

Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres —

**Part 3: Cylinders made of seamless
stainless steel with an R_m value of less
than 1 100 MPa**

The European Standard EN 1964-3:2000 has the status of a
British Standard

ICS 23.020.30

National foreword

This British Standard is the official English language version of EN 1964-3:2000.

The UK participation in its preparation was entrusted by Technical Committee PVE/3, Gas containers, to Subcommittee PVE/3/3, Transportable gas containers — Cylinders 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;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 54, an inside back cover and back cover.

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 May 2000

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ISBN 0 580 34833 4

Amendments issued since publication

Amd. No.	Date	Comments

English version

Transportable gas cylinders - Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres - Part 3: Cylinders made of seamless stainless steel with an R_m value of less than 1 100 MPa

Bouteilles à gaz transportables –Spécifications pour la conception et la fabrication de bouteilles à gaz rechargeables et transportables en acier sans soudure, d'une capacité en eau comprise entre 0,5 litre et 150 litres inclus - Partie 3: Bouteilles en acier inoxydable sans soudure ayant une valeur R_m inférieure à 1 100 MPa

Ortsbewegliche Gasflaschen - Gestaltung und Konstruktion von nahtlosen wiederbefüllbaren ortsbeweglichen Gasflaschen aus Stahl mit einem Fassungsraum von 0,5 Liter bis einschließlich 150 Liter - Teil 3: Nahtlose Flaschen aus nichtrostendem Stahl mit einem R_m -Wert von weniger als 1 100 MPa

This European Standard was approved by CEN on 11 December 1999.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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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 August 2000, and conflicting national standards shall be withdrawn at the latest by August 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 in 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 in the technical annexes of the ADR.

This standard supports the objectives of EU directives 94/55 and 96/49.

This standard is one of a series of three standards concerning refillable seamless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases:

- Part 1: Cylinders made of seamless steel with an R_m value of less than 1 100 MPa;
- Part 2: Cylinders made of seamless steel with an R_m value of 1 100 MPa and above;
- Part 3: Cylinders made of seamless stainless steel with an R_m value of less than 1 100 MPa.

Introduction

The purpose of this standard is to provide a specification for the design, manufacture, inspection and approval of refillable, transportable seamless steel gas cylinders made of materials belonging to the group generally known as stainless steels.

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

The standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable transportable seamless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases. This standard is applicable to cylinders manufactured from stainless steel with an R_m value of less than 1 100 MPa.

NOTE This standard is also suitable for the manufacture of cylinders of water capacity less than 0,5 l.

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.

EN 473	Qualification and certification of NDT personnel - General principles.
EN 1089-1:1996	Transportable gas cylinders - Gas cylinder identification (excluding LPG) - Part 1: Stampmarking.
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 10028-1	Flat products made of steels for pressure purposes - Part 1: General requirements.
EN 10045-1	Metallic materials - Charpy impact test - Part 1: Test method.
EN 10052	Vocabulary of heat treatment terms for ferrous products.
EN 10088-1	Stainless steels - Part 1: List of stainless steels.
EN 10088-2	Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip for general purposes.
EN ISO 3651-2	Determination of resistance to intergranular corrosion of stainless steels - Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels - Corrosion test in media containing sulfuric acid (ISO 3651-2:1998).

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).

EURONORM 6-55 Bend test for steel.

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, or, for austenitic steels in the solution annealed condition, 1 % proof stress

3.1.2

quenching

hardening heat treatment in which a cylinder, which has been heated to a uniform temperature above the upper critical point (A_{c3} , as defined in EN 10052) of the steel, is cooled rapidly in a suitable medium

3.1.3

tempering

softening heat treatment which follows quenching, in which the cylinder is heated to a uniform temperature below the lower critical point (A_{c1} , as defined in EN 10052) of the steel

3.1.4

solution annealing

softening heat treatment for austenitic steels in which a cylinder is heated to a uniform temperature above the upper critical point (A_{c3} , as defined in EN 10052) of the steel followed by rapid cooling

3.1.5

cryoforming

a process where the cylinder is subjected to a controlled low temperature deformation treatment that results in a permanent increase in strength

3.1.6

batch

a quantity of up to 200 cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness, length and design made from the same steel cast and subjected to the same heat treatment for the same duration of time

3.1.7

burst pressure

highest pressure reached in a cylinder during a burst test

3.1.8

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	Calculated minimum thickness, in millimetres, of the cylindrical shell.
a'	Guaranteed minimum thickness, in millimetres, of the cylindrical shell (see Figure 1).
a_1	Required minimum thickness, in millimetres, of a concave base at the knuckle (see Figure 2).
a_2	Required minimum thickness, in millimetres, at the centre of a concave base (see Figure 2).
A	Percentage elongation.
b	Required minimum thickness, in millimetres, at the centre of a convex base (see Figure 1).
d_1	Dimension, in millimetres, of acceptable burst profile for quenched and tempered cylinders (see Figure 8).
d_2	Dimension, in millimetres, of acceptable burst profile for cryoformed or solution annealed cylinders with less than 7,5 mm wall thickness (see Figure 9).
D	Outside diameter of the cylinder, in millimetres (see Figure 1).
D_f	Diameter of former, in millimetres (see Figure 5).
F	Design stress factor (variable) (see 3.1.9).
h	Outside height (concave base end), in millimetres (see Figure 2).
H	Outside height of domed part (convex head or base end), in millimetres (see Figure 1).
L	Overall length of cylinder, in millimetres.
L_o	Original gauge length, in millimetres, according to EN 10002-1 (see Figure 4).
n	Ratio of diameter of 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_w	Working pressure, in bar ¹⁾ , above atmospheric pressure.
p_y	Observed yield pressure, in bar ¹⁾ , above atmospheric pressure.
r	Inside knuckle radius, in millimetres (see Figure 1).
R_e	Minimum guaranteed value of yield stress (see 3.1.1), in megapascals.
R_{ea}	Value of the actual yield stress in megapascals determined by the tensile test (see 7.1.2.1).
R_g	Minimum guaranteed value of tensile strength, in megapascals.
R_m	Actual value of tensile strength, in megapascals, determined by the tensile test (see 7.1.2.1).
S_o	Original cross-sectional area of tensile test piece, in square millimetres, according to EN 10002-1.
t	Actual thickness of the test specimen in millimetres.
u	Ratio of distance between platens in flattening test to actual thickness of test piece.
V	Water capacity of cylinder, in litres.
w	Width, in millimetres, of tensile test piece (see Figure 4).

4 Materials

4.1 General provisions

4.1.1 Materials for the manufacture of gas cylinders shall fall within one of the following categories.

- a) Internationally recognized cylinder steels.
- b) Nationally recognized cylinder steels.
- c) New cylinder steels resulting from technical progress.

For all categories the requirements of 4.2 shall be satisfied. For all categories, the relevant conditions specified in 4.3 or 4.4 shall be fulfilled.

¹⁾ 1 bar = 10⁵ Pa = 0,1 MPa

4.1.2 There is a risk of sensitization to intergranular corrosion resulting from the hot processing of austenitic and duplex stainless steels. Intergranular corrosion testing shall be carried out for such materials in accordance with 7.1.2.5.

4.1.3 The cylinder manufacturer shall identify the cylinders with the cast of steel from which they are made.

4.1.4 Grades of steel used for cylinder manufacture shall be compatible with the intended gas service, e.g. corrosive gases, embrittling gases. (See EN ISO 11114-1:1997.)

Some grades of stainless steel may be susceptible to environmental stress corrosion cracking. Special precautions shall be taken in such cases.

4.1.5 Some grades of stainless steel may be susceptible to phase transformation at low temperatures resulting in a brittle alloy. Special precautions shall be taken in such cases.

4.2 Controls on chemical composition

4.2.1 The following are the four broad categories of stainless steels.

Category

Ferritic
Martensitic
Austenitic
Austenitic/Ferritic (Duplex)

Recognized steels are listed in EN 10088-1. Other grades of stainless steel may also be used.

4.2.2 The cylinder manufacturer shall obtain and provide certificates of cast analyses of the steels supplied for the manufacture of gas cylinders.

Should check analyses be required, they shall be carried out either on specimens taken during manufacture from material in the form as supplied by the steelmaker to the cylinder manufacturer, or from finished cylinders avoiding decarburized zones, on those stainless steel grades where applicable, from the cylinder surface. In any check analysis, the maximum permissible deviation from the limits specified for cast analyses shall conform to the values specified in EN 10028-1.

NOTE EN 10028-1 is a general standard which cross references the actual permissible deviations given in the other parts of EN 10028.

4.3 Heat treatment

4.3.1 The cylinder manufacturer shall provide a certificate stating the heat treatment process applied to the finished cylinders.

4.3.2 Ferritic and martensitic steel categories shall be quenched and tempered. Austenitic and duplex (austenitic/ferritic) steel categories shall be solution annealed.

4.3.3 The actual temperature to which a type of steel is subjected for a given tensile strength shall not deviate by more than 30 °C from the temperature specified by the cylinder manufacturer.

4.4 Cold working or cryoforming

Cold working or cryoforming is used to enhance finished mechanical properties in certain stainless steel materials.

For cylinders that are subjected to cold working or to the cryoforming process, all heat treatment requirements refer to the cylinder preform operations. Cold worked or cryoformed cylinders shall not be subjected to any subsequent heat treatment.

4.5 Test requirements

The material of the finished cylinders shall satisfy the requirements of clause 7.

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.

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

5.2 Calculation of cylindrical shell thickness

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

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

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

R_e/R_g shall be limited to 0,90.

The calculated minimum wall thickness shall also satisfy the equation:

$$a \geq \frac{D}{250} + 1 \text{ mm}$$

with an absolute minimum of $a = 1,5 \text{ mm}$.

When choosing the minimum guaranteed value of the thickness of the cylindrical shell (a'), the manufacturer shall take into account all requirements for prototype and production testing, particularly the burst and yield pressure test requirements of 7.2.2.2.

The guaranteed minimum wall thickness (a') shall be equal to or greater than the calculated wall thickness (a).

5.3 Calculation of convex ends (heads and base ends)

5.3.1 The shapes shown in Figure 1 are typical for convex heads and base ends. Shapes A and B are base ends formed from tubing, shapes D and E are base ends formed during the piercing of a billet, and shapes C and F are heads.

5.3.2 The thickness (b) at the centre of the convex end shall be not less than that required by the following criteria:

where the inside knuckle radius (r) is not less than $0,075 D$, then

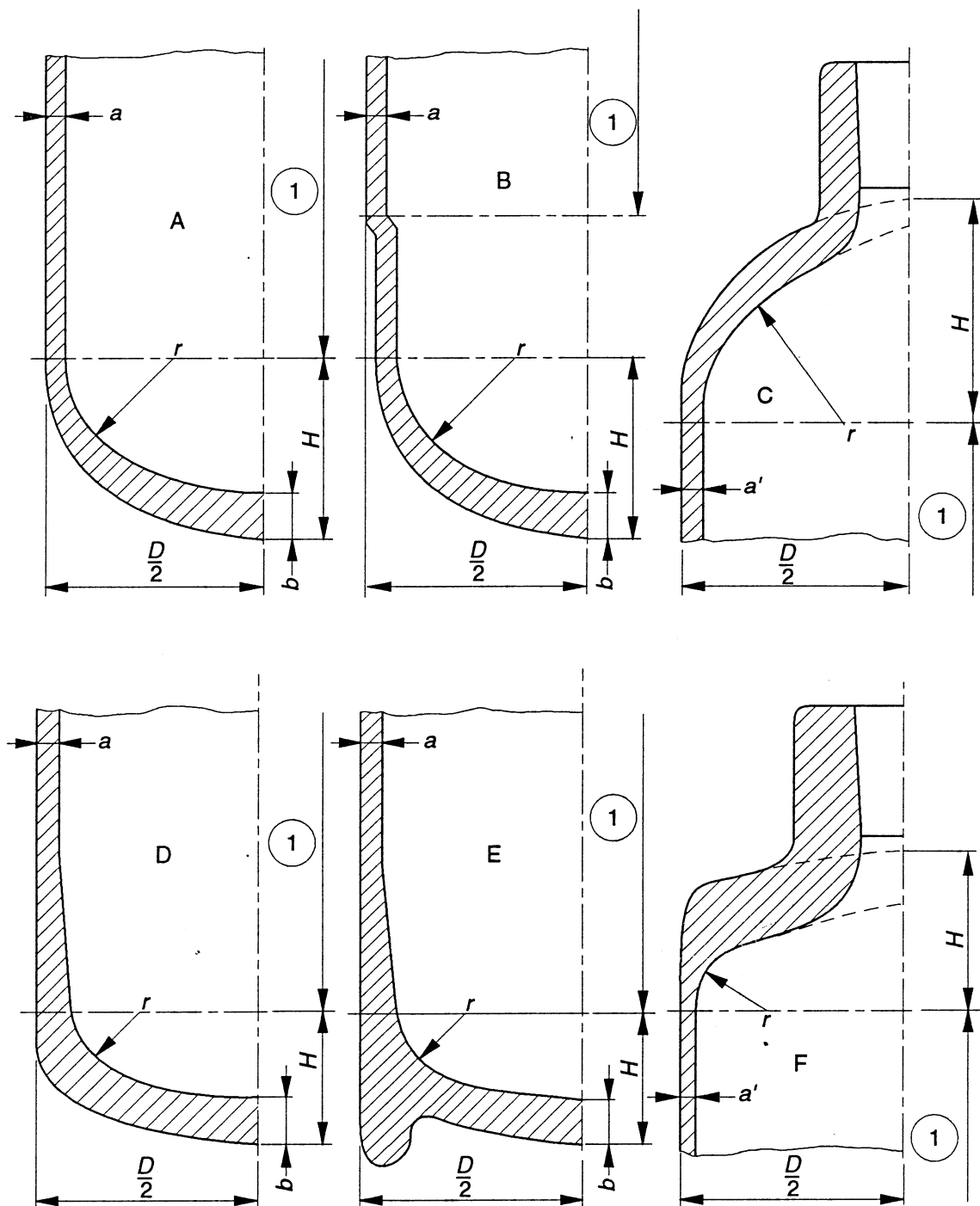
$$b \geq 1,5a \text{ for } 0,40 > H/D \geq 0,20$$

$$b \geq a \text{ for } H/D \geq 0,40.$$

In order to obtain a satisfactory stress distribution in the region where the end joins the cylindrical part, any thickening of the end that may be required shall be gradual from the point of juncture. For the application of this rule, the point of juncture between the cylindrical part and the end is defined by the horizontal line indicating dimension H in Figure 1.

Shape B shall not be excluded from this requirement.

The cylinder manufacturer shall prove by the pressure cycling prototype test as required in A.1 that the design is satisfactory.



Key
1 Cylindrical part

Figure 1 - Typical convex ends

5.4 Calculation of concave base ends

When concave base ends are used, the dimensions defined in Figure 2 shall be not less than the following calculated values:

$$a_1 = 2a; a_2 = 2a; h = 0,12D; r = 0,075D.$$

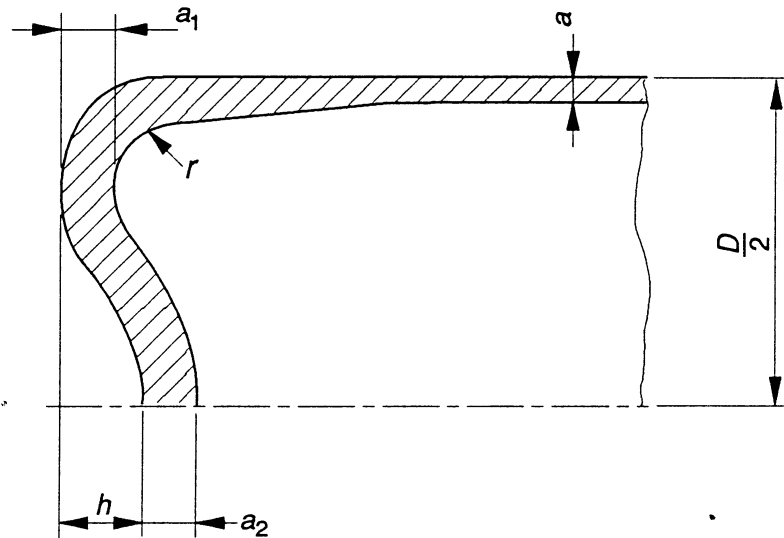


Figure 2 - Concave base ends

In order to obtain a satisfactory stress distribution, the thickness of the cylinder shall increase progressively in the transition area region between the cylindrical part and the base, and the wall shall be free from defects.

The cylinder manufacturer shall prove by the pressure cycling prototype test as required in A.1 that the design is satisfactory.

5.5 Neck design

5.5.1 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 of thread, and the sealant used in the fitting of the valve.

NOTE For recommended valving torques see EN ISO 13341.

5.5.2 The thickness of the wall in the cylinder neck shall be sufficient to prevent permanent expansion of the neck during initial and subsequent fitting of the valve into the cylinder. Where the cylinder is specifically designed to be fitted with neck reinforcement, such as a neck-ring or shrunk-on collar, this may be taken into account (see EN ISO 13341).

5.6 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 by a method other than welding, brazing or soldering. Any gaps which may form water traps shall be sealed to prevent ingress of water, by a method other than welding, brazing or soldering.

5.7 Neck-rings

As agreed between the parties, a neck-ring, if provided, 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 not less than 1 000 N, also that the minimum torque required to turn the neck-ring is greater than 100 N·m.

5.8 Design drawing

A fully dimensioned drawing shall be prepared which includes the specification of the material, and details of the permanent fittings.

6 Construction and workmanship

6.1 General

The cylinder shall be produced by:

- a) forging or drop forging from a solid ingot or billet; or
- b) manufacturing from seamless tube; or
- c) pressing from a flat plate; or
- d) cold working or cryoforming preform.

Metal shall not be added in the process of closure of the end. Manufacturing defects shall not be corrected by plugging of bases.

6.2 Wall thickness

Each cylinder shall be examined for thickness. The wall thickness at any point shall not be less than the minimum thickness specified.

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. See annex B.

6.4 Ultrasonic examination

Except as identified in C.6, all cylinders shall be ultrasonically examined for defects in accordance with annex C.

6.5 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.

6.6 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.

6.7 Mean diameter

The mean external diameter shall not deviate more than ± 1 % from the nominal design diameter.

6.8 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm per metre length.

6.9 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.