INTERNATIONAL STANDARD

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Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing —

Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa

Bouteilles à gaz — Bouteilles à gaz rechargeables en acier sans soudure — Conception, construction et essais —

Partie 4: Bouteilles en acier inoxydable avec une valeur Rm inférieure à 1 100 MPa

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

ISO 9809 consists of the following parts, under the general title *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing*:

— *Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

— *Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

— *Part 3: Normalized steel cylinders*

— *Part 4: Stainless steel cylinders with tensile strength less than 1 100 MPa*

Introduction

The purpose of ISO 9809 is to provide a specification for the design, manufacture, inspection, and testing of a seamless stainless steel cylinder for worldwide usage. The objective is to balance the design and economic efficiency against international acceptance and universal utility.

ISO 9809 aims to eliminate the concern about climate, duplicate inspections, and restrictions currently existing because of the lack of definitive International Standards. This International Standard should not be construed as reflecting on the suitability of the practice of any nation or region.

This part of ISO 9809 has been prepared to address the general requirements on the design, construction, and initial inspection and test of pressure receptacles of the UN model regulations for the transportation of dangerous goods.[6]

It is intended to be used under a variety of regulatory regimes but has been written so that it is suitable for use with the conformity assessment system in paragraph 6.2.2.5 of the above mentioned model regulations.

Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing —

Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa

1 Scope

This part of ISO 9809 specifies the minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations, and tests at manufacture of refillable seamless stainless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied, and dissolved gases. This part of ISO 9809 is applicable to cylinders with a maximum actual tensile strength, R_{ma}, of less than 1 100 MPa.

NOTE If so desired, cylinders of water capacity less than 0,5 l and between 150 l and 500 l can be manufactured to be in full compliance with this part of ISO 9809.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

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 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

ISO 7438, *Metallic materials — Bend test*

ISO 9329-1, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 1: Unalloyed steels with specified room temperature properties*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
yield strength
stress value corresponding to the 0,2 % proof stress or for austenitic steels in the solution-annealed condition, 1 % proof stress

3.2
quenching
hardening heat treatment in which a cylinder, which has been heated to a uniform temperature above the upper critical point Ac_3 of the steel, is cooled rapidly in a suitable medium

3.3
tempering
toughening heat treatment which follows quenching, in which the cylinder is heated to a uniform temperature below the lower critical point Ac_1 of the steel

3.4
solution annealing
softening heat treatment for austenitic and duplex stainless steels in which a cylinder is heated to a uniform temperature above the upper critical point (Ac_3, as defined in ISO 10052) of the steel followed by rapid cooling

3.5
cryoforming
process where the cylinder is subjected to a controlled low-temperature deformation treatment that results in a permanent increase in strength

3.6
batch
quantity of up to 200 cylinders plus cylinders for destructive testing of the same nominal diameter, thickness, length, and design made successively on the same equipment, from the same cast of steel, and subjected to the same heat treatment for the same duration of time

3.7
test pressure
p_h
required pressure applied during a pressure test

Note 1 to entry: It is used for the cylinder wall thickness calculation.

3.8
burst pressure
p_b
highest pressure reached in a cylinder during a burst test

3.9
design stress factor
F
ratio of the equivalent wall stress at test pressure (p_h) to guaranteed minimum yield strength (R_{eg})

3.10
working pressure
settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder

4 Symbols

A percentage elongation after the fracture for a gauge length of L_o

a calculated minimum thickness of the cylindrical shell, in millimetres

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

a_1 guaranteed minimum thickness of a concave base at the knuckle, in millimetres (see Figure 2)

a_2 guaranteed minimum thickness at the centre of a concave base, in millimetres (see Figure 2)

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

c_1 maximum permissible deviation of burst profile for quenched and tempered cylinders, in millimetres (see Figure 11)

c_2 maximum permissible deviation of the burst profile for cryoformed or solution-annealed cylinders with less than 7,5 mm wall thickness, in millimetres (see Figure 12)

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

D_f diameter of former, in millimetres (see Figure 6)

F design stress factor (variable) (see 3.7)

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

h outside depth (concave base end), in millimetres (see Figure 2)

L_o original gauge length as defined in ISO 6892, in millimetres (see Figure 5)

l overall length of the cylinder, in millimetres (see Figure 3)

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

p_b measured burst pressure above the atmospheric pressure, in bar

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

p_h hydraulic test pressure above the atmospheric pressure, in bar

p_y observed pressure when the cylinder starts yielding during the hydraulic burst test above the atmospheric pressure, in bar

r inside knuckle radius, in millimetres (see Figures 1 and 2)

R_{ea} actual value of the yield strength as determined by the tensile test, in MPa (see 10.2)

R_{eg} minimum guaranteed value of the yield strength (see 7.1.1) for the finished cylinder, in MPa

R_{ma} actual value of the tensile strength as determined by the tensile test, in MPa (see 10.2)

R_{mg} minimum guaranteed value of the tensile strength for the finished cylinder, in MPa

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

t actual thickness of the test specimen, in millimetres

t_m average cylinder wall thickness at the position of testing during the flattening test, in millimetres

u ratio of the distance between the knife edges or platens in the flattening test to the average cylinder wall thickness at the position of the test

V water capacity of the cylinder, in litres

w width of the tensile test piece, in millimetres (see Figure 5)

5 Inspection and testing

To ensure that the cylinders conform to this part of ISO 9809, they shall be subject to inspection and testing in accordance with Clauses 9, 10, and 11 by an inspection body (hereafter referred to as "the inspector") authorized to do so.

Equipment used for the measurement, testing, and examination during the production shall be maintained and calibrated within a documented quality management system.

NOTE Evaluation of conformity can be performed in accordance with the regulations recognized by the country(ies) where the cylinders are intended to be used.

6 Materials

6.1 General requirements

6.1.1 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 relevant conditions specified in 6.2 and 6.3 shall be satisfied.

6.1.2 There is a risk of sensitization to the 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 10.6.

6.1.3 The cylinder manufacturer shall establish the means to identify the cylinders with the cast of steel from which they are made.

6.1.4 The grades of the steel used for the cylinder manufacture shall be compatible with the intended gas service, e.g. corrosive gases and embrittling gases (see ISO 11114-1).

6.1.5 Some grades of stainless steel can be susceptible to environmental stress corrosion cracking. Special precautions shall be taken in such cases, such as appropriate coating.

6.1.6 Some grades of stainless steel can be susceptible to phase transformation at low temperatures resulting in a brittle alloy. Special precautions shall be taken in such cases, i.e. not using the cylinder below the minimum acceptable temperature.

6.2 Controls on chemical composition

6.2.1 The following are the four broad categories of stainless steels:

— ferritic;

— martensitic;

— austenitic;

— austenitic/ferritic (duplex).

Recognized steels are listed in ISO 15510. Other grades of stainless steel can also be used provided that they fulfil all the requirements of this part of ISO 9809.

6.2.2 The cylinder manufacturer shall obtain and make available certificates of cast (heat) analyses of the steels supplied for the construction of gas cylinders.

Should check analyses be required, they shall be carried out either on the specimens taken during the manufacture from the material in the form as supplied by the steel maker to the cylinder manufacturer, or from finished cylinders. In any check analysis, the maximum permissible deviation from the limits specified for the cast analyses shall conform to the values specified in ISO 9329-1.

6.3 Heat treatment

6.3.1 The cylinder manufacturer shall certify the heat treatment process applied to the finished cylinders.

6.3.2 The finished cylinders made from the ferritic or martensitic steel categories shall be quenched and tempered, except if they are cold worked (see 6.4).

6.3.3 For the ferritic and martensitic steels, the heat treatment process shall achieve the required mechanical properties.

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

6.4 Cold working or cryoforming

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

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

6.5 Failure to meet test requirements

In the event of failure to meet the test requirements, retesting or reheat treatment and retesting shall be carried out as follows to the satisfaction of the inspector:

a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. 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, the cause of test failure shall be identified.

   1) If the failure is considered to be due to the heat treatment applied, the manufacturer can subject all the cylinders implicated by the failure to a further heat treatment, e.g. if the failure is in a test representing the prototype or batch cylinders. Test failure shall require reheat treatment of all the represented cylinders prior to retesting.

      Whenever the cylinders are reheat treated, the minimum guaranteed wall thickness shall be maintained.

      Only the relevant prototype or batch tests needed to prove the acceptability of the new batch shall be performed again. If one or more tests prove even partially unsatisfactory, all the cylinders of the batch shall be rejected.

   2) If the failure is due to a cause other than the heat treatment applied, all the cylinders with imperfections shall be either rejected or repaired such that the repaired cylinders pass the test(s) required for the repair. They shall then be reinstated as part of the original batch.

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 guaranteed minimum yield strength (R_{eg}) of the material in the finished cylinder.

7.1.2 Cylinders can be designed with one or two openings along the central cylinder axis only.

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 Formulae (1) and (2), and additionally, Formula (3) shall be satisfied.

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

where the value of F is equal to 0,77.

The wall thickness shall also satisfy Formula (2)

$$a \geq \frac{D}{250} + 1 \quad (2)$$

with an absolute minimum of a = 1,5 mm.

The burst ratio shall be satisfied by Formula (3).

$$p_b/p_h \geq 1,6 \quad (3)$$

NOTE It is generally assumed that p_h = 1,5 × the working pressure for compressed gases for the cylinders designed and manufactured to this part of ISO 9809.

7.3 Calculation of convex ends (heads and bases)

7.3.1 The thickness, b, at the centre of a 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

— $b \geq 1,5\ a$ for $0,40 > H/D \geq 0,20$ and

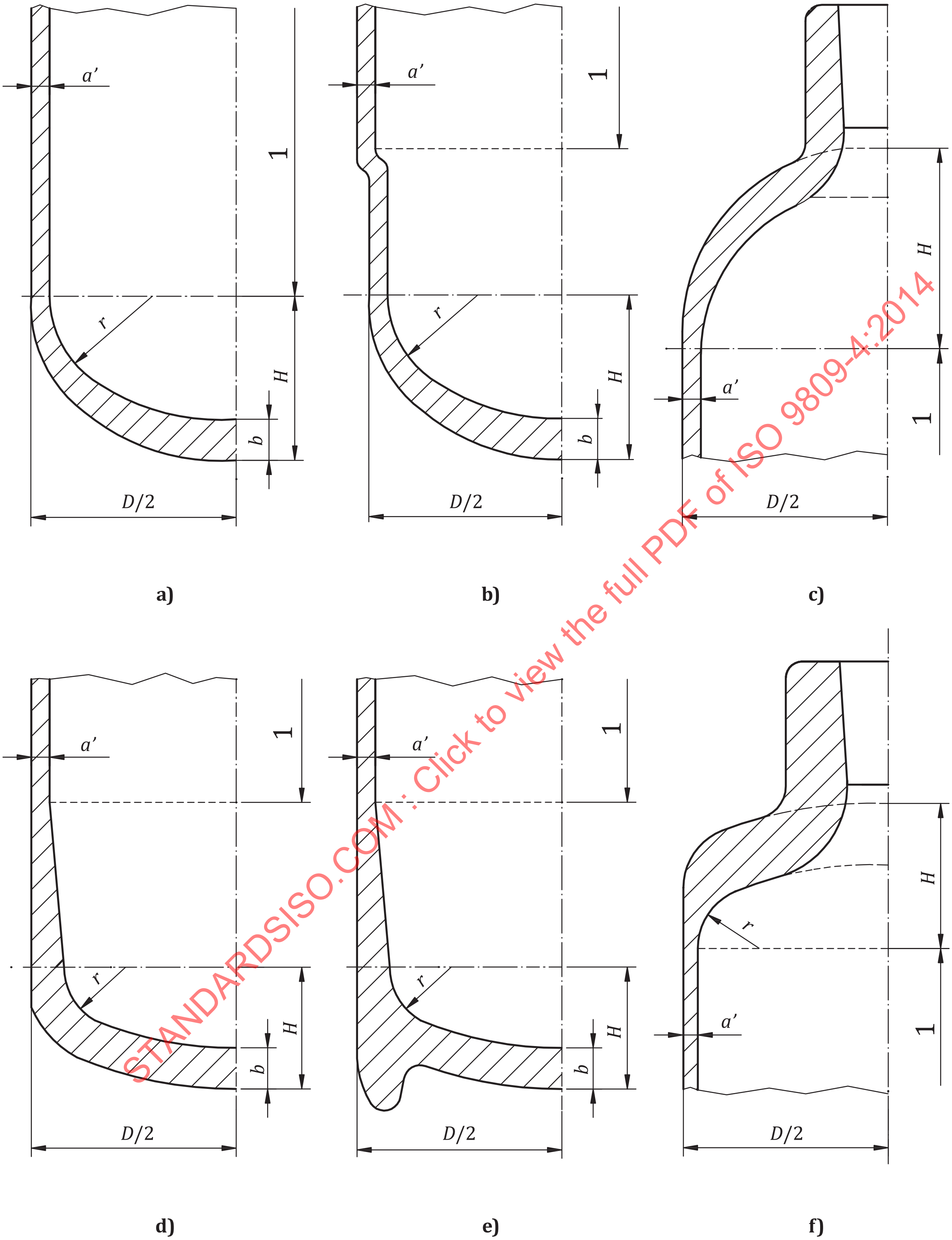
— $b \geq a$ for $H/D \geq 0,40$.

To obtain a satisfactory stress distribution in the region where the end joins the shell, any thickening of the end that can be required shall be gradual from the point of juncture, particularly at the base. For the application of this rule, the point of juncture between the shell and the end is defined by the horizontal lines indicating the dimension H in Figure 1.

Shape b) shall not be excluded from this requirement.

7.3.2 The design shall be verified and considered satisfactory by the application of the pressure cycling test given in 9.2.2.

The shapes shown in Figure 1 are typical of the convex heads and base ends. Shapes a), b), d), and e) are base ends and shapes c) and f) are heads.



Key

1 cylindrical part

Figure 1 — Typical convex ends

7.4 Calculation of the concave base ends

When concave base ends (see Figure 2) are used, the following design values are recommended:

— $a_1 \geq 2\ a$;

— $a_2 \geq 2\ a$;

— $h \geq 0{,}12\ D$;

— $r \geq 0{,}075\ D$.

The design drawing shall at least show the values for a_1, a_2, h, and r.

To obtain a satisfactory stress distribution, the thickness of the cylinder shall increase progressively in the transition region between the cylindrical part and the base.

The design shall be verified and considered satisfactory by the application of the pressure cycling test given in 9.2.2.

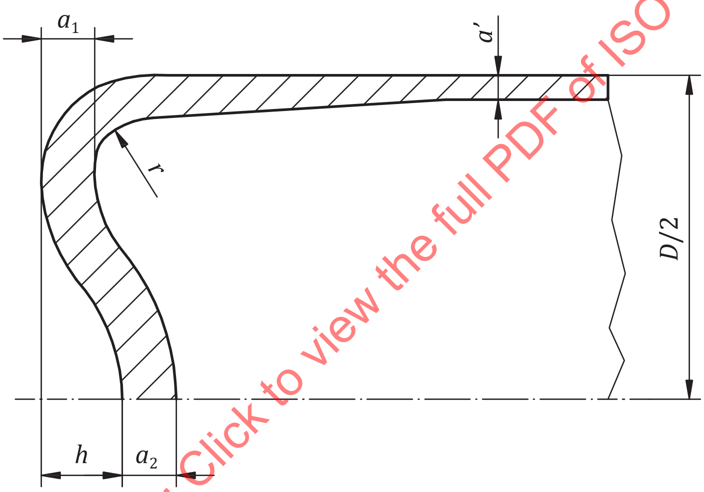


Figure 2 — Concave base ends

7.5 Neck design

7.5.1 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 can vary according to the diameter of the thread, the form of the thread, and the sealant used in the fitting of the valve.

NOTE For guidance on torques, see ISO 13341.

7.5.2 In establishing the minimum thickness, consideration should be given to obtaining a thickness of the wall in the cylinder neck which will prevent the permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without the support of an attachment. The external diameter and thickness of the formed neck end of the cylinder shall not be damaged (no permanent expansion or crack) by the application of the maximum torque required to fit the valve to the cylinder (see ISO 13341) and the stresses when the cylinder is subjected to its test pressure. In specific cases (e.g. very thin-walled cylinders) where these stresses cannot be supported by the neck itself, the neck can be designed to require reinforcement, such as a neck ring or shrunk-on collar, provided the reinforcement material and dimensions are clearly specified by the manufacturer and this configuration is part of the type approval procedure.

7.6 Foot rings

When a foot ring is provided, it shall be sufficiently strong and made of a 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. Any gaps which can form water traps shall be sealed by a method other than welding, brazing, or soldering.

7.7 Neck rings

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

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

7.8 Design drawing

A fully dimensioned drawing shall be prepared which includes the specification of the material and details relevant to the design of the permanent fittings. Dimensions of non-safety-related fittings can be agreed between the customer and manufacturer and need not be shown on the design drawing.

8 Construction and workmanship

8.1 General

The cylinder shall be produced by

a) forging or drop forging from a solid ingot or billet,

b) manufacturing from seamless tube,

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.

8.2 Wall thickness

During production, each cylinder or semi-finished shell shall be examined for thickness. The wall thickness at any point shall be not less than the minimum thickness specified.

8.3 Surface imperfections

The internal and external surfaces of the finished cylinder shall be visually inspected to determine that they are free from imperfections which could adversely affect the safe working of the cylinder.

NOTE See Annex A for examples of imperfections and guidance on their evaluation.

8.4 Ultrasonic examination

8.4.1 After the completion of the final heat treatment and cold working and after the final cylindrical wall thickness has been achieved, each cylinder shall be ultrasonically examined for internal, external, and subsurface imperfections, in accordance with Annex B.

The ultrasonic examination is not necessary for small completed cylinders with a cylindrical length of less than 200 mm or where the product of $p_h \times V < 600$ (for $R_{ma} \geq 650$ MPa) or $p_h \times V < 1\,200$ (for $R_{ma} < 650$ MPa).

8.4.2 Regardless of the size of the cylinder, in addition to the ultrasonic examination as specified in 8.4.1, the cylindrical area to be closed (that creates the shoulder and in case of cylinders made from tube, also the base) shall be ultrasonically examined prior to the forming process to detect any defects that after closure could be positioned in the cylinder ends.

8.5 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.

For cold stretch and cryoformed cylinders, higher values are acceptable provided they are validated by the pressure cycling test and the maximum shall be specified on the approved design drawing.

8.6 Mean diameter

The mean external diameter of the cylindrical part outside the transition zones on a cross section shall not deviate by more than ±1 % from the nominal design diameter.

For cold stretch and cryoformed cylinders, higher values are acceptable provided they are validated by the pressure cycling test and the maximum shall be specified on the approved design drawing.

8.7 Straightness

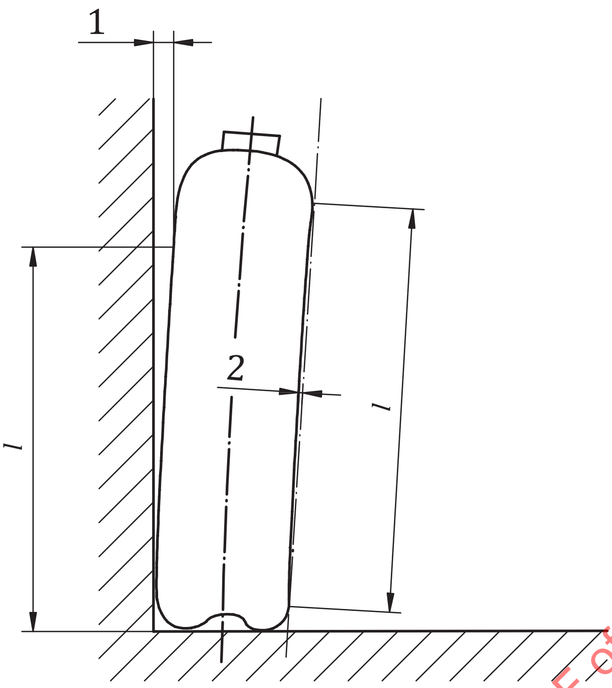
The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm/m in length (see Figure 3).

For cold stretch and cryoformed cylinders, higher values can be used provided that it is acceptable for the intended application and safety is not compromised.

8.8 Verticality and stability

For a cylinder designed to stand on its base, the deviation from vertical shall not exceed 10 mm/m in length (see Figure 3) and the outer diameter of the surface in contact with the ground is recommended to be greater than 75 % of the nominal outside diameter.

For cold stretch and cryoformed cylinders, higher values for deviation from vertical can be used provided that it is acceptable for the intended application and safety is not compromised.



Key

1 maximum 0,01 × l (see 8.8)

2 maximum 0,003 × l (see 8.7)

Figure 3 — Illustration of the deviation of the cylindrical part of the shell from a straight line and from vertical

8.9 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.

NOTE For example, where the neck thread is specified to be in accordance with ISO 11116-1, the corresponding gauges are specified in ISO 11116-2.

Neck threads shall be accurately cut, of full form, and free from any sharp profiles, e.g. burrs.

9 Type approval procedure

9.1 General requirements

A technical specification of each new design of cylinder, or cylinder family as defined in f), including design drawing, design calculations, steel details, manufacturing process, and heat treatment details, 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 at least one of the following applies.

a) It is manufactured in a different factory.

b) It is manufactured by a different process (see 8.1). This includes the case when major process changes are made during the production period, e.g. end forging to spinning, change in heat treatment process, etc.

c) It is manufactured from a steel of different specified chemical composition limits from that used in the existing type approval.

d) It is given a different heat treatment beyond the limits stipulated in 6.3 and 6.4.

e) The base or the base profile has changed, e.g. concave, convex, hemispherical, or also if there is a change in base thickness/cylinder diameter ratio.

f) The overall length of the cylinder has increased by more than 50 % (cylinders with a length/diameter ratio less than 3 shall not be used as reference cylinders for any new design with this ratio greater than 3).

g) The nominal outside diameter has changed.

h) The guaranteed minimum thickness has changed.

i) The hydraulic test pressure (p_h) 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).

j) The guaranteed minimum yield strength (R_{eg}) and/or the guaranteed minimum tensile strength (R_{mg}) for the finished cylinder have changed.

9.2 Prototype test

9.2.1 General requirements

A minimum of 30 cylinders which are guaranteed by the manufacturer to be representative of the new design shall be made available for the prototype testing. However, if for special applications the total number of cylinders required is less than 30, a sufficient number of 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.

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 cylinders (those taken for mechanical testing) meet the requirements of 7.3 to 7.6, the measurements being taken on at least three transverse sections of the cylindrical part and on a longitudinal section of the base and head,

— the materials conform to the requirements of Clause 6, and

— the selected cylinders conform to the requirements of 7.6, 7.7, 7.8, and 8.5 to 8.9 inclusive, the internal and external surfaces of the cylinders are free of any defect which should make them unsafe to use (for examples, see Annex A), and

b) supervise the following tests on the cylinders selected:

— the tests specified in 10.1.2 a) (hydraulic burst test) on two cylinders, the cylinders bearing representative stamp markings;

— the tests specified in 10.1.2 b) (mechanical testing) on two cylinders, the test pieces being identifiable with the batch;

NOTE For cylinders made from austenitic stainless steel, impact tests are not required (see 10.4).

— the tests specified in 9.2.3 (base check) on the two cylinders selected for mechanical testing;

— an intergranular corrosion test in accordance with 10.6 for cylinders made from austenitic and duplex steels;

— the tests specified in 9.2.2 (pressure cycling test) on three cylinders, the cylinders bearing representative stamp markings;

— the neck threads conform to the geometrical requirements for all inspected cylinders.

9.2.2 Pressure cycling test

This test shall be carried out on cylinders bearing representative markings 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 a hydraulic test pressure (p_h) > 450 bar, the upper cyclic pressure can be reduced to two-thirds of this 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 shall have an absolute maximum of 30 bar.

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

The frequency of the 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 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 the minimum value(s) specified on the drawings by more than 15 %.

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

9.2.3 Base check

A meridian section shall be made in the base centre of the cylinder and one of the surfaces, thus obtained, polished for examination under a magnification of between x 5 and x 10.

The cylinder shall be regarded as defective if the presence of cracks is detected. It shall also be regarded as defective if the dimensions of any pores or inclusions present reach values considered to pose a threat to safety.

In cases where the base is suspected to be plugged, the section shall be etched after the first examination to verify the absence of a plug. Plugged cylinders shall not be approved.

In no case shall the sound thickness (i.e. the thickness with no imperfections) in the base centre be less than the minimum specified thickness (see 7.4).

9.3 Type approval certificate

If the results of the checks according to 9.1 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 at the completion of the cylinder manufacture, i.e. at any stage after the heat treatment.

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

— the type approval certificate,

— the certificates stating the cast analysis of the steel supplied for the construction of the cylinders,

— an evidence that appropriate heat treatment has been performed,

— the certificates showing the ultrasonic examination results,

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

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

10.1.2 During the batch testing, the inspector shall undertake the following.

— Ascertain that the type approval certificate has been obtained and that the cylinders conform to it.

— Check whether the requirements given in Clauses 6, 7, and 8 have been met and, in particular, check by an external and internal visual examination of the cylinders whether their construction is satisfactory. The inspector shall verify that the requirements of 7.7, 7.8, and 8.2 to 8.9 have been fulfilled by the manufacturer. The visual examination shall cover at least 10 % of the cylinders submitted. However, if an unacceptable imperfection is found (for examples, see Annex A), 100 % of cylinders shall be visually inspected.

— Select the necessary cylinders per batch for destructive testing and carry out the tests specified in 10.1.2 a) (hydraulic burst tests) and 10.1.2 b) (mechanical testing). Where alternative tests are permitted, the purchaser and manufacturer shall agree which tests are to be carried out. Where cold working or cryoforming causes inhomogeneity of mechanical properties within the cylinder, sufficient sets of test pieces shall be taken in accordance with Figure 4 to prove the design.

— Check whether the information supplied by the manufacturer referred to in 10.1.1 is correct; random checks shall be carried out.

— Assess the results of the hardness testing specified in 11.3.

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

a) on one cylinder, one hydraulic burst test (see 10.5);

b) on a further cylinder:

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

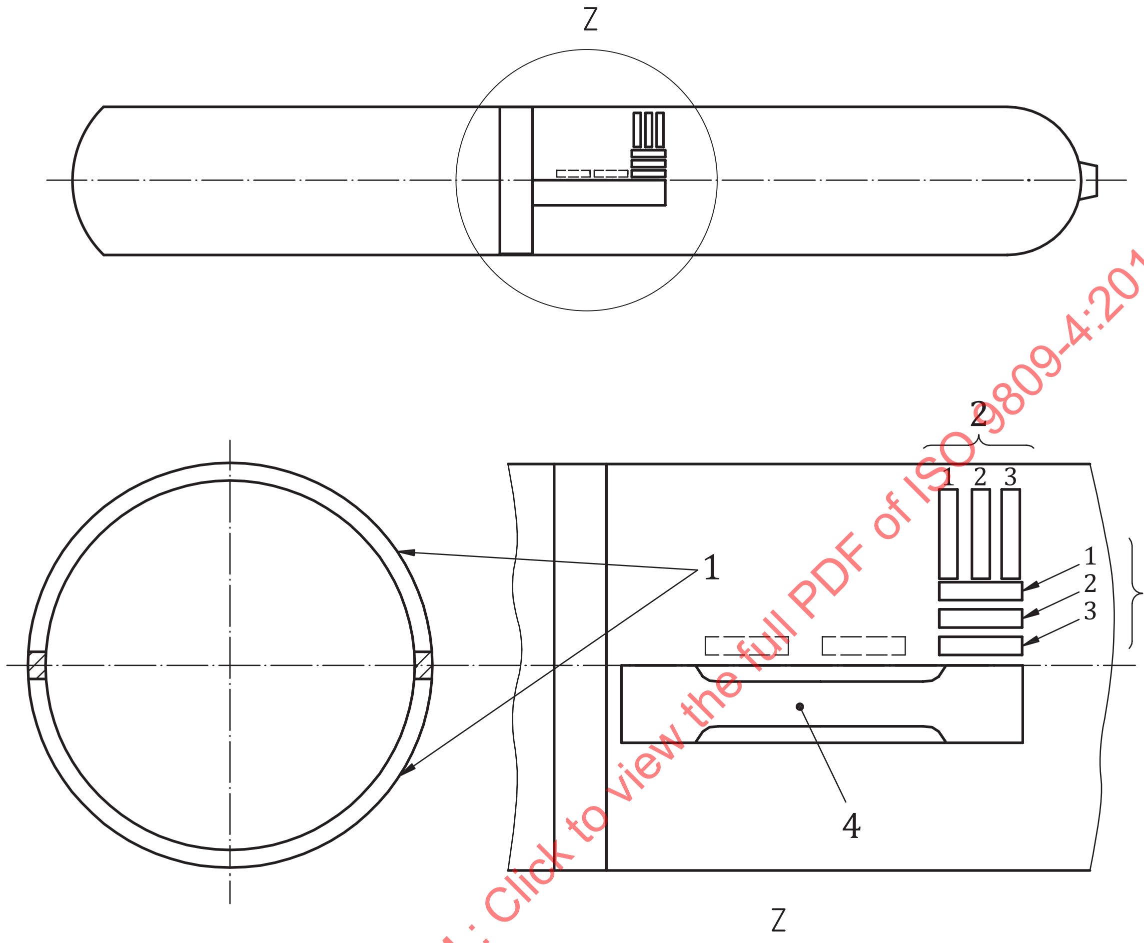
  — either two bend tests (see 10.3.1) in a circumferential direction, one flattening test (see 10.3.2), or one ring flattening test (see 10.3.3);

  — when necessary and when the thickness of the cylinder permits the machining of a test piece at least 3 mm thick, three impact tests in the transverse or longitudinal direction as required in 10.4;

  — for cylinders made from austenitic and duplex steels, an intergranular corrosion test in accordance with 10.6.

— for cylinders made from continuously cast material, a base check in accordance with the requirements of 9.1.3 shall be carried out.

NOTE For the location of test pieces, see Figure 4.



Key

1 bend test pieces or flattening ring test pieces

2 transverse impact test pieces

3 longitudinal impact test piece (alternative positions shown dashed)

4 tensile test pieces

Figure 4 — Typical location of the test pieces

10.2 Tensile test

10.2.1 A tensile test shall be carried out on the material taken from the cylindrical part of the cylinder by adopting either of the following procedures.

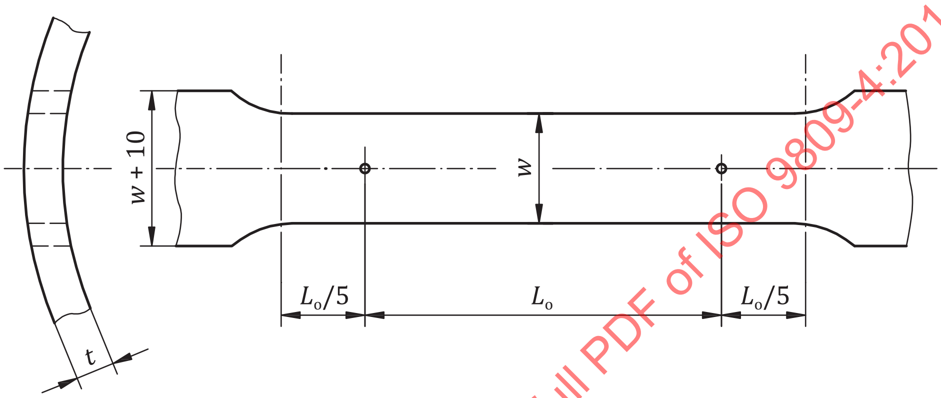
a) The rectangular specimens shall be prepared in accordance with Figure 5 and with a gauge length $L_0 = 5{,}65\sqrt{S_0}$. The two faces of the test piece, representing the inside and outside surfaces of the cylinder, shall not be machined. The minimum percentage elongation values shall be those given for the material in ISO 9328-1, when in the same condition. The elongation values for other material grades not covered by ISO 9328-1 shall be agreed between the cylinder manufacturer and the relevant authority. However, the elongation after fracture (A) measured shall in no case be less than 14 %.

b) The machined round specimens shall be prepared having the maximum diameter practicable, the elongation (A) measured on a gauge length of five times the specimen diameter being no less than those specified in 10.2.1 a) plus 2 %, but in no case less than 16 %.

It is recommended that the machined round specimens are not used for wall thickness less than 3 mm.

10.2.2 The tensile test shall be carried out in accordance with ISO 6892.

NOTE Attention is drawn to the method of measurement of elongation described in ISO 6892, particularly in cases where the tensile test piece is tapered, resulting in a point of fracture away from the middle of the gauge length.



NOTE $w \leq 4t$; $w < D/8$.

Figure 5 — Tensile test piece

10.3 Bend test and flattening test

10.3.1 Bend test

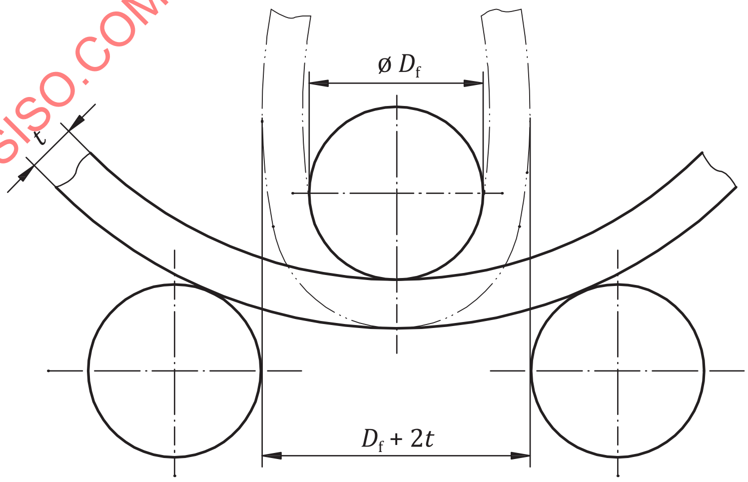


Figure 6 — Illustration of the bend test

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 with a width of 25 mm or 4 t, whichever is greater, into equal parts. Each test piece shall be of sufficient length to permit the bend test to be carried out correctly. Only the edges of each strip can be machined.

10.3.1.2 The test piece shall not crack when bent inwards around the former until the inside surfaces are not further apart than the diameter of the former (see Figure 6).

10.3.1.3 The diameter of the former (D_f) shall be established from Table 1.

For the actual tensile strength (R_{ma}) given in Table 1, $D_f \leq n \times$ the test piece thickness (t).

10.3.2 Flattening test

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

10.3.2.2 The test cylinder shall be flattened between the wedge-shaped knife edges with a 60° included angle, the edges being rounded to a nominal radius of 13 mm. The length of the wedges shall be not less than the width of the flattened cylinder. The longitudinal axis of the cylinder shall be at an angle of 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 1. The flattened cylinder shall remain visually uncracked.

Table 1 — Bend test and flattening test requirements

Actual tensile strength, R_{ma} MPa	Bend test n	Flattening test (cylinder or ring) u[a]
$R_m \leq 440$	2	6
$440 < R_m \leq 520$	3	6
$520 < R_m \leq 600$	4	6
$600 < R_m \leq 700$	5	7
$700 < R_m \leq 800$	6	8
$800 < R_m \leq 900$	7	9
$R_m > 900$	8	9

[a] Distance between the knife edges or platens = $u \times t_m$, where t_m is the average cylinder wall thickness at the position of testing.

10.3.3 Ring flattening test

The ring flattening test shall be carried out on one ring with a width of 25 mm or 4 t, whichever is greater, taken from the cylinder body. Only the edges of the ring can be machined. The ring shall be flattened between the platens until the distance between the platens is in accordance with Table 1. The flattened ring shall remain visually uncracked.

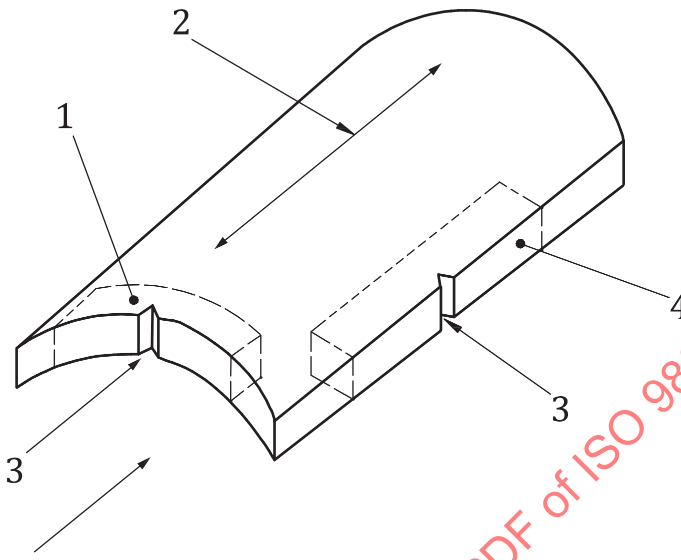
10.4 Impact test

NOTE For cylinders made from austenitic stainless steel, impact tests are not required. They are only required for ferritic and martensitic steels.

10.4.1 Except for the requirements set out below, the test shall be carried out in accordance with ISO 148-1.

The impact test pieces shall be taken in the direction as required in Table 2 from the wall of the cylinder. The notch shall be perpendicular to the face of the cylinder wall (see Figure 7). For longitudinal tests, the test piece shall be machined all over (on six faces). If the wall thickness does not permit a final test piece width of 10 mm, the width shall be as near as practicable to the nominal thickness of the cylinder wall. The test pieces taken in the transverse direction shall be machined on four faces only, the outer face of the cylinder wall unmachined and the inner face optionally machined as shown in Figure 8.

10.4.2 Minimum acceptance values shall be as given in Table 2.



Key

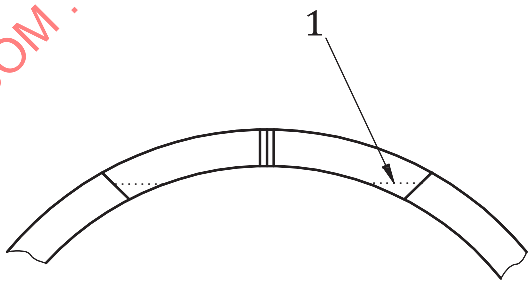
1 transverse test piece

2 cylinder longitudinal axis

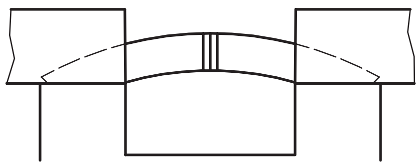
3 Charpy V-notch perpendicular to the wall

4 longitudinal test piece

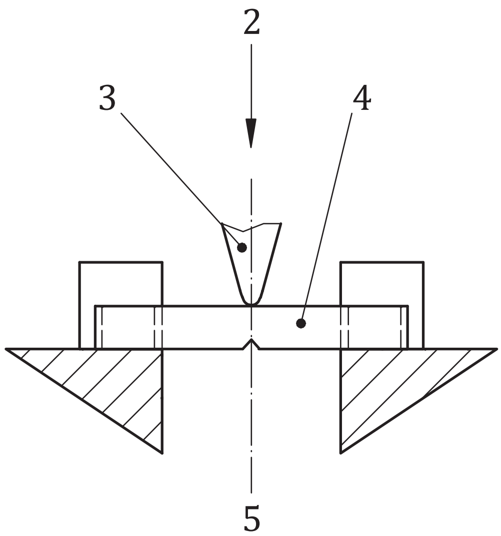
Figure 7 — Description of the transverse and longitudinal impact test pieces



a) Test piece taken from the cylinder wall



b) Front view of the test piece in the impact tester



c) Top view of the test piece in the impact tester

Key

1 machining optional

2 direction of strike

3 striking anvil

4 test piece

5 centre of strike

Figure 8 — Description of the transverse impact testing

Table 2 — Impact test acceptance values

Cylinder diameter *D*, mm	> 140			≤ 140
Direction of testing	transverse			longitudinal
Width of test piece, mm	3 to 5	> 5 to 7,5	> 7,5 to 10	3 to 10
Test temperature[a], °C	-50			-50
Impact Value[b], J/cm^2				
— **Mean of three test pieces**	30	35	40	60
— **Individual test piece**	24	28	32	48

[a] For applications at lower temperatures, the test shall be carried out at the lowest temperature specified.

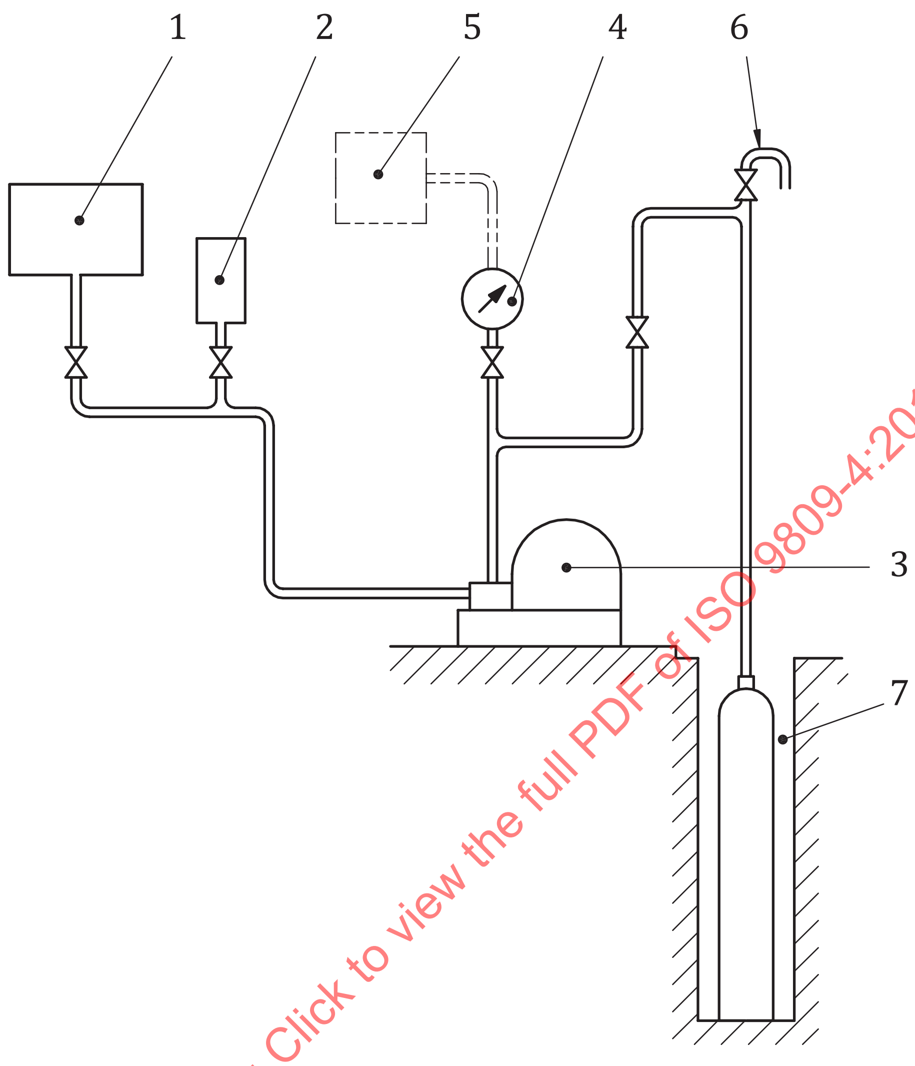
[b] The impact value (J/cm^2) is calculated by dividing the impact energy (J) by the actual cross sectional area below the notch (cm^2) of the Charpy test specimen.

10.5 Hydraulic burst test

10.5.1 Test installation

The test equipment shall be capable of operating in accordance with the test conditions specified in 10.5.2 and of accurately producing the information specified in 10.5.3.

A typical hydraulic burst test installation is illustrated in Figure 9.



Key

1 test fluid reservoir

2 tank for measuring the test fluid (The test fluid reservoir can also be used as the measuring tank.)

3 pump

4 pressure gauge

5 pressure/time curve recorder

6 vent or air-release valve

7 test well with cylinder

Figure 9 — Typical hydraulic burst test installation

10.5.2 Test conditions

As the cylinder and test equipment are being filled with water, 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) In 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) In the second stage, the pump discharge rate shall be maintained at as constant a level as is possible until the cylinder bursts.

10.5.3 Interpretation of test results

10.5.3.1 Interpretation of the burst test results shall involve

a) the examination of the pressure/time curve or pressure/volume-of-water-used curve, to determine the pressure at which the plastic deformation of the cylinder commences, together with the burst pressure, and

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

10.5.3.2 For the results of a burst 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 $\frac{1}{F}\times$ the test pressure.

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

b) The actual burst pressure (p_b) shall be equal to or greater than 1,6 × the test pressure.

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

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

10.5.3.4 The main fracture shall be in the cylindrical portion and shall not be brittle, i.e. the fracture edges shall be inclined with respect to the wall. The tear shall not reveal a significant defect in the metal and in no case shall reach the neck. For concave bases, the tear shall not run further than the cylindrical body at the base end and, for convex bases, the tear shall not reach the centre of the base.

10.5.3.5 For cylinders with a wall thickness less than 7,5 mm, the fracture shall be acceptable only if it conforms to one of the following descriptions.

a) For quenched and tempered cylinders:

— longitudinal, without branching (see Figure 10);

— longitudinal, with a side branching at each end which in no case extends beyond the longitudinal plane normal to the fracture plane ($c_1 \leq D/4$; see Figure 11);

b) For cryoformed or solution-annealed cylinders:

— longitudinal, without branching (see Figure 10);

— longitudinal, with a side branching at each end which in no case exceeds half the cylinder circumference ($c_2 \leq D/2$; see Figure 12).

10.5.4 Acceptance criteria

Figures 10, 11, and 12 illustrate the satisfactory burst test profiles, and the batches represented by such results shall be accepted.

If the configuration of the fracture does not conform to Figures 10, 11, or 12 but all other material and mechanical tests are satisfactory, an investigation of the cause of the non-conformity shall be undertaken prior to the acceptance or rejection of the batch.

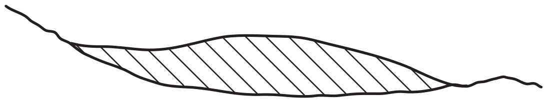


Figure 10 — Acceptable burst profiles: longitudinal without branching

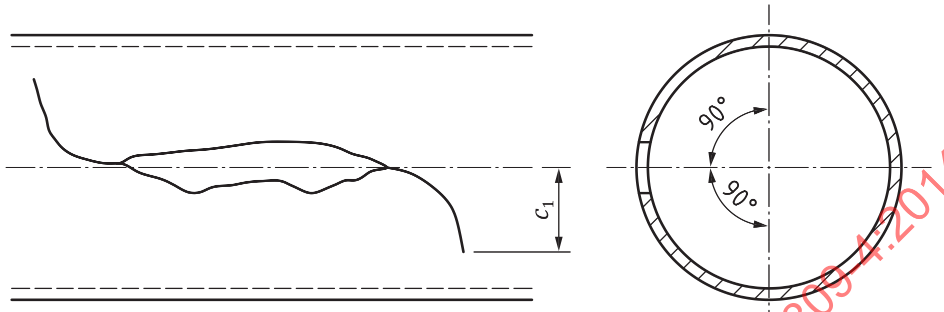


Figure 11 — Acceptable burst profiles: longitudinal with side branching, $c_1 < (\pi D/4)$

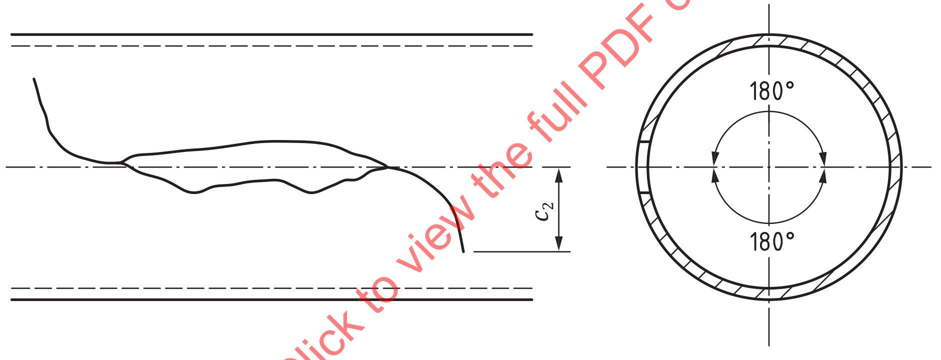


Figure 12 — Acceptable burst profiles for cryoformed or solution annealed cylinders only: longitudinal with side branching, $c_2 < (\pi D/2)$

10.6 Intergranular corrosion test

This test is required on austenitic and duplex stainless steel grades only.

The test shall be carried out in accordance with ISO 3651-2.

The test requires that the specimens be taken from a part of the cylinder that provides specimen geometry suitable for bend testing.

11 Tests/examinations on every cylinder

11.1 General

During production, the examinations specified in 8.2 and 8.4 shall be carried out on all cylinders.

Following the final heat treatment, 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;

NOTE The test method requirements are given below. Additional guidance for these test methods and equipment control (calibration and maintenance) can be found in ISO 6406. 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.

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 within a measuring tolerance of 0/+3 % or +10 bar, whichever is lower.

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. During the period that the cylinder is under test pressure, it shall be visible (including the base) and remain dry. After the test, the cylinder shall show no visible permanent deformation and no trace of moisture implying leakage.

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 within a measuring tolerance of 0/+3 % or +10 bar, whichever is lower.

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 remeasured.

The cylinder shall be rejected if it shows a permanent expansion (i.e. a volumetric expansion after the pressure has been released) in excess of 10 % 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. the total expansion less the permanent expansion) under the test pressure can be established for each cylinder.

11.3 Hardness test

A hardness test in accordance with ISO 6506-1, ISO 6508-1, 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, dependent upon the heat treatment used for the production of the cylinder and the intended gas service (e.g. embrittling gases).

NOTE Methods for measuring the surface indentations other than those given in ISO 6506-1 or ISO 6508-1 can be used subject to agreement between the parties concerned provided that an equal level of accuracy can be demonstrated.

11.4 Leak 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.

For cylinders with base ends formed by spinning, typical testing procedures include:

— pneumatic leakage test where the bottom end can be clean and free from all moisture on the test pressure side;

NOTE The inside area of the cylinder bottom surrounding the closure can be subjected to a pressure equal to at least 2/3 times the test pressure of the cylinder for a minimum of 1 min. This area can be not less than 20 mm in diameter around the closure and at least 6% of the total bottom area. The opposite side can be covered with water or another suitable medium and closely examined for indication of leakage. Cylinders that leak can be rejected.

— low pressure pneumatic test;

— helium leak test.

11.5 Capacity check

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

12 Certification

Each batch of cylinders shall be covered by a certificate signed by the inspector to the effect that the cylinders meet the requirements of this part of ISO 9809 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 permanently marked 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 regulations of the countries of use.

NOTE Attention is drawn to the requirements for marking in relevant regulations that might override the requirements given in this International Standard.

Annex A
(informative)

Description and evaluation of manufacturing imperfections and conditions for rejection of seamless steel gas cylinders at the time of final inspection by the manufacturer

A.1 Introduction

Several types of imperfections can occur during the manufacturing of a seamless steel gas cylinder.

Such imperfections can be mechanical or material. They can be due to the basic material used, manufacturing process, heat treatments, manipulations, necking, machining or marking operations, and other circumstances during manufacture.

The aim of this annex is to identify the manufacturing imperfections most commonly met and to provide general guidelines to the inspectors that perform the visual inspection. Nevertheless, extensive field experience, good judgment, and independence from production are necessary for the inspector to detect and to be able to evaluate and judge an imperfection at the time of the visual inspection.

A.2 General

A.2.1 It is essential to perform the visual internal and external inspection under the following good conditions.

— The surface of the metal, in particular of the inner wall, shall be completely clean, dry, and free from oxidation products, corrosion, scale, etc., as these could obscure other more serious imperfections. Where necessary, the surface shall be cleaned under closely controlled conditions by suitable methods before further inspection.

— Appropriate sources of illumination with sufficient intensity shall be used.

— After the cylinders have been closed and the threads have been cut, the internal neck area shall be examined by means of an introscope, dental mirror, or other suitable appliance.

A.2.2 Small imperfections can be removed by local dressing, grinding, machining, or other appropriate method.

Great care shall be taken to avoid introducing new injurious imperfections.

After such a repair, the cylinders shall be re-examined and if the cylindrical wall thickness is reduced, it shall be rechecked.

A.3 Manufacturing imperfections

The most commonly found manufacturing imperfections and their definitions are listed in Table A.1.

Rejection limits for repair or reject are also included in Table A.1. These rejection limits have been established following considerable field experience. They apply to all sizes and types of cylinders and service conditions. Nevertheless, some customer specifications, some types of cylinders, or some special service conditions can require stronger conditions.

A.4 Rejected cylinders

All rejected cylinders shall be rendered unserviceable for their original application.

It can be possible to produce cylinders for different service conditions from rejected cylinders.

Table A.1 — Manufacturing imperfections

Imperfection	Description	Condition for rejection and/or action	Repair/reject
bulge	visible swelling of the wall	all cylinders with such an imperfection	reject
dent (flats)	a depression in the wall that has neither penetrated nor removed metal with a depth greater than 1 % of the external cylinder diameter (see Figure A.1) (see also excessive grinding or machining)	when the depth of the dent exceeds 2 %[a] of the external diameter of the cylinder	reject
		when the depth of the dent is greater than 1 mm and when the diameter of the dent is less than 30 × its depth[a)]	permit repair
cut, gouge, and metallic or scale impression	an impression in the wall where metal has been removed or redistributed (due basically to the introduction of foreign bodies on the mandrel or matrix during the extrusion or drawing operations)	inside imperfection: if not superficial with sharp notches more than 5 % of the wall thickness[b]	reject
		outside imperfection: when the depth exceeds 5 % of the wall thickness	repair possible (see A.2.2)
dent containing cut or gouge	a depression in the wall which contains a cut or gouge (see Figure A.2)	all cylinders with such imperfections	reject
excessive grinding or machining	local reduction of wall thickness by grinding or machining	when the wall thickness is reduced to below the minimum design thickness	reject
		when it results in the formation of a dent	see "dent" above
rib	a longitudinal raised surface with sharp corners having a height of 3 % or more than the wall thickness (see Figure A.3)	inside imperfection: when the height exceeds 5 % of the wall thickness or when the length exceeds 10 % of the length of the cylinders	repair, if possible, or reject (see A.2.2)
		outside imperfection: when the height exceeds 5 % of wall thickness or when the length exceeds five times the thickness of the cylinders	
groove	a longitudinal notch having a depth of 3 % or more than the wall thickness (see Figure A.4)	inside imperfection: when the depth exceeds 5 % of the wall thickness or when the length exceeds 10 % of the length of the cylinders	repair, if possible, or reject (see A.2.2)
		outside imperfection: when the depth exceeds 5 % of the wall thickness or when the length exceeds 5 times the thickness of the cylinders	
lamination	layering of the material within the cylinder wall and sometimes appearing as a discontinuity, crack lap, or bulge at the surface (see Figure A.5)	inside imperfection: all cylinders with such imperfection	repair, if possible, or reject
		outside imperfection: all cylinders with such imperfection	repair, if possible, or reject (see A.2.2)

a On small diameter cylinders, these general limits can be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small cylinders.

b Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.

Table A.1 *(continued)*

Imperfection	Description	Condition for rejection and/or action	Repair/reject
crack	split and material separation	when not removable within the thickness tolerance	reject
		when removable within the thickness tolerance	repair
neck cracks	appear as lines which run vertically down the thread and across the thread faces (They shall not be confused with tap marks = thread machining marks.) (see Figure A.6)	all cylinders with such imperfections	reject
shoulder folds and/or shoulder cracks	folding with peaks and troughs situated in the internal shoulder area, which can propagate into the threaded area of the shoulder (see Figure A.7); cracks which can start from folds in the internal shoulder area and propagate into the cylindrical machined or threaded area of the shoulder (Figure A.8 shows exactly where shoulder cracks start and how they propagate.)	Folds or cracks that are visible as a line of oxide running into the threaded portion shall be removed by a machining operation until the lines of oxide are no longer visible (see Figure A.7). After machining, the whole area shall be re-inspected carefully and the wall thickness verified.	repair if possible
		if folding or lines of oxide have not been removed by machining, if cracks are always visible, or if the wall thickness is unsatisfactory	reject
		Folds which extend beyond the machined area and are clearly visible as open depressions where no oxides have been trapped into the metal shall be accepted provided that the peaks are smooth and the root of the depression is rounded.	acceptable
internal cracks in base	splits in the metal at the bottom of the cylinder in star form	when not removable within the thickness tolerance	reject
		when removable within the thickness tolerance	repair
“orange peel” surface	orange peel appearance due to discontinuous metal flow	if sharp cracks are visible in the orange peel surface	reject
internal neck threads damaged or out of tolerance	neck threads damaged, with dents, cuts, or burrs, or out of tolerance	When the design permits it, threads can be retapped and rechecked by the appropriate thread gauge and carefully visually re-examined. The appropriate number of effective threads shall be guaranteed.	repair
		if not repairable	reject
pitting	severe surface corrosion	all cylinders with such imperfections visible after the shot blasting	reject
non-conformity with the design drawing		all cylinders presenting such an imperfection	repair, if possible, or reject

[a] On small diameter cylinders, these general limits can be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small cylinders.

[b] Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.

Table A.1 *(continued)*

Imperfection	Description	Condition for rejection and/or action	Repair/reject
neck ring not secure	neck ring turns under application of low torque or pulls off under low axial load (See ISO 11117 for guidance.)	all cylinders presenting such an imperfection	repair possible according to approved method only
arc or torch burns	partial burning of the cylinder metal, the addition of weld metal, or the removal of metal by scarfing or cratering	all cylinders presenting such an imperfection	reject

[a] On small diameter cylinders, these general limits can be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small cylinders.

[b] Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.

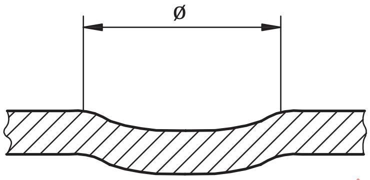


Figure A.1 — Dent

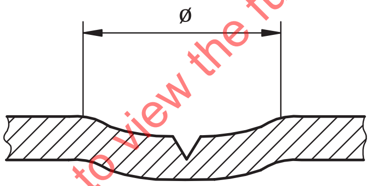


Figure A.2 — Dent containing cut or gouge

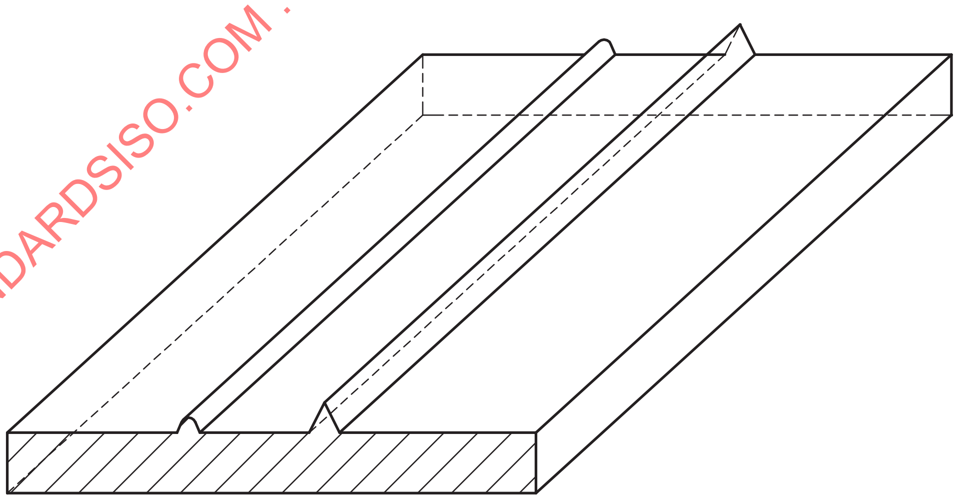


Figure A.3 — Rib

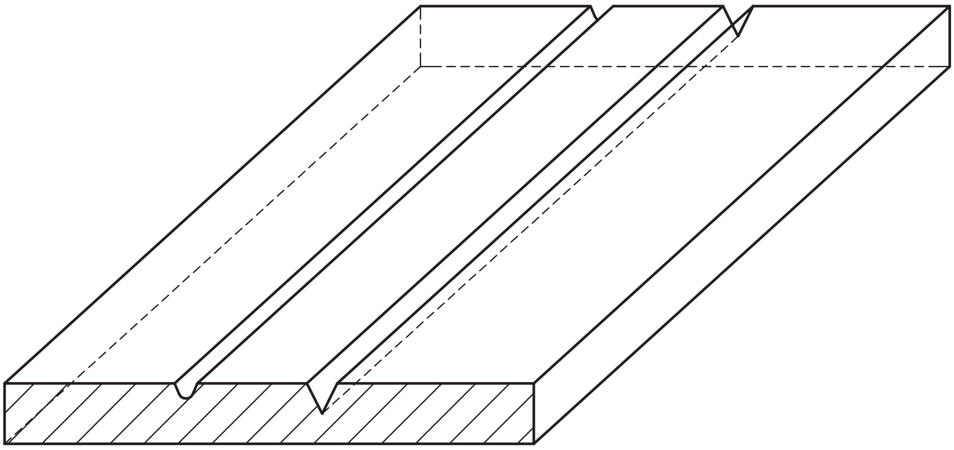


Figure A.4 — Groove

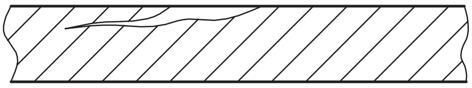
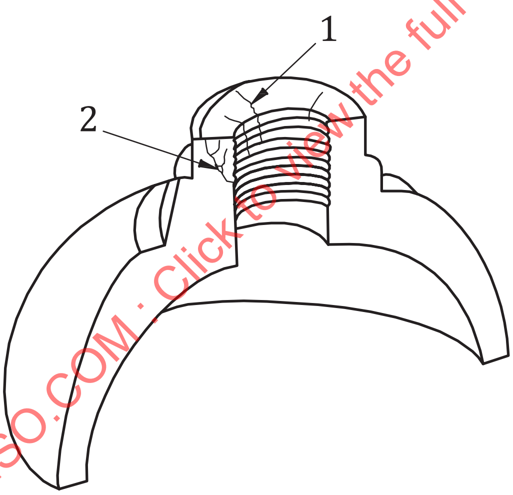


Figure A.5 — Lamination

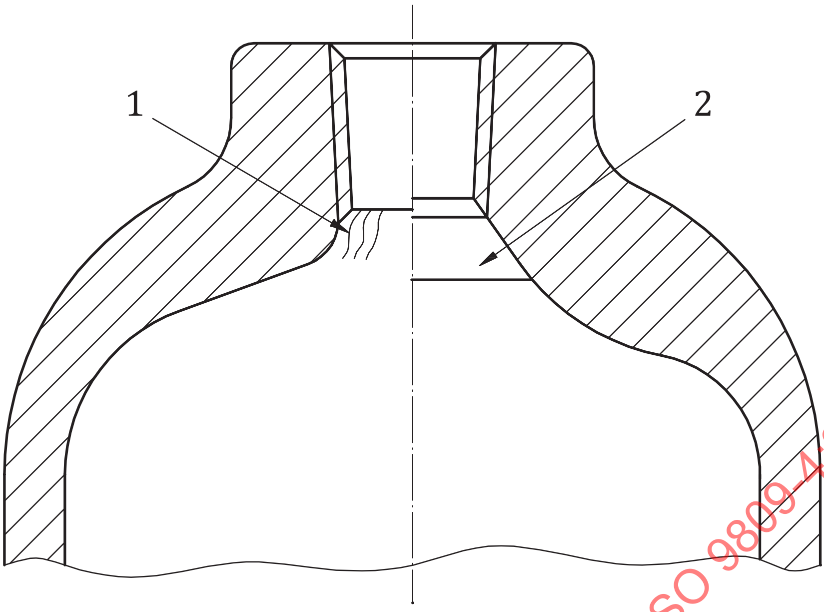


Key

1 neck cracks

2 propagated crack in the neck

Figure A.6 — Neck cracks

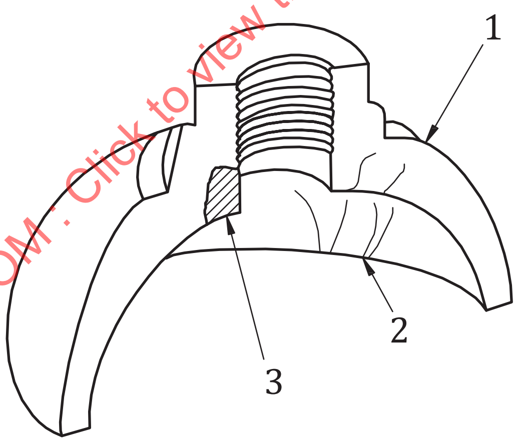


Key

1 folds or cracks

2 after machining

Figure A.7 — Cylinder shoulder folds or cracks before and after machining



Key

1 shoulder cracks

2 propagated crack in the shoulder

3 folds

Figure A.8 — Shoulder cracks

Annex B
(normative)

Ultrasonic examination

B.1 General

This annex is based on techniques used by cylinder manufacturers. Other techniques of ultrasonic examination can be used, provided that these have been demonstrated to be suitable for the manufacturing method.

B.2 General requirements

The ultrasonic examination equipment shall be capable of at least detecting the reference standard notches as described in B.3.2. It shall be serviced regularly in accordance with the manufacturer's operating instructions to ensure that its accuracy is maintained. The inspection records and approval certificates for the equipment shall be maintained.

The operation of the ultrasonic examination equipment shall be by a qualified and experienced personnel certified at least to level 1 and supervised by a personnel certified at least to level 2 in accordance with ISO 9712. Other standards which meet or exceed these minimum requirements can be used subject to the approval of the inspector. The inner and outer surfaces of any cylinder which is to be examined ultrasonically shall be in a condition suitable for an accurate and reproducible examination.

For flaw detection, the pulse echo system shall be used. For thickness measurement, either the resonance method or the pulse echo system shall be used. Either the contact or immersion techniques of examination shall be used.

A coupling method which ensures adequate transmission of ultrasonic energy between the test probe and the cylinder shall be used.

B.3 Flaw detection of the cylindrical parts

B.3.1 Procedure

The cylinders to be examined and the search unit shall have a rotating motion and translation relative to one another such that a helical scan of the cylinder will be described. The velocity of the rotation and translation shall be constant within ±10 %. The pitch of the helix shall be less than the width covered by the probe (at least a 10 % overlap shall be guaranteed) and be related to the effective beam width such as to ensure 100 % coverage at the velocity of the rotational and translation used during the calibration procedure.

An alternative scanning method can be used for transverse detection of imperfections, in which the scanning or relative movement of the probes and the work piece is longitudinal, the sweeping motion being such as to ensure a 100 % surface coverage with approximately 10 % overlapping of the sweeps.

The cylinder wall shall be examined for longitudinal imperfections with the ultrasonic energy transmitted in both circumferential directions and, for transverse imperfections, in both longitudinal directions.

For concave based cylinders where hydrogen embrittlement or stress corrosion can occur (see ISO 11114-1), the transition region between the cylindrical part and the cylinder base shall also be examined for transverse imperfections in the direction of the base. For the area to be considered, see

Figure B.1. In this case, or when optional examination is carried out on the transition areas between the wall and neck and/or wall and base, this can be conducted manually, if not carried out automatically.

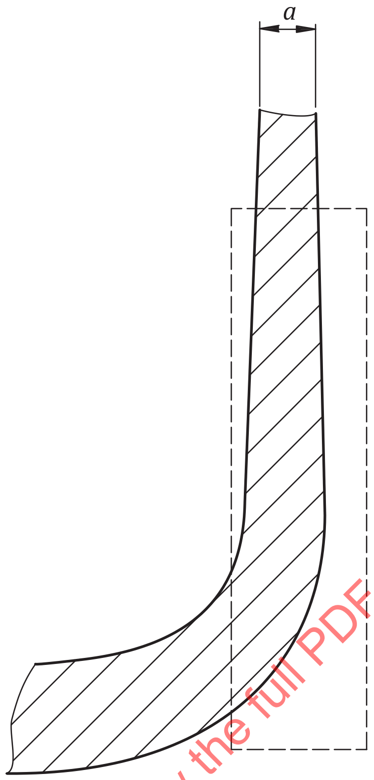


Figure B.1 — Base/wall transition region

One of the following two methods shall be used.

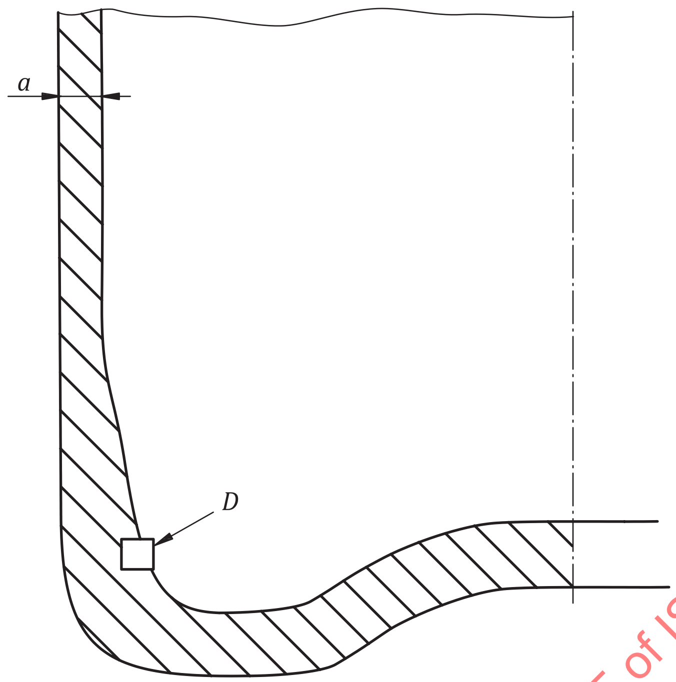
— Method A

The ultrasonic sensitivity shall be set at +6 dB to improve the detection of imperfections equivalent to 5 % of the cylindrical wall thickness in this thickened portion.

— Method B

The ultrasonic system shall be calibrated using a standard reference artefact of a cylinder with a notch at the sidewall-to-base transition (SBT) area shown in Figure B.2.

The depth of the notch (T) for SBT shall be (10 ± 1) % of the guaranteed minimum wall thickness (a'), with a minimum of 0,2 mm and a maximum of 1 mm, over the full length of the notch.



Key

D approximate notch location

a guaranteed minimum wall thickness (*a*')

Figure B.2 — Schematic representation of the reference notch for SBT

The effectiveness of the equipment shall be periodically checked by putting a reference standard through the examination procedure. This check shall be carried out at least at the beginning and end of each shift. If during this check the presence of the appropriate reference notch is not detected, all cylinders examined subsequent to the last acceptable check shall be retested after the equipment has been reset.

B.3.2 Reference standard

A reference standard of convenient length shall be prepared from a cylinder which is dimensionally and acoustically representative of the cylinder to be examined, as demonstrated by the manufacturer. The reference standard shall be free from discontinuities which can interfere with the detection of the reference notches.

Reference notches, both longitudinal and transverse, shall be machined on the outer and inner surface of the standard. The notches shall be separated such that each notch can be clearly identified.

The dimensions and shape of notches are of crucial importance for the adjustment of the equipment (see Figures B.3 and B.4).

— The length of the notches (*E*) shall not be greater than 50 mm.

— The width (*W*) shall be not greater than twice the nominal depth (*T*). However, where this condition cannot be met, a maximum width of 1,0 mm is acceptable.

— The depth of the notches (*T*) shall be (5 ± 0,75) % of the guaranteed minimum wall thickness (*a*'), with a minimum of 0,2 mm and a maximum of 1,0 mm, over the full length of the notch. Run-outs at each end are permissible.

— The notch shall be sharp edged at its intersection with the surface of the cylinder wall. The cross section of the notch shall be rectangular except where spark erosion machining methods are employed, when it is acknowledged that the bottom of the notch will be rounded.

