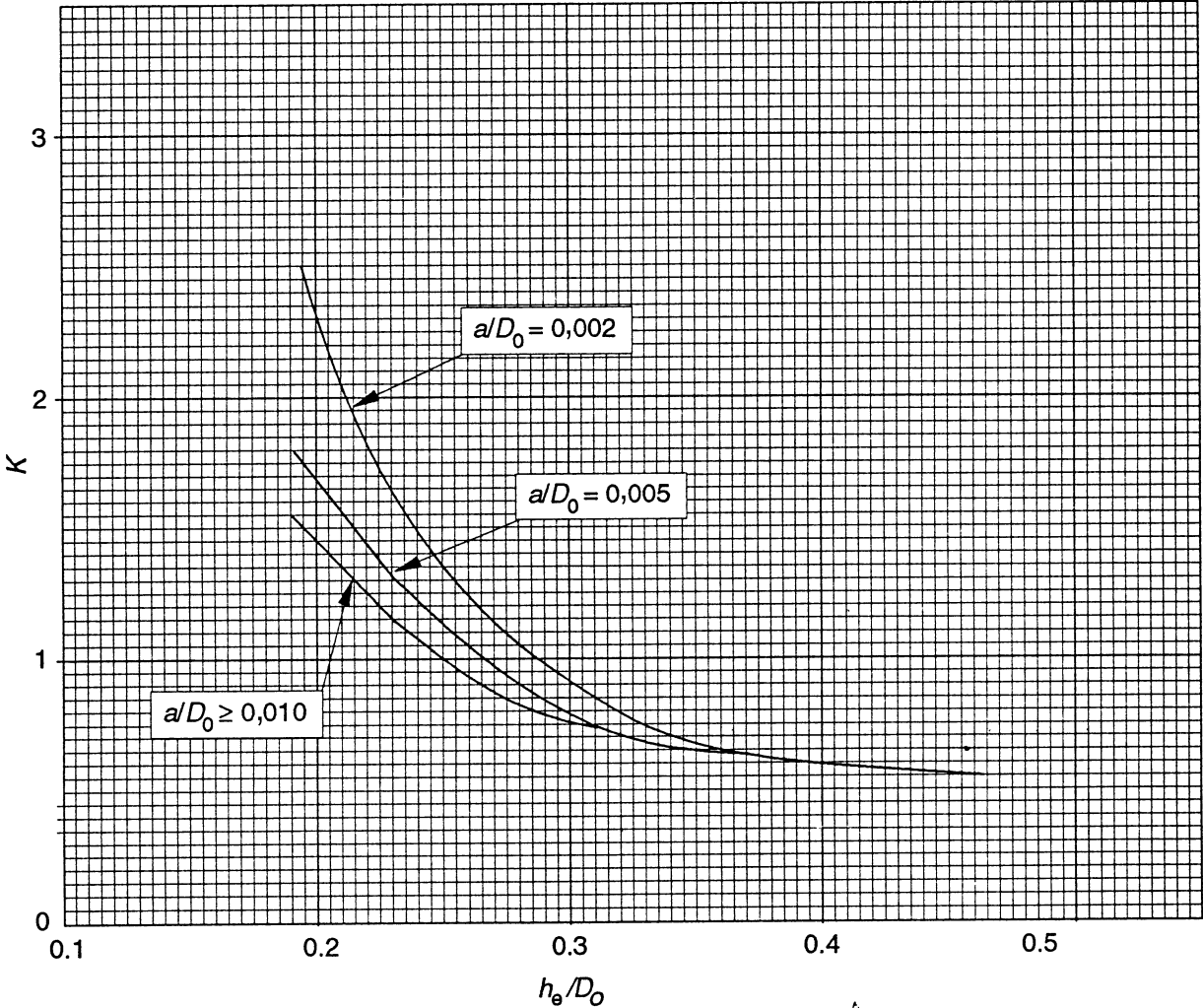


Figure 1a) - Shape factor K

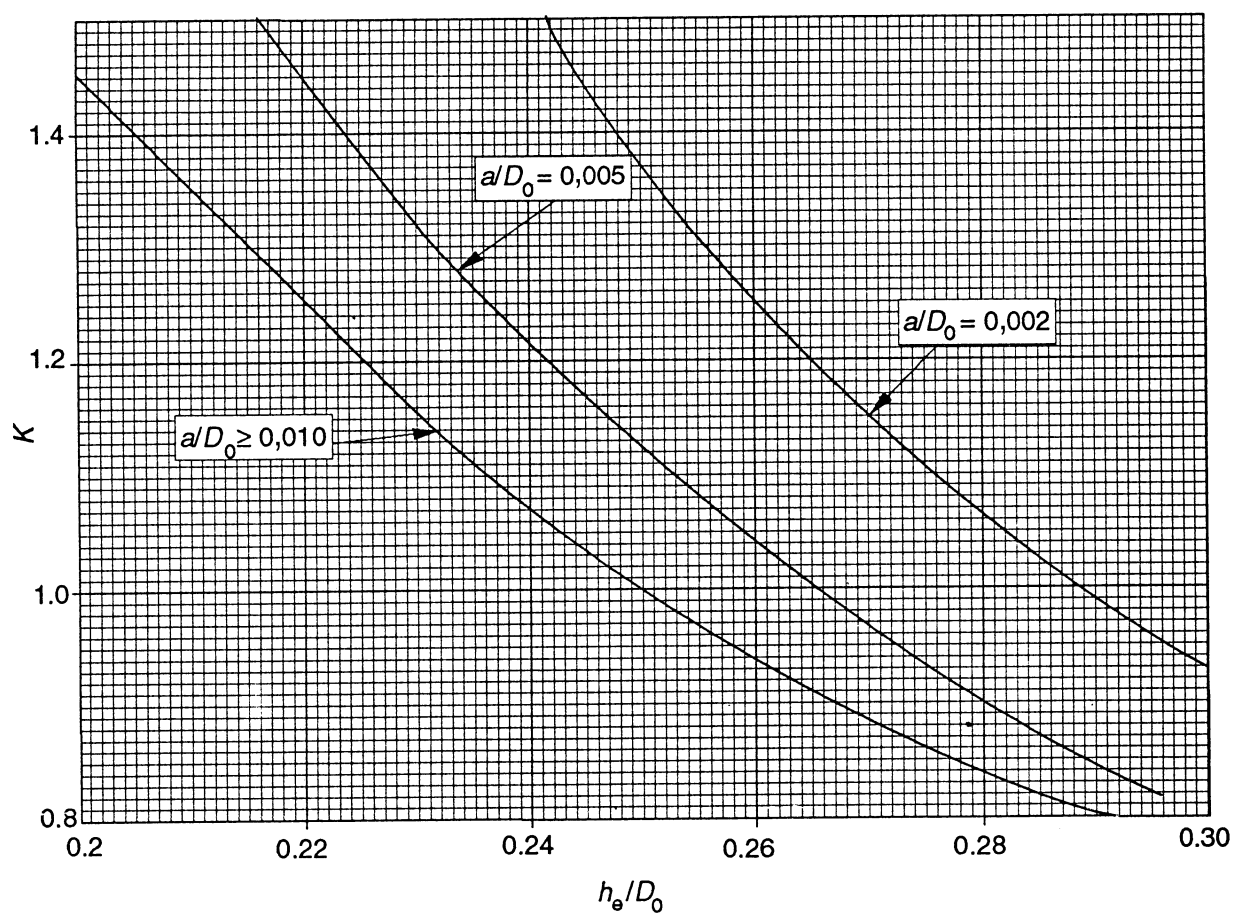
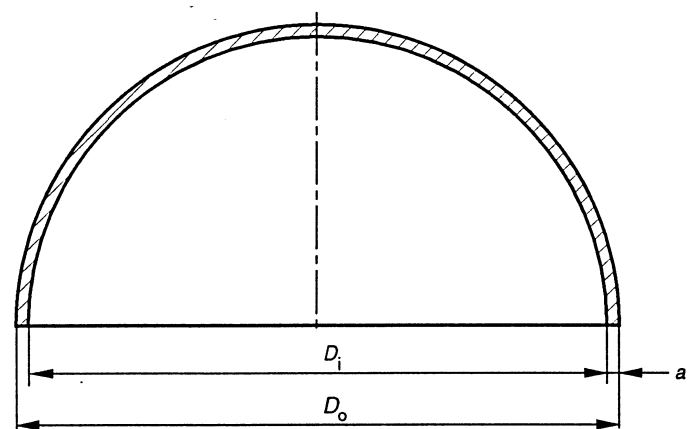
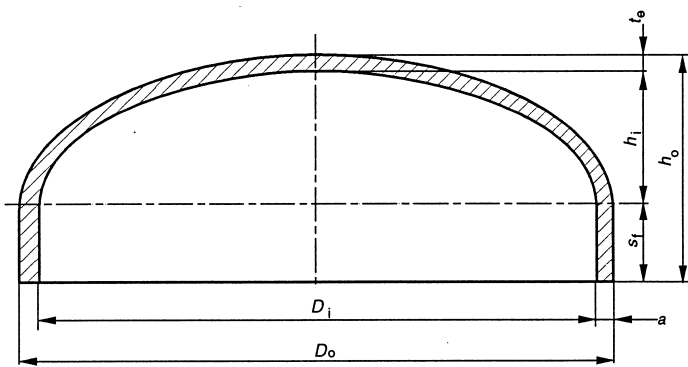


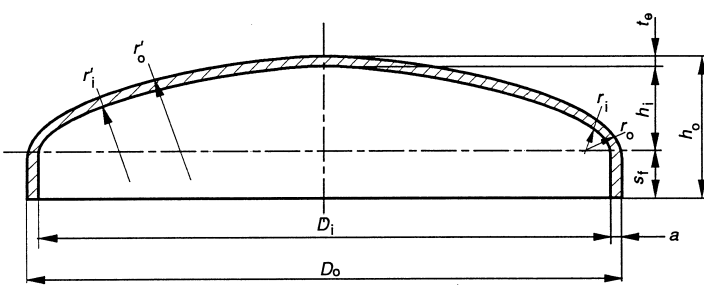
Figure 1b) - Shape factor K [enlargement of figure 1a)]



a) Hemispherical



b) Semi-ellipsoidal



c) Torispherical

Figure 2 - Domed ends

5.4 Neck design

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 the fitting of the valve. The torques specified in EN ISO 13341:1997 shall not be exceeded, since this could result in permanent damage to the cylinder. Where the cylinder manufacturer specifies a lower maximum torque than that indicated in EN ISO 13341:1997 (but within the range of EN ISO 13341:1997), the manufacturer shall notify any such requirements to the purchaser of aluminium alloy cylinders.

5.5 Foot-rings

As agreed between the parties, a foot-ring, if provided shall be sufficiently strong and made of material compatible with that of the cylinder. In addition, the shape should preferably be cylindrical and shall give the cylinder sufficient stability. The foot-ring shall be secured to the cylinder. Any gaps which may form water traps shall be sealed to prevent ingress of water.

5.6 Neck-rings

When a neck ring is provided, it shall be of material compatible with that of the cylinder, and shall be securely attached.

The manufacturer shall ensure that the axial load required to remove the neck ring is greater than 10 times the weight of the empty cylinder and not less than 1 000 N, also that the minimum torque to turn the neck ring is greater than 100 Nm.

The valve protection requirements are specified in EN 962:1996.

5.7 Design drawing

A fully dimensioned drawing shall be supplied which includes the specification of the material and makes reference to this standard.

6 Construction and workmanship

6.1 Welding

Prior to welding, the components shall be treated and inspected according to approved procedures. These procedures shall be laid down in a welding procedure document to be supplied for prototype testing. Welding shall be according to the approved welding procedures, which shall be in accordance with EN 288-4:1992. Test pieces and acceptance criteria shall be in accordance with EN 288-4:1992, clause 7. The number of test pieces shall be in accordance with EN 288-4:1992, table 1.

If welding is carried out manually, the welders shall be approved in accordance with to EN 287-2.

Before the cylinders are closed, longitudinal welds shall be visually examined from both sides in accordance with EN 970.

6.2 Non-destructive examination of welds

6.2.1 General requirements

NDE shall be carried out in accordance with the design basis selected in 5.2 (ie. 100 % NDE or spot checks).

The examination shall be performed in accordance with EN 1435 and the minimum sensitivity shall be such as to reveal a defect having a thickness equal to 2 % of the combined thickness of the weld and the backing material (if used).

6.2.2 Specific requirements for cylinders with test pressure (p_t) $\leq$ 60 bar

The circumferential and longitudinal welds and the bung or boss butt-welds shall be radiographed in order to establish satisfactory machine settings.

This shall be carried out on the introduction, or reintroduction after a period exceeding three days, of a new design of cylinder (see annex A) to a production line, for the first cylinder welded, or more at the discretion of the inspection body. The radiographs shall be assessed in accordance with EN 30042:1994 and bulk production shall not commence unless they are found to be satisfactory.

Thereafter during production of that design of cylinder, in order to demonstrate that satisfactory welds are being produced consistently, one cylinder shall be selected at random at the beginning and end of each working shift's production or at intervals not exceeding 12 h, whichever is the shorter, and radiographed as above. Defect acceptance criteria shall be in accordance with EN 30042:1994 quality level C. If the radiographs show no unacceptable defects, the whole of the production of the relevant working shift shall be accepted subject to further tests as specified in C.2.

Should any of the radiographs show an unacceptable defect, production shall be stopped and the whole of the relevant shift's production shall be quarantined until it is demonstrated that the cylinders are satisfactory, either by radiography or by other appropriate means approved by the inspection body.

Production shall not be restarted until the cause of the defect has been established and rectified, and the starting up test procedure, as specified above, has been repeated.

Any weld repairs shall be according to an approved welding procedure. All weld repairs should be radiographed. After rewelding and where necessary re-radiography, all cylinders shall be reheat treated as part of a new batch or production run in accordance with C.4, and shall be retested accordingly. Acceptance criteria shall be in accordance with annex D.

6.2.3 Specific requirements for cylinders with test pressure (p_t) $>$ 60 bar

For cylinders under this category NDE shall be carried out as required in 6.2.1. At least 10 % of the cylinders per batch shall be radiographed.

6.3 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. Such defects shall be removed by local dressing. The wall thickness of any dressed area shall not be less than the minimum thickness specified.

6.4 Neck threads

The internal neck threads shall conform to a recognized standard agreed between the parties to permit the use of a corresponding valve thus minimizing neck stresses following the valve torquing operation. Internal neck threads shall be checked using gauges corresponding to the agreed neck thread, or by an alternative method agreed between the parties.

For example, where the neck thread is specified to be in accordance with EN 629-1, the corresponding gauges are specified in EN 629-2.

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.

6.5 Out-of-roundness

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

6.6 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 10 mm per metre length.

6.7 Eccentricity

When measured on the same cross-section of a cylinder, the minimum and maximum wall thicknesses of the shell shall not deviate by more than 10 % from the average of these two thicknesses.

However, for cylinders with a wall thickness of less than 4 mm, the difference between the minimum and maximum wall thicknesses of the shell measured on the same cross-section shall be less than or equal to 0,8 mm.

6.8 Stability

For a cylinder designed to stand on its base, the deviation from vertical shall be less than 1 % of its height, and the outer diameter of the surface in contact with the ground shall be greater than 75 % of the nominal outside diameter (D_o).

7 Tests

7.1 General

Every cylinder submitted to any test shall be identifiable to the batch, and either to the welder and welding machine, or in the case of an automatic machine to the welding machine.

7.2 Mechanical tests

7.2.1 *General requirements*

All mechanical tests for checking the quality of the metal used for gas cylinders shall be carried out on material taken from cylinders on which all operations affecting mechanical properties have been completed. They do not need to have been pressure tested.

Except for the requirements set out below, the mechanical tests shall be carried out in accordance with EN 10002-1, EN 10003-1, EURONORM 6:1955 and EURONORM 12:1955.

NOTE EURONORM 6:1955 and EURONORM 12:1955 were drafted as tests for steel. For the purposes of this standard, the procedures specified are considered suitable for aluminium.

7.2.2 *Types of test and evaluation of test results*

The number, the localization and type of test specimens shall be taken as shown in figure 3 and the tests shall be performed as described in 7.2.3 to 7.2.7

7.2.3 *Tensile test on parent material*

7.2.3.1 The test piece on which the tensile test is carried out shall conform to the provisions of EN 10002-1.

The two faces of the test piece corresponding to the internal and external walls of the cylinder shall not be machined.

7.2.3.2 The elongation after fracture shall not be less than 12 % where the tensile test is carried out on a single test piece taken from the cylinder wall. The tensile test may also be carried out on four test pieces distributed uniformly throughout the cylinder wall. The results shall be as follows:

- no individual value may be less than 11 %;
- the average of the four measurements shall be at least 12 %.

7.2.3.3 The value obtained for tensile strength shall not be less than R_g . The yield stress (R_{ea}) to be determined during the tensile test shall be that used in accordance with 3.1.1 for the cylinder calculation. The value obtained for the yield stress shall not be less than R_e .