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Gas cylinders – Seamless steel and seamless aluminium-alloy gas cylinders and tubes – Periodic inspection and testing (ISO 18119:2018)

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National foreword

This British Standard is the UK implementation of EN ISO 18119:2018.

The UK participation in its preparation was entrusted to Technical Committee PVE/3/7, Gas containers - Gas cylinder (receptacle) operations.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Gas cylinders - Seamless steel and seamless aluminium-alloy gas cylinders and tubes - Periodic inspection and testing (ISO 18119:2018)

Bouteilles à gaz - Bouteilles et tubes à gaz en acier et en alliages d'aluminium, sans soudure - Contrôles et essais périodiques (ISO 18119:2018)

Gasflaschen - Nahtlose Gasflaschen und Großflaschen aus Stahl und Aluminiumlegierungen - Wiederkehrende Inspektion und Prüfung (ISO 18119:2018)

This European Standard was approved by CEN on 17 May 2018.

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European foreword

This document (EN ISO 18119:2018) has been prepared by Technical Committee ISO/TC 58 "Gas cylinders" in collaboration with 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of an identical text or by endorsement, at the latest by April 2019, and conflicting national standards shall be withdrawn at the latest by April 2019.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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Endorsement notice

The text of ISO 18119:2018 has been approved by CEN as EN ISO 18119:2018 without any modification.

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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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*.

This first edition cancels and replaces ISO 6406:2005 and ISO 10461:2005, which have been technically revised. It also incorporates the Amendment ISO 10461:2005/Amd 1:2006.

The main changes are:

— a section has been added for symbols used in the document;

— a detailed account of steps to be taken if the actual cylinder wall thickness is less than the minimum design wall thickness has been added;

— a clearer way to ultrasonically test cylinders with a built-in footring, especially for seamless steel cylinders with a convex base, has been added;

— improved guidelines have been added for dealing with the effects of heating of seamless aluminium-alloy cylinders.

Introduction

This document provides information and procedures for the periodic inspection and testing of seamless steel and seamless aluminium-alloy cylinders and the condition of the test equipment. The principal aim of periodic inspection and testing is that at the completion of the test the cylinders have been requalified and are suitable to be reintroduced into service for a further period of time.

This document requires that well-trained and competent personnel undertake the work as described in this document, who consult the cylinder's manufacturer if there are doubts about aspects of the document, so that the cylinder manufacturer's current recommendations are taken into account.

This document has been written so that it is suitable to be referenced in the UN *Model Regulations*[23].

Gas cylinders – Seamless steel and seamless aluminium-alloy gas cylinders and tubes – Periodic inspection and testing

CAUTION — Some of the tests specified in this document involve the use of processes that could lead to a hazardous situation.

1 Scope

This document specifies the requirements for periodic inspection and testing to verify the integrity of cylinders and tubes to be re-introduced into service for a further period of time.

This document is applicable to seamless steel and seamless aluminium-alloy transportable gas cylinders (single or those that comprise a bundle) intended for compressed and liquefied gases under pressure, of water capacity from 0,5 l up to 150 l and to seamless steel and seamless aluminium-alloy transportable gas tubes (single or those that comprise a bundle) intended for compressed and liquefied gases under pressure, of water capacity greater than 150 l. It also applies, as far as practical, to cylinders of less than 0,5 l water capacity.

This document does not apply to the periodic inspection and maintenance of acetylene cylinders or to the periodic inspection and testing of composite cylinders.

NOTE Unless noted by exception, the use of the word "cylinder" in this document refers to both cylinders and tubes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 7866, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

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

ISO 9809-1, *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*

ISO 10286, *Gas cylinders — Terminology*

ISO 11621, *Gas cylinders — Procedures for change of gas service*

ISO 13769[1)], *Gas cylinders — Stamp marking*

ISO 22434, *Transportable gas cylinders — Inspection and maintenance of cylinder valves*

ISO 25760, *Gas cylinders — Operational procedures for the safe removal of valves from gas cylinders*

1) To be published. Stage at the time of publication: ISO/FDIS 13769:2018.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10286 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
liquefied gas
gas, which, when packaged under pressure, is partially liquid at temperatures above −50 °C

Note 1 to entry: A distinction is made between

a) high pressure liquefied gas: a gas with a critical temperature between −50 °C and 65 °C, and

b) low pressure liquefied gas: a gas with a critical temperature above 65 °C.

3.2
rejected cylinder
cylinder not fit for service

3.3
competent authority
any national body or authority designated or otherwise recognized as such, having jurisdiction for the transport of dangerous goods and the approval of gas cylinders

Note 1 to entry: Adapted from UN *Model Regulations*[23].

3.4
minimum design wall thickness
thickness of the cylinder wall calculated from the design standard, taking into account the material properties and dimensions at time of manufacture

3.5
stove
treat by heating in a stove or an oven in order to apply a desired surface coating

4 Abbreviated terms and symbols

FBH	flat bottom hole
PE	permanent expansion
SBT	sidewall-to-base transition region
UT	ultrasonic testing
C	compressibility (expressed in m^2/N or Pa^{-1})
D	depth of notch in ultrasonic test sample (expressed in mm)
K	factor for individual temperature (listed in Table C.1)
L	length of notch in ultrasonic test sample (expressed in mm)
P	pressure (expressed in bar)
V	cylinder water capacity (expressed in l)

W width of notch in ultrasonic test sample (expressed in mm)

X flaw length (expressed in mm)

Y flaw depth ratio

t_{mc} minimum measured wall thickness of the calibration specimen (expressed in mm)

t_m minimum design wall thickness (expressed in mm)

5 Intervals between periodic inspections and tests

A cylinder shall be due for periodic inspection and testing on its first receipt by a filler following the expiry of the established interval or, in the absence of regulations, in accordance with the UN *Model Regulations*[23]. Annex A lists the intervals for period inspection and testing as outlined in the 19th revised edition of the UN *Model Regulations*. The expiry date is based on the last test date shown on the cylinder. Other means of indicating the expiry date may be used.

Provided the cylinder has not been subjected to abusive and abnormal conditions such as being involved in an accident, heat exposure or other severe conditions that would render it unsafe, there is no requirement for the user to return a cylinder before the contents have been used even though the periodic inspection and testing interval has lapsed. However, cylinders, particularly those containing corrosive gases, should be retested within a period not exceeding twice the time interval.

Seamless steel or seamless aluminium-alloy cylinders used for self-contained breathing apparatus or self-contained underwater breathing apparatus that are not covered by transport regulations may be submitted for inspection within the interval shown in Table A.1.

6 List of procedures for periodic inspections and tests

Assessment of conformity to this document shall be carried out in accordance with the applicable regulations of the countries of use.

Tests and examinations performed to demonstrate compliance shall be conducted using instruments calibrated before being put into service and thereafter according to an established programme.

Each cylinder shall be submitted to periodic inspections and tests. The following procedures, when applicable, form the requirements for such inspections and tests and are explained more fully in subsequent clauses:

a) identification of cylinder and preparation for inspection and tests (see Clause 7);

b) depressurization and de-valving procedures (see Clause 8);

c) external visual inspection (see Clause 9);

d) inspection of cylinder neck (see Clause 10);

e) check of internal condition (see Clause 11);

f) supplementary tests (see Clause 12);

g) cylinder repairs (see Clause 13);

h) pressure test or UT (see Clause 14);

i) inspection of valve and other accessories (see Clause 15);

j) replacement of cylinder parts (see Clause 16);

k) final operations (see Clause 17);

l) rejection and rendering cylinder unserviceable (see Clause 18).

These procedures should be performed in the sequence listed in order to improve the safety of the operation and to detect potential harmful damage. In particular, the external visual inspection (see Clause 9) shall be carried out before the internal visual inspection (when required) (see Clause 11), the pressure test, or UT (see Clause 14).

When a cylinder passes the above listed procedures but the condition of the cylinder remains in doubt, additional, supplementary tests shall be performed to confirm its suitability for continued service (see Clause 12) or the cylinder shall be rendered unserviceable in accordance with Clause 18.

Depending on the reason for rejection, some cylinders may be recovered in accordance with Annex B.

Mechanical properties of seamless steel and seamless aluminium-alloy cylinders can be affected by heat exposure. Therefore, the maximum temperature for any operation shall be limited in accordance with the manufacturer's recommendation (for seamless aluminium-alloy cylinders, see 17.1.2.3).

Cylinders that fail an inspection or test and cannot be recovered shall be rendered unserviceable in accordance with Clause 18.

The eyesight acuity of operators is critical and should be checked by an optician on a yearly basis.

7 Identification of cylinder and preparation for inspection and tests

The labelling and permanent markings on the cylinder shall be checked and the information recorded before carrying out any further work. When a toxic, flammable or pyrophoric gas is involved, the owner or the individual presenting the cylinder for retest shall inform the testing facility accordingly. Cylinders with incorrect or illegible markings or unknown gas contents shall be set aside for special handling.

Cylinders intended for a change of gas service shall be evaluated in accordance with ISO 11621.

For seamless steel cylinders, the following applies in addition:

If the contents are identified as hydrogen or other embrittling gas, only those cylinders manufactured or qualified as hydrogen cylinders shall be used for that service. Check that the cylinder is compatible for hydrogen service, i.e. with respect to the maximum tensile strength and internal surface condition. Seamless steel cylinders marked in accordance with ISO 13769 are stamped “H”. Seamless steel cylinders that have not been checked or are not stamped “H” shall not be reintroduced into hydrogen service. Their suitability for their new, intended service shall be evaluated in accordance with ISO 11621.

8 Depressurization and de-valving procedures

8.1 General

Cylinders that require an internal visual inspection shall be depressurized and emptied in a safe, controlled manner and de-valved prior to inspection in accordance with ISO 25760.

Particular attention shall be given to cylinders containing flammable, oxidizing, corrosive or toxic gases to eliminate risks at the internal inspection stage. See Annex C for a list of gases that are corrosive to cylinder material.

Cylinders (other than those with a footring) to be ultrasonically inspected may be examined without being depressurized or having the valve removed.

WARNING — The uncontrolled opening and/or removal of valves from cylinders can lead to injury, death and/or property damage.

When ultrasonically testing cylinders that are under pressure, care shall be taken to ensure the safety of personnel and property (e.g. by placing a valve protection device over the valve or by depressurizing the cylinder to 5 bar or less).

8.2 Cylinders requiring de-valving

All cylinders received for testing for which an internal visual inspection is required shall be safely de-valved in accordance with ISO 25760.

Cylinders with a footring shall be de-valved for internal inspection and may be subsequently evaluated by UT.

8.3 Cylinders not requiring de-valving

Cylinders without a footring that are to be evaluated by UT do not require the valves to be removed unless otherwise specified in this document.

8.4 Cylinders requiring shot blasting

Cylinders that require shot blasting shall be depressurized before processing.

9 External visual inspection

9.1 Preparation

If a cylinder's external condition prevents or hinders a proper visual inspection of the surface, then the cylinder shall be prepared before the inspection. If any welded or brazed attachment (e.g. neckring) is seen, the cylinder shall be rendered unserviceable in accordance with Clause 18.

The cylinder shall be cleaned and have all loose coatings, labels, corrosion products, tar, oil or other foreign matter removed from its external surface. The cylinder shall not at this stage be brushed or blasted until after the external visual inspection has been completed in order to not remove signs of previous damage. Seamless aluminium-alloy cylinders should be prepared for visual examination (see Annex F). They shall not be shot blasted using steel media; however, blasting may be conducted with other appropriate media (e.g. walnut shells, dry ice pellets, etc.).

The method used to clean the cylinder shall be a validated, controlled process. Care shall be taken at all times to avoid damaging the cylinder taking into account the information provided in Annex B.

If fused nylon, polyethylene or a similar coating has been applied and it is damaged or prevents proper inspection, then this coating shall be removed. If the coating has been removed by the application of heat, then care shall be taken that the applied temperature has not altered the mechanical properties of the cylinder material. The temperatures at which damage occurs are as follows:

a) For seamless steel cylinders: in no case shall the temperature of the cylinder have exceeded 300 °C.

b) For seamless aluminium-alloy cylinders: in no case shall the temperature of the cylinder have exceeded the limits specified in 17.1.2.3.

For both seamless steel and seamless aluminium-alloy cylinders, contact the manufacturer if there is doubt about heat exposure. If the manufacturer cannot be consulted, the cylinder shall be rendered unserviceable in accordance with Clause 18.

9.2 Inspection procedure

The external surface of each cylinder shall be inspected for the following in accordance with Table B.1, Table B.2 or Table B.3 as applicable:

a) dents, cuts, gouges, bulges, cracks, laminations or excessive base wear;

b) heat damage, torch damage or electric arc burns;

c) corrosion;

d) other defects such as illegible, incorrect or unauthorized stamp markings, or unauthorized additions or modifications;

e) integrity of all permanent attachments;

f) vertical stability.

Corrosion is likely to occur in the footring area, especially the transition area cylindrical part/footring, and the gap-area convex base/footring. When inspecting cylinders with footrings, extra attention shall be given to these areas.

At this stage, the cylinder shall be visually inspected for signs of corrosion (see Table B.2 for rejection criteria). Attention shall be given to areas where water can be trapped. These areas include the entire base area and the neckring. If corrosion is detected, then the corrosion products and paint shall be removed (e.g. shot blasted), particularly where the corrosion appears on the cylinder shell. If the extent of the corrosion cannot be determined, including doubt about the remaining wall thickness, then the cylinder shall be rejected.

Rejection criteria shall be in accordance with Annex B. Cylinders no longer suitable for future service shall be rendered unserviceable in accordance with Clause 18.

10 Inspection of cylinder neck

10.1 Cylinder-to-valve threads

After the valve is removed, the cylinder-to-valve threads shall be examined to identify the type of thread (e.g. see ISO 11363-2) and to ensure that they are:

— clean and of full form, and

— free of damage (e.g. burrs, cracks, cross-threading, corrosion, etc.).

Cylinders in toxic or corrosive gas service shall have their threads gauged for wear and ovality using a plug gauge (see Figures 1, 2 and 3). The threads of cylinders in other gas services may be verified using appropriate gauges in cases of doubt.

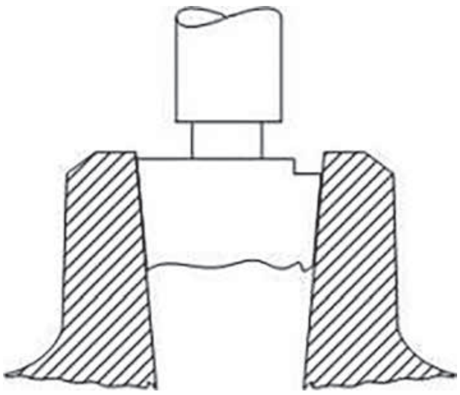
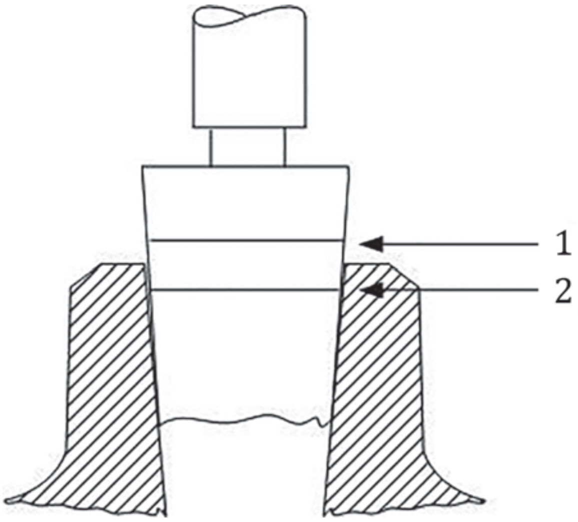


Figure 1 — Example of a calibrated upper thread plug gauge (thread failed)

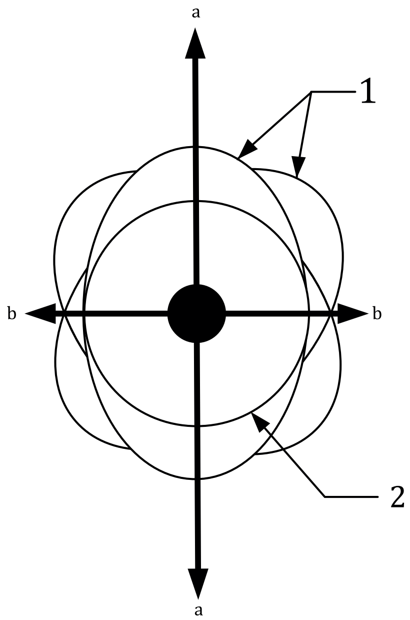


Key

1 maximum

2 minimum

Figure 2 — Example of a "Go/no-go" plug gauge (thread passed)



Key

1 oval thread in cylinder neck

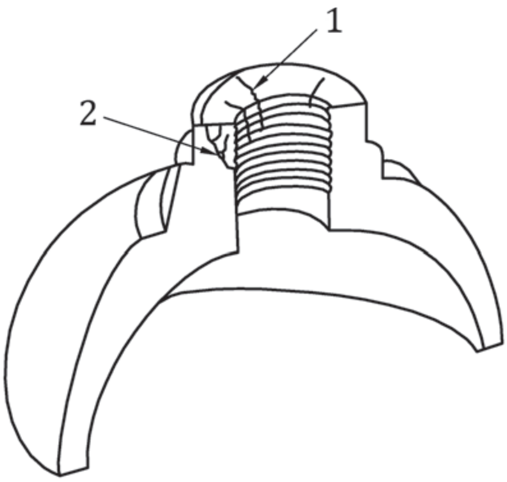
2 plain taper plug gauge

a Large movement.

b Small movement.

Figure 3 — Ovality check

Neck cracks manifest themselves as lines that run down the thread across the thread faces (see Figure 4). Special attention should be paid to look for the presence of cracks in the area at the bottom of the last thread. They should not be confused with tap marks (tap stop marks). See Figure 5.

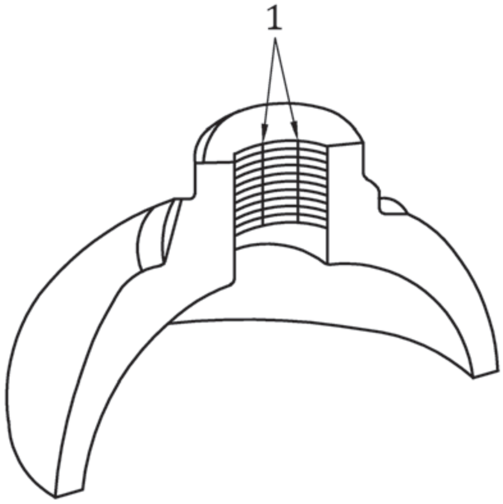


Key

1 neck crack

2 propagated crack in the neck

Figure 4 — Neck cracks



Key

1 tap marks

Figure 5 — Tap marks

10.2 Other neck surfaces

Other surfaces of the neck (e.g. face, O-ring seat, external neck surface, etc.) shall also be examined to ensure they are free from cracks and imperfections in accordance with Annex B.

When a tube is removed from its mounting, external neck threads shall be gauged.

10.3 Damaged internal neck threads

When necessary, threads may be re-tapped to clean and rectify the appropriate number of effective threads. After re-tapping, the threads shall be checked using the applicable thread gauge (e.g. ISO 11363-2). Neck wall thickness shall remain unchanged after re-tapping.

10.4 Neckring and collar attachment

When a neckring/collar is attached, an examination shall be carried out to ensure that it is secure and to inspect for external thread damage. A neckring shall only be changed using a procedure approved by the cylinder manufacturer or, if they are unavailable, approved by the competent authority. The new neckring shall be checked to ensure that it is secure by following the minimum requirements for pull-off force and axial rotation torque in accordance with ISO 9809-1 or ISO 7866, as applicable.

Threads shall be gauged and inspected after this change. If damage to the cylinder material has occurred by replacement of the neckring/collar, the cylinder shall be rendered unserviceable in accordance with Clause 18.

11 Check of internal condition

11.1 General

If the cylinder is not to be evaluated by UT in accordance with 14.4, then it shall be subjected to an internal visual inspection. An internal inspection shall be performed for cylinders requiring UT and when the valve is removed.

Prior to carrying out an internal visual inspection, the cylinder shall be depressurized and, if necessary, purged in accordance with ISO 25760.

For seamless aluminium-alloy cylinders susceptible to sustained-load cracking (e.g. those manufactured from AA 6351 or AA 6082 alloy), the internal side of the shoulder shall be examined visually and the neck area shall be examined using a non-destructive examination method such as eddy current testing.

11.2 Internal visual inspection

11.2.1 Preparation

11.2.1.1 General

Whenever the internal surface of a cylinder is not adequately visible, a suitable cleaning method shall be applied.

The method used to clean the cylinder shall be a validated, controlled process. Care shall be taken at all times to avoid damaging the cylinder taking into account the information provided in Annex B.

11.2.1.2 Suitable cleaning methods for seamless steel cylinders

If necessary, suitable cleaning methods such as shot-blasting, water jet abrasive cleaning, flailing, steam jet, hot water jet, rumbling, chemical cleaning or others may be used on seamless steel cylinders.

If the cylinder has been cleaned by one of the above methods, it shall be inspected after the cleaning operation.

11.2.1.3 Suitable cleaning methods for seamless aluminium-alloy cylinders

If necessary, suitable cleaning methods such as water jet abrasive cleaning, flailing, steam jet, hot water jet, chemical cleaning, blasting with glass beads or others may be used on seamless aluminium-alloy cylinders (see Annex F or consult the cylinder manufacturer). Cleaning with material other than alumina or glass beads, etc. shall be avoided. Hard media can embed itself in the aluminium alloy. Alkaline solutions and paint strippers that are harmful to aluminium and its alloys shall not be used.

If the cylinder has been cleaned by one of the above methods, it shall be dried immediately after being cleaned and inspected.

Ensure that any aqueous liquid does not stay in the cylinder for more than two hours.

11.2.2 Inspection requirements

Internal visual inspections shall be conducted in good lighting on a cylinder that is both clean and dry, suitable enough for proper inspection of all surfaces to identify any imperfections similar to those listed in 9.2 a) and 9.2 c). These inspections may be augmented by the use of a boroscope, dental mirror or another suitable device. When magnification is used, the final assessment of the imperfection shall be carried out as if no magnification had been used.

When needed, the severity of a detected imperfection may be further evaluated by using other devices or methods.

Precautions shall be taken to ensure that the method of illumination presents no risks to the tester while performing the operation (e.g. use of a filament lamp in a potentially explosive environment shall be avoided).

Any cylinder showing presence of foreign matter or signs of more than light surface corrosion shall be cleaned internally (see 11.2.1).

Alternative methods may be substituted for the internal visual inspection for cylinders that contain non-corrosive gases that have a water capacity less than 0,5 l and an internal neck diameter less than 9 mm. These alternative methods include:

— looking for free moisture at the time of depressurizing after the cylinder has been in an inverted position for at least one minute and prior to valve removal;

— looking for contamination (e.g. rust in the test medium following the hydraulic volumetric expansion test).

If any moisture is present upon inversion of the cylinder or if rust contamination is observed in the hydraulic volumetric expansion test medium, the cylinder shall be either re-examined after cleaning in accordance with 11.2.1.1 or rendered unserviceable in accordance with Clause 18.

11.2.3 Cylinders with footrings

Special attention shall be given to inspect cylinders with footrings for defects in critical areas, i.e. the transition (footring) zone and the cylinder base.

11.2.4 Cylinders with internal coatings

Cylinders used in certain applications (e.g. corrosive gases) can have an internal coating such as an electrochemical deposit, cladding, paint or a film to inhibit corrosion.

Since the hydraulic volumetric expansion test medium can affect the coating, the manufacturer shall be contacted in case of doubt to determine the correct type of testing to be used.

Care shall be taken when a coating might contain flammable components, e.g. hydrocarbons in paint or a corrosion inhibitor.

A damaged coating shall be removed to allow for a complete visual inspection. When the damaged coating (e.g. cladding) cannot be removed, the manufacturer shall be consulted for guidance on how to prepare the cylinder for periodic inspection and testing.

If the manufacturer cannot be consulted, the cylinder shall be rendered unserviceable in accordance with Clause 18.

12 Supplementary tests

12.1 General

Evaluation of the type and/or severity of an imperfection found on visual inspection may require additional tests or methods of examination, e.g. ultrasonic techniques, check weighing or other non-destructive tests.

After satisfactory evaluation, the cylinder may be further processed in accordance with Annex B.

12.2 Additional test for seamless aluminium-alloy cylinders possibly subjected to heat damage

If it is suspected that the cylinder has been exposed to high temperature, a hardness test in accordance with ISO 6506-1 or a conductivity test as performed during manufacture shall be carried out. Test results shall meet the required design values at the time of manufacture.

All hardness tests shall be performed in the suspected heat-damaged area of the cylinder taking adequate care to ensure deep impressions are not formed.

12.3 Hammer test on cylinders with footrings

Cylinders with footrings shall be suspended freely for the hammer test. The minimum hammer weight shall be 0,25 kg.

The footring shall have a tight fit to the cylinder. The hammer test gives an indication regarding the fitting of the footring to the cylinder and the condition of the area where the footring is shrunk-on. After hitting the footring with a hammer, the resulting sound shall be clear/bell-like.

If the sound is dull or flat, it is an indication that the footring is not tight to the cylinder and/or corrosion could have built up between the footring and the cylinder. In the latter case, the footring shall be replaced or the cylinder shall be rendered unserviceable in accordance with Clause 18.

13 Cylinder repairs

Operations that can result in loss of cylinder wall thickness (e.g. external and/or internal shot blasting, repair of notches) shall be completed before the inspection and testing procedure in accordance with Annex B.

Grinding operations shall be checked using UT.

14 Pressure test or UT

14.1 General

Each cylinder shall be submitted to either a pressure test (14.2 or 14.3) or UT (14.4). Either the proof pressure test or the hydraulic volumetric expansion test may be replaced by a pneumatic proof pressure test.

WARNING — Appropriate measures shall be taken to ensure safe operation and to contain any energy that might be released. It should be noted that pneumatic proof pressure tests require more precautions than hydraulic volumetric expansion tests, regardless of the size of the cylinder or tube. Any error in carrying out this test is highly likely to lead to a rupture under gas pressure. Therefore, these tests shall be carried out only after ensuring that the safety measures adopted satisfy the safety requirements.

Special care shall be taken using air as the medium for the pneumatic pressure test due to the oxidizing potential of high pressure air. At 300 bar, the partial pressure of oxygen is approximately 60 bar.

When air is used for the pneumatic pressure test, the cylinder shall not have internal flammable materials (e.g. coatings containing hydrocarbons). Special care shall be taken during the periodic inspection and testing of cylinders that have been used in flammable gas service.

Each cylinder subjected to a pressure test shall also undergo an internal visual inspection. A suitable fluid, normally water, shall be used as the test medium for the hydraulic volumetric expansion test. This test may be either a proof pressure test or a volumetric expansion test as appropriate to the design specification of the cylinder. The test pressure shall be in accordance with the stamp markings on the cylinder. When applicable and when the test pressure is not marked on the cylinder, the test pressure shall be derived from the appropriate design standard.

If a cylinder fails either the proof pressure test or the volumetric expansion test, these results shall be final. None of the other test methods shall be applied and the cylinder shall be rendered unserviceable in accordance with Clause 18.

14.2 Proof pressure test

14.2.1 General

The following method shall be used for carrying out the proof pressure test. Any cylinder failing to comply with the acceptance criteria of this test shall be rendered unserviceable in accordance with Clause 18.

The test pressure shall be held for cylinders for at least 30 s and for tubes for at least 2 min with the cylinder or tube isolated from the pressure source, during which time there shall be no decrease in the indicated pressure, evidence of leakage or visible deformation.

For seamless aluminium-alloy cylinders, it shall be ensured that any aqueous liquid does not stay in the cylinder for more than two hours.

14.2.2 Test equipment

14.2.2.1 All rigid pipework, flexible tubing, valves, fittings and components forming the pressure system of the test equipment shall be designed to withstand a working pressure of at least 1,5 times the maximum test pressure of any cylinder that is tested.

14.2.2.2 Pressure gauges (also known as pressure indicating devices) shall be at least to an Industrial Class 1 (±1 % deviation from the end value) with a scale appropriate to the test pressure (e.g. EN 837-1 or EN 837-3).

They shall be checked for accuracy against a calibrated master gauge at regular intervals at least once a month.

When an analogue pressure gauge is used, a maximum reading of between 1,5 and 2 times the value being measured shall prevail.

14.2.2.3 The design and installation of the equipment, the connection of the cylinders and the operating procedures shall avoid trapping air in the system when a liquid medium is used.

14.2.2.4 All joints within the system shall be visibly leak tight.

14.2.2.5 A control device shall be fitted to the test equipment to ensure that no cylinder is subjected to a pressure in excess of its test pressure by more than the tolerances given in 14.2.3.3. The pressure relief device's tolerance shall not exceed the upper tolerance shown in 14.2.3.3 plus 10 %.

14.2.3 Test criteria

14.2.3.1 More than one cylinder at a time may be tested provided that all cylinders have the same test pressure. If multiple test points are used, then in case of leakage when it is not possible to determine the location of the leak, every cylinder being tested shall be individually retested.

14.2.3.2 Before applying pressure, the external surface of the cylinder shall be dry.

14.2.3.3 The pressure indicated on the pressure gauge shall not be less than the test pressure and shall not exceed the test pressure by 3 % or 10 bar, whichever is lower.

14.2.3.4 On attaining the test pressure, the pressure shall be held for cylinders for at least 30 s and for tubes for at least 2 min, with the cylinder or tube isolated from the pressure source.

14.2.3.5 If there is a leakage in the pressure system, it shall be corrected and the cylinders retested.

14.2.4 Acceptance criteria

During the hold period, the pressure, as indicated on the pressure gauge, shall remain constant.

There shall be an absence of visible leakage (liquid when the test is hydraulic) on any part of the external surface of the cylinder. This check can be made during the hold period if safe to do so (e.g. by using a remotely operated camera) or immediately following the test.

There shall be no visible permanent deformation.

If the applied pressure exceeds the test pressure by more than 3 % or 10 bar, whichever is lower, the cylinder shall be set aside for further evaluation or rendered unserviceable in accordance with Clause 18.

14.3 Hydraulic volumetric expansion test

Annex D outlines typical methods for carrying out the hydraulic volumetric expansion test and gives details for determining the volumetric expansion of seamless steel and seamless aluminium-alloy cylinders by the preferred water jacket method or the non-water jacket method. The test methods, equipment and procedure chosen shall be approved by the competent authority.

Care shall be taken that the entire external surface of the cylinder is wet without the presence of any bubbles.

The permanent volumetric expansion of the cylinder expressed as a percentage of the total expansion at test pressure shall not exceed the percentage given in the design specification.

On attaining the test pressure, the pressure shall be held for cylinders for at least 30 s and for tubes for at least 2 min, with the cylinder or tube isolated from the pressure source.

When this design specification requirement is not known, a maximum of 5 % PE shall be applied.

If this PE value is exceeded, the cylinder shall be rendered unserviceable in accordance with Clause 18.

For seamless aluminium-alloy cylinders, it shall be ensured that any aqueous liquid does not stay in the cylinder for more than two hours.

14.4 UT

14.4.1 General

UT of seamless steel and seamless aluminium-alloy cylinders within the framework of periodic inspections may be carried out in lieu of the proof pressure test described in 14.2 or the hydraulic volumetric expansion test described in 14.3, and the internal visual inspection described in 11.2.

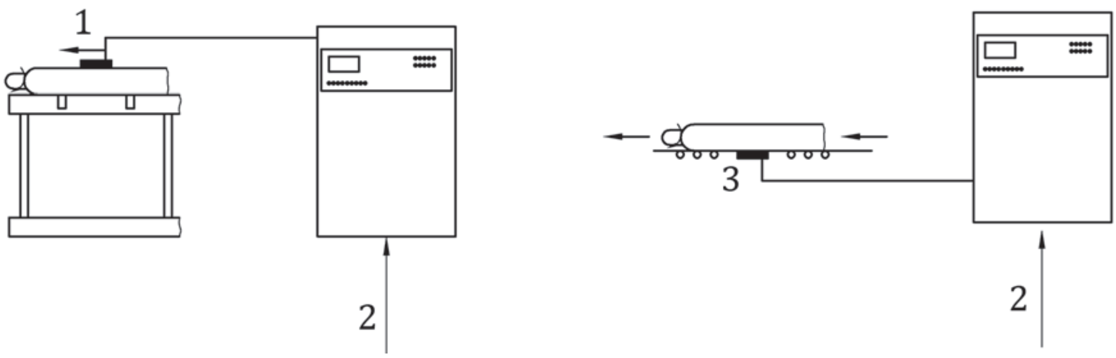
14.4.2 Requirements

14.4.2.1 General

The cylindrical part of the cylinder from the shoulder to the base including the SBT shall be examined ultrasonically [e.g. with the help of an automated examination device (see Figure 6)]. See Figure 7 for an example of a reference specimen's SBT location, sidewall and notch placement.

When an examination is required for the transitional area from the shoulder to the neck area of the cylinder, a supplementary manual examination shall be performed.

Since the effect of fire- or heat-exposure to the cylinder material cannot be determined using UT, cylinders that are suspected to or have experienced this kind of exposure shall not be examined ultrasonically, unless they have been proven to be suitable for further service. See the fire damage information in Table B.1.



a) UT system with cylinder in air **b) UT system with cylinder submerged in water**

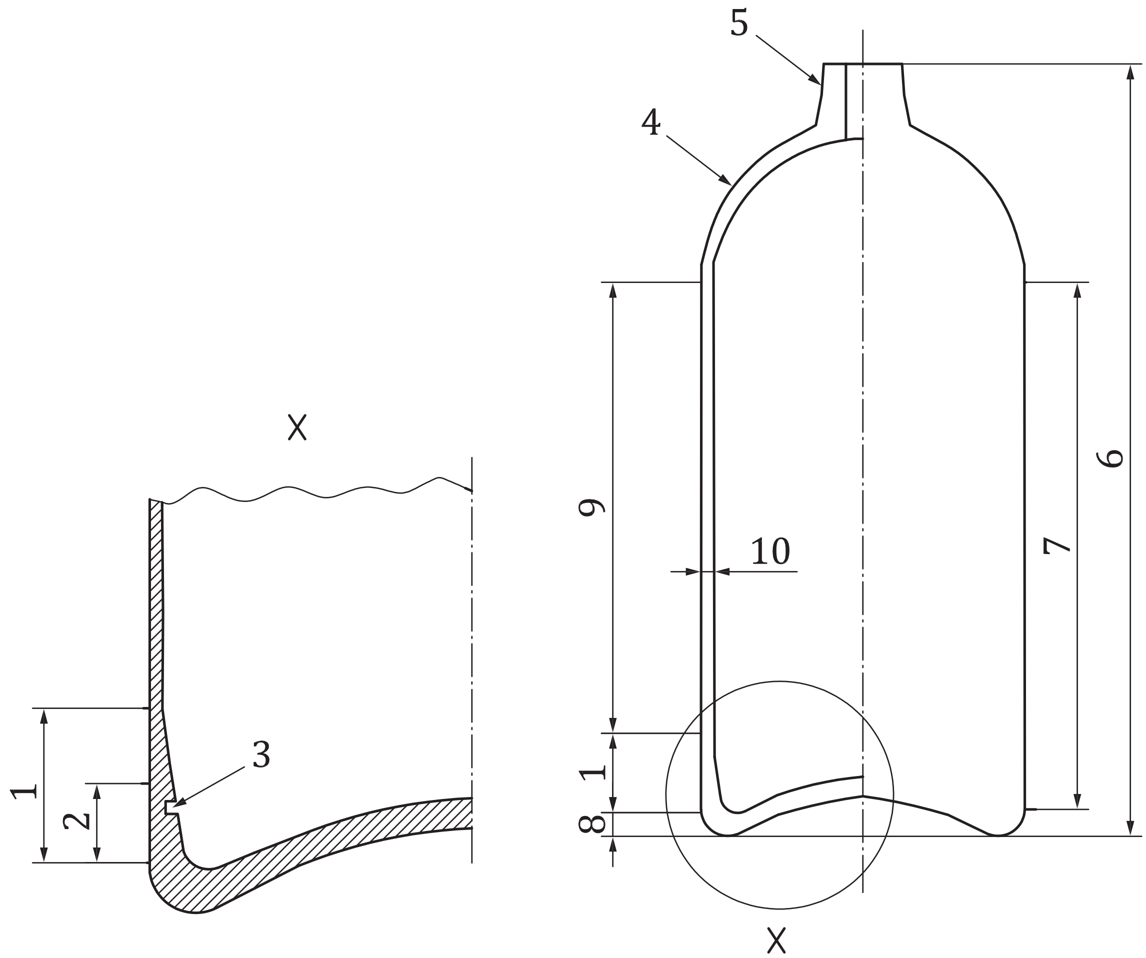
Key

1 UT transducers, moving

2 UT equipment

3 cylinder movement

Figure 6 — Examples of two types of UT devices for cylinders



Key

1 SBT
2 notch location (lower half of SBT)
3 SBT notch
4 shoulder, head or crown
5 neck
6 overall height
7 sidewall, including transition
8 base
9 sidewall
10 wall thickness
X detail of cylinder SBT, SBT notch and notch location

SOURCE Compressed Gas Association (CGA). This adapted figure is reproduced from Reference [20] with permission from the Compressed Gas Association. All rights reserved.

NOTE 1 Notch depth (10 ± 1) % of minimum design wall thickness, t_m.

NOTE 2 Notch placement perpendicular to cylinder outer wall.

Figure 7 — Example of a reference specimen's SBT location, sidewall and notch placement

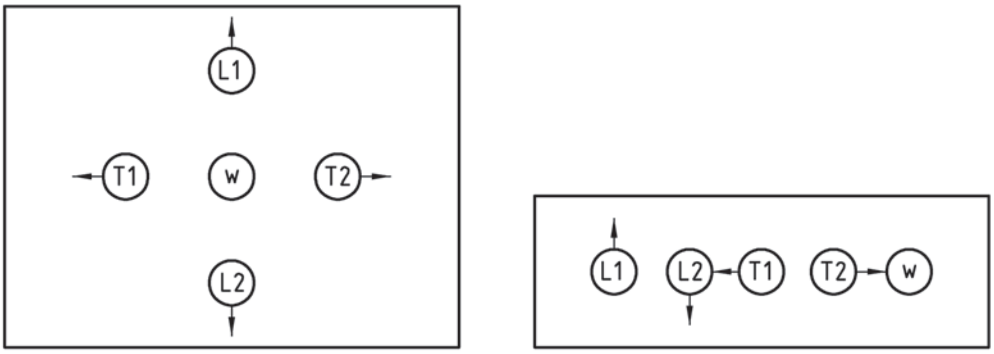
14.4.2.2 Examination equipment

The installation shall be able to scan the whole surface of the cylindrical part of the cylinder, including the adjacent transitions to the base and shoulder. An inspection system shall have a number and type of transducers and different beam directions required to identify all the reference features in the calibration piece. Typical examples of suitable ultrasonic transducer arrangements are shown in Figure 8.

The pulse repetition rate of the transducers, rotational speed of the cylinder and axial speed of the scanning head shall be mutually adjusted in such a way that the system is capable of locating all of the calibration flaws. Any ultrasonic method (e.g. the pulse echo, guided wave) that demonstrates the ability to detect defects and to measure wall thickness, compatible with the size (length and circumference) of the cylinder under examination, shall be used. The most common techniques used today are the contact or the immersion type. Other techniques may be used. See Figure 9 for examples of the techniques used.

When applicable, e.g. with a helix-based system, at least 10 % overlap of the effective beam width shall be guaranteed.

Acoustic coupling shall be continuously monitored. Loss of coupling shall invalidate the test. In such cases, the UT shall be repeated.



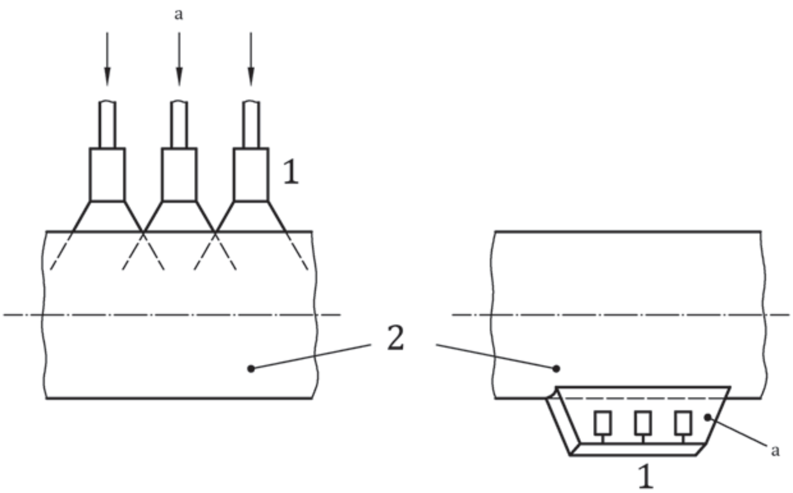
Key

L1, L2 longitudinal transducers

T1, T2 transverse transducers

w wall thickness transducer

Figure 8 — Examples of the arrangement of transducers



Key

1 transducers

2 cylinder

a Water.

Figure 9 — Examples of coupling techniques

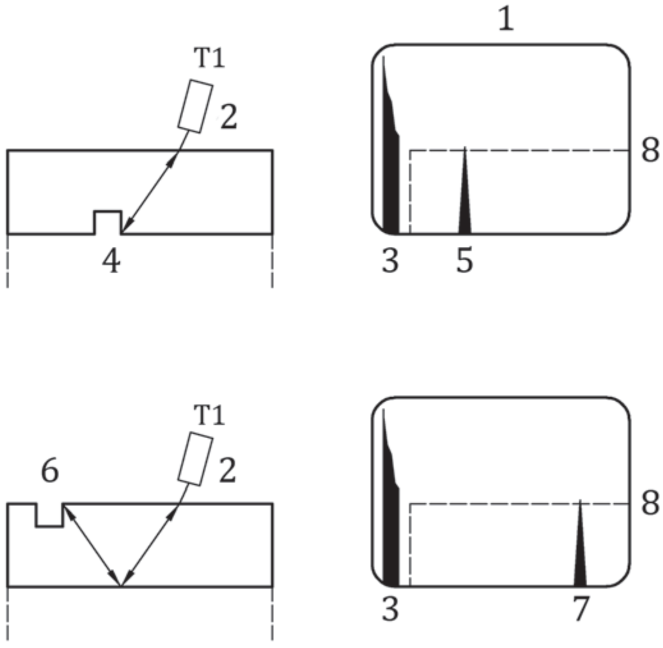
The cylinder wall shall be examined using UT transducers capable of detecting the specified calibration notches. The examination shall cover longitudinal defects when scanning in both circumferential directions (clockwise and anti-clockwise) and circumferential defects when scanning in both longitudinal directions (forward and backward) and consider these defects to be located on the internal and external surfaces.

The cylinder wall shall be examined using UT transducers capable of measuring the actual wall thickness using a normal transducer (angle of refraction 0°) and comparing the value to the minimum design wall thickness. The uncertainty of the system shall be ±5 % or ±0,1 mm, whichever is lower. The uncertainty shall be taken into account when verifying the wall thickness.

The cylinders to be examined and the search unit with the transducers shall go through a rotating motion and translation relative to one another. This rotating and translating motion shall result in an overlapping helix pattern that ensures 100 % inspection of the cylinder sidewall. The speeds of translation and rotation shall not exceed the speed used during calibration.

The UT unit shall have a screen capable of depicting the various defects present in the calibration cylinder. The installation shall have an automatic alarm when a fault signal is indicated. See Figure 10 for examples of flaw alarms.

A distinction in the defect detection between internal and external flaws shall be possible.



Key

T1 transverse transducer
1 screen
2 calibration specimen wall
3 UT signal trace from calibration specimen wall
4 inner reference notch
5 UT signal trace from inner reference notch
6 outer reference notch
7 UT signal trace from outer reference notch
8 alarm level

Figure 10 — Flaw alarm examples

14.4.2.3 Manual ultrasonic unit

The requirements in 14.4.2.2 shall apply as appropriate for the selection of the transducers and servicing of the unit.

14.4.2.4 Cylinders

The external and internal surfaces of any cylinder to be examined ultrasonically shall be in a suitable condition for a reliable and reproducible test. In particular, the external surface shall be free of corrosion, non-adhering paint, dirt and oil.

UT is only reliable when the noise signals caused by the surface are at least 50 % below the corresponding reference signal.

14.4.2.5 Personnel

The examination equipment shall be operated by, and its operation supervised by, qualified and experienced personnel only, as defined in ISO 9712. The tester shall be certified to ISO 9712 Level I or any other national standard acceptable to the competent authority as a minimum for UT. A Level II or Level III operator shall supervise the Level I operator and offer an interpretation of the results.

The ultrasonic testing facility shall retain a Level III operator for the entire UT programme.

14.4.3 Calibration

14.4.3.1 General

Calibration of the UT defect examination and wall thickness measurement shall use a calibration specimen with notches. A specimen of convenient length shall be prepared that is representative of the cylinder or tube to be tested with a similar nominal diameter, wall thickness, external surface finish and material with similar acoustic velocities (e.g. any ferritic steel may represent any other ferritic steel, and any aluminium alloy may represent any other aluminium alloy) as the cylinder under test. Different coatings (e.g. powder coatings vs wet painting) and thicknesses give different acoustic responses that can require the use of a dedicated calibration specimen.

The calibration specimen shall have a known minimum wall thickness that is representative of the minimum design wall thickness of the cylinder or tube under test but no more than that specified by the Level III operator.

Calibration specimens shall be protected to prevent their deterioration.

14.4.3.2 Defect detection

14.4.3.2.1 UT notch requirements and dimensions

For manual and automated defect examination, a minimum of four rectangular notches is required as reference notches in the calibration specimen (see Figure 11). The notches can be produced either by means of electrical erosion or sawing, or by machining. The bottom corners of the notch may be rounded. The notches shall be located so that there is no interference from any other defect in the calibration specimen. The form and dimensions of the calibration specimen shall be verified. The four notches shall be as follows:

— inner notch in longitudinal direction;

— inner notch in transverse direction;

— outer notch in longitudinal direction;

— outer notch in transverse direction;

with the following dimensions in each case:

— length, *L*: 50 mm;

— depth, *D*:

— For seamless steel cylinders:

  — 5 % criterion: for cylinders with actual tensile strength ≥ 950 MPa or cylinders intended to contain embrittling gases (see ISO 11114-1), the depth *D* shall be 5 % (±0,75 %) of the minimum measured wall thickness, t_{mc}, of the calibration specimen. The notch in the calibration specimen shall be located in the sidewall at a position where the wall thickness does not exceed 115 % of the minimum measured wall thickness. However, the notch depth shall not be less than 0,2 mm or greater than 1 mm; or

  — 10 % criterion: for cylinders with actual tensile strength < 950 MPa and not intended to contain embrittling gases (see ISO 11114-1), the depth *D* shall be 10 % (±1 %) of the minimum measured wall thickness, t_{mc}, of the calibration specimen. . The notch in the calibration specimen shall be located in the sidewall at a position where the wall thickness does not exceed 115 % of the minimum measured wall thickness. However, the notch depth shall not be less than 0,2 mm or greater than 1 mm.

— For seamless aluminium-alloy cylinders, the depth *D* shall be 10 % (±1 %) of the minimum measured wall thickness, t_{mc}, of the calibration specimen. The notch in the calibration specimen shall be located in the sidewall at a position where the wall thickness does not exceed 115 % of the minimum measured wall thickness. However, the notch depth shall not be less than 0,2 mm or greater than 2 mm.

— width, *W*: ≤ 2 *D.*

When a 10 % criterion as explained above is used, a fifth inner transverse transition notch is required to examine the SBT region. The fifth notch shall have the same width and length as the previously described four notches with the notch depth (10 ± 1) % of minimum design wall thickness (see Figure 9).

14.4.3.2.2 Internal inspection notch requirements

When using UT for checking a cylinder's internal condition in lieu of internal visual inspection, one of the following calibration reference notch groupings shall be required.

— For seamless steel cylinders:

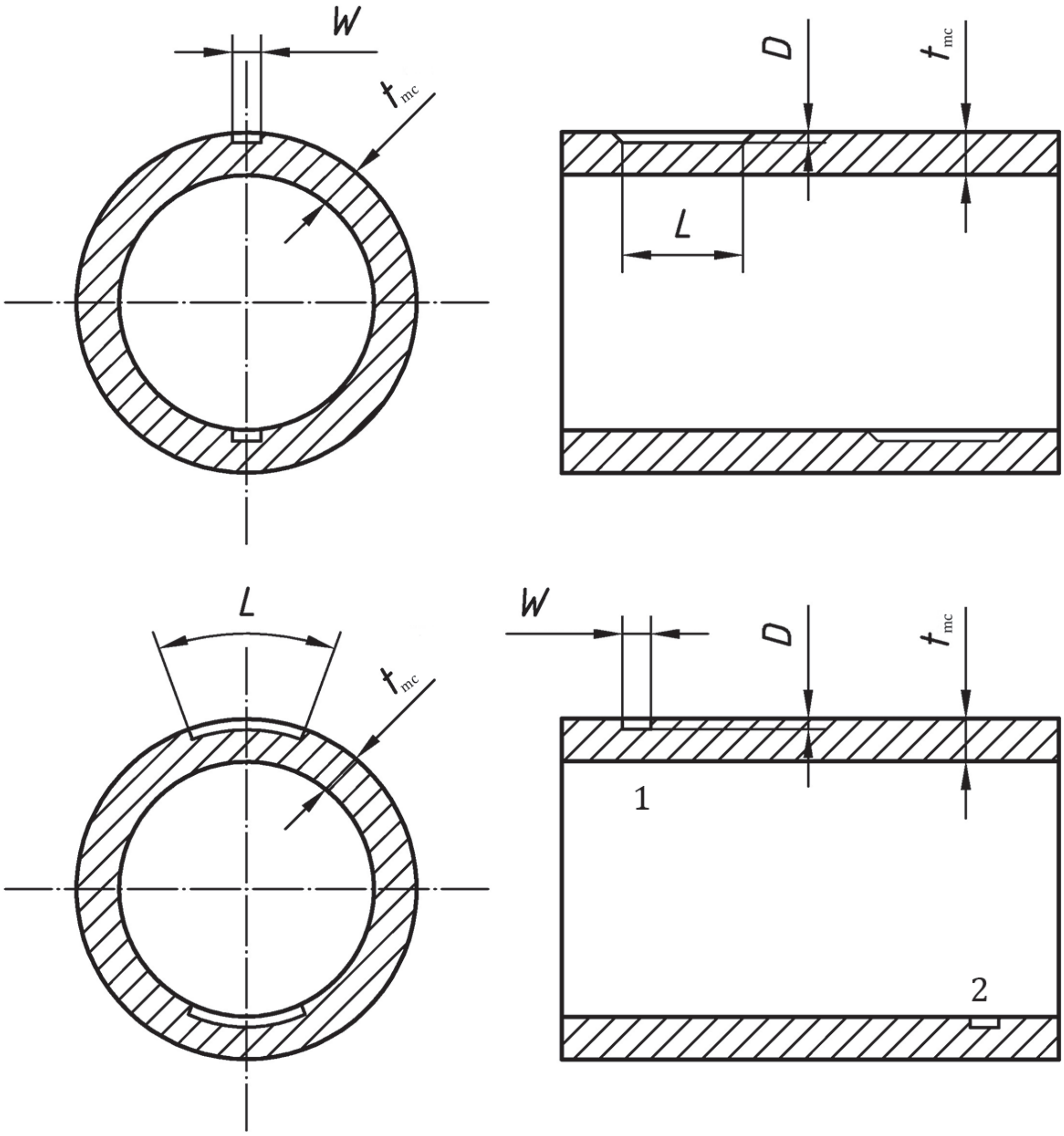
  — when using the 5 % criterion (see 14.4.3.2.1), it shall be confirmed on a typical specimen that the system is capable of detecting a 10 % (with a machining tolerance of 1 %) SBT notch (see Figure 11); or

  — when using the 10 % criterion (see 14.4.3.2.1), in addition to a fifth SBT notch (see Figure 11) with previously specified dimensions, a FBH shall be machined with a depth of 1/3 minimum measured wall thickness and a diameter less than or equal to 2 times the minimum measured wall thickness (see Figure 12).

— For seamless aluminium-alloy cylinders:

  — internal longitudinal and transverse reference notches with the dimensions as specified in 14.4.3.2.1, except that the depth shall be 5 % (with a machining tolerance of 1 %) minimum measured wall thickness; or

  — 10 % internal longitudinal and transverse reference notches with the dimensions as previously specified for the four notches and a FBH with a depth of 1/3 minimum measured wall thickness and a diameter less than or equal to 2 times the minimum measured wall thickness (see Figure 12).



Key

1 outer notch

2 inner notch

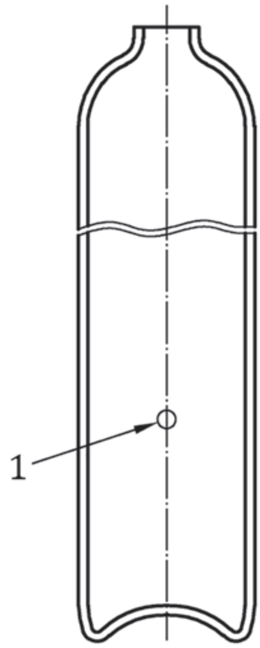
D depth of the notches: 5 % (±0,75 %) t_{mc} or 10 % (±1 %) t_{mc}, in mm

L length of notches: 50 mm

t_{mc} minimum measured wall thickness of the calibration specimen, in mm

W width of the notches: ≤2D, in mm

Figure 11 — Examples of reference notches



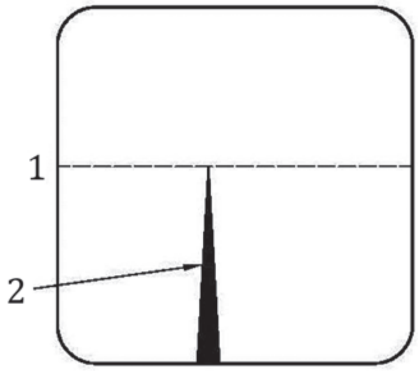
Key

1 FBH

Figure 12 — Typical FBH notch

14.4.3.2.3 Calibration procedures

During the calibration procedure, the UT equipment shall be adjusted so that the amplitude of the echoes from the reference notches, at the least sensitive used area of the transducer, equals the alarm level (see Figure 13). The alarm and signal amplitude levels shall be set to consistently detect required reference notches within the calibration specimen, e.g. 50 % of the screen height. On automated systems, this step shall be performed at the rotational speed of the cylinder, as at the time of the actual testing (see 14.4.2.2). This sensitivity is the reference sensitivity.



Key

1 alarm level

2 signal of reference notch

Figure 13 — Reference notch amplitude

14.4.3.3 Wall thickness

To calibrate the manual and automated wall thickness measurement, a patch with a diameter equal to at least 2 times the effective beam width at the point of entrance on the calibration specimen shall be used, the exact wall thickness being known.

14.4.3.4 Frequency of calibration

The UT equipment shall be calibrated at least at the beginning and at the end of each operator shift, regardless of length, and when any equipment affecting UT is changed, e.g. change of transducer, transducer cable, wheel, encoder, drive belts. Calibration shall also be undertaken whenever there is a change of diameter or when the calibration specimen is no longer applicable (see 14.4.3.1).

NOTE Some systems allow calibration of multiple types of cylinders prior to the test programme.

Calibration shall also be undertaken at the end of operations that are of a duration less than that of a normal shift.

If, during the calibration, the presence of the respective reference notch is not detected, all cylinders examined after the last acceptable calibration shall be re-examined after the equipment has been recalibrated.

14.4.4 Performing the examination

14.4.4.1 Defect detection in cylindrical section by automated installation

The cylindrical section of the cylinder and the transitions to the shoulder and to the base shall be examined for longitudinal and transverse defects using an automatic examination device.

The minimum design wall thickness of the cylinder shall be known. This value can be obtained from one of the following: the cylinder marking, the type approval, a calculation, etc. This value is set as the alarm level in the evaluation unit of the ultrasonic wall thickness measuring device.

At no time shall the speeds used during calibration be exceeded during the examination. It shall be ensured that the system provides 100 % coverage of the surface being examined (see also 14.4.2.2).

14.4.4.2 Wall thickness measurements in cylinder end of cylinders with footrings

14.4.4.2.1 Cylindrical part of the cylinder

As UT cannot cover the complete cylindrical part of cylinders with footrings (the transition zone to the footring and the cylindrical part where the footring is installed), thorough internal and external visual inspections shall be performed in accordance with Clause 11 and 9.2, respectively.

The critical area in the transition zone (cylindrical part just before the footring) shall be checked, taking into account the accessibility and roughness of the test surface. It shall be ensured that the transducers scan up to the edge of the footring (see Figure 14).

14.4.4.2.2 Cylinder base

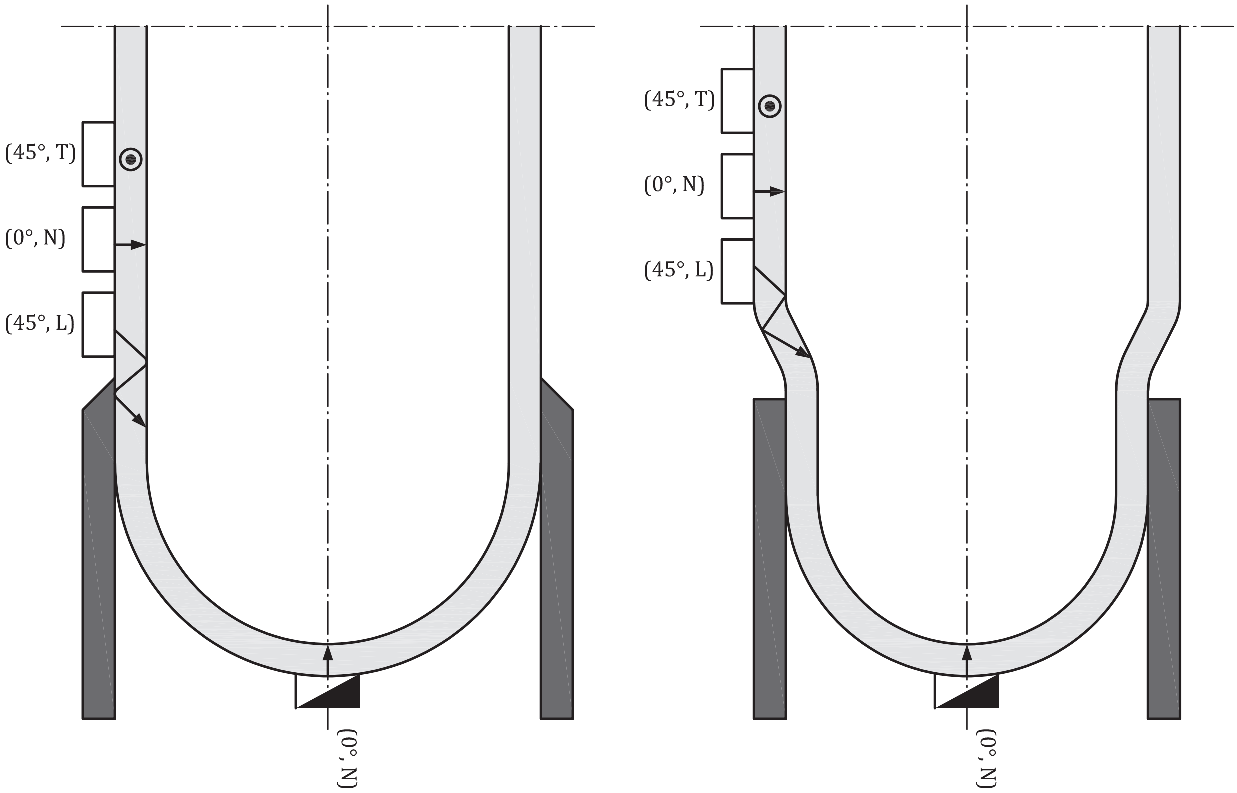
The base area of the cylinders shall be examined for wall thickness by using a normal transducer (see Figure 12). This can be performed either manually or using an automated system. As a minimum, the centre of the base area shall be measured.

14.4.4.2.3 Wall and base thickness measurements by automated installation

The cylindrical section shall be examined 100 % for loss of wall thickness. If possible, the base thickness shall also be measured on the automated installation.

14.4.4.2.4 Base thickness measurements by manual testing

If the base measurement has not already been performed using an automatic UT device, it shall be manually measured at the centre of the base with a normal ultrasonic transducer.



Key

N	normal transducer
L	longitudinal transducer (longitudinal of base shape)
T	transverse transducer (transverse of base shape)
☐	automated operation (common practice)
◪	manual or automated operation (common practice)

Figure 14 — Defect detection in cylinder ends with footrings

14.4.5 Interpretation of results

Cylinders examined to the examination sensitivity in accordance with 14.4.3.2 and 14.4.3.3 when no defect signal above the alarm level has been recorded have passed the examination.

When a defect signal above the alarm level (as a result of a defect, below minimum design wall thickness, loose paint or internal contamination) has been recorded (see Figure 15), the cylinder shall be further processed by one of the following:

a) the cylinder may be re-examined after removing internal and/or external coatings and/or the interior cleaned; or

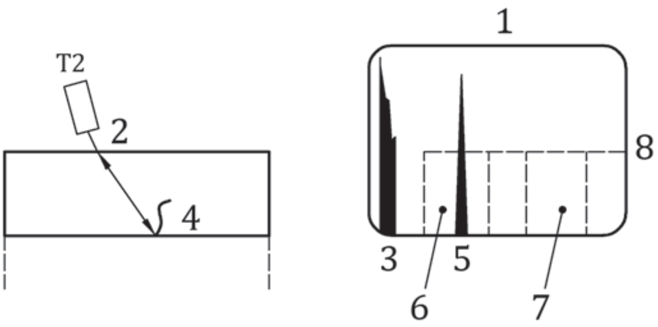
b) the cylinder may be re-evaluated in accordance with Annex B.

If a) or b) are not carried out or are unsuccessful, the cylinder shall be rendered unserviceable in accordance with Clause 18.

If it can be established that the sensitivity used during the examination was too high, the cylinder may be re-examined after adjusting the gain settings and recalibration to an acceptable and safe level.

The measured thickness of the base shall not be less than the minimum design base thickness as specified in original documentation, e.g. design drawing, type approval, etc. If original documentation containing base thickness values is not available, then the measured base thickness shall be greater than 1,5 times the minimum design sidewall thickness for convex bases and 2 times the minimum design sidewall thickness for concave bases.

Certain geometrically determined indications in the test results such as external ribs caused by the deep drawing process or hardness measurement spots shall be evaluated.



Key

T2 transverse transducer
1 screen
2 cylinder wall
3 UT signal from cylinder wall
4 crack on internal surface
5 UT signal from crack
6 region of signals from cracks on internal surface
7 region of signals from cracks on external surface
8 alarm level

Figure 15 — Example of detection of crack in transverse direction

14.4.6 Records

In addition to the required records as specified in 17.7, the following information shall be recorded:

a) identification of ultrasonic equipment used and its calibration records in accordance with 14.4.3.4;

b) unique identification of the calibration cylinder used;

c) name of the UT operator;

d) results of examination. If subsequent evaluation in accordance with 14.4.5 and Annex B requalifies the cylinder, the basis of requalification shall be recorded.

Reference to this document may also be recorded.

15 Inspection of valve and other accessories

If a used valve or any other accessory is to be reintroduced into service, it shall be ensured that only valves inspected and maintained in accordance with ISO 22434 or other accessories are fitted.

16 Replacement of cylinder parts

Replacement of footrings (seamless steel cylinders only) and neckrings that are an integral part of the design may be carried out. Also, the removal of cuts, gouges and other imperfections may be carried out.

All operations involving the application of heat shall conform to the heat limits given in 17.1. All corrosion products shall be removed prior to repair.

NOTE When a change of a footring (seamless steel cylinders only) and/or neckring is carried out, the empty weight can change.

17 Final operations

17.1 Drying, cleaning and painting

17.1.1 Drying and cleaning

The interior of each acceptable (passed) cylinder shall be thoroughly dried by a suitable method immediately after the hydraulic volumetric expansion test so that there is no trace of free water. See 17.1.2.2 for seamless steel cylinders and 17.1.2.3 for aluminium-alloy cylinders, respectively, for maximum temperature values to be used.

The interior of the cylinder shall be inspected to ensure that it is dry and free from other contaminants.

17.1.2 Painting and coating

17.1.2.1 General

Cylinders are sometimes repainted using paints that require stoving. Plastic coatings can also be re-applied. Care shall be taken if valved cylinders and in particular cylinders containing residual flammable gas are to be stoved, due to the possibilities of valve degradation and/or risk of an explosion due to leakage of gas. In addition, some gases are susceptible to heat decomposition/reaction.

If a surface finish that requires heat treatment is applied (e.g. powder coating), it shall be checked that the temperature does not affect the valve integrity. If this cannot be ascertained, the valve shall be removed before this type of surface finish is applied.

Paint or coating shall be applied so that markings stamped on the cylinder remain legible.

17.1.2.2 Seamless steel cylinders

In no case shall the temperature of a seamless steel cylinder exceed 300 °C since overheating could change the mechanical properties of the cylinder.

17.1.2.3 Seamless aluminium-alloy cylinders

Seamless aluminium-alloy cylinders are normally manufactured using precise heat treatment to obtain the final mechanical properties of the cylinders. Therefore, the maximum temperature for any operation shall be limited.

In no case shall the temperature of seamless aluminium-alloy cylinders exceed that recommended by the manufacturer since overheating can change the mechanical properties of the cylinders.

Cylinders manufactured from AA 6XXX heat-treatable aluminium alloys (e.g. AA 6061) shall not be heated to temperatures exceeding 175 °C. Only testing facilities that can control heat input and record time and temperature shall heat cylinders. The total cumulative time at temperatures between 110 °C and 175 °C shall be limited to the time recommended by the cylinder manufacturer. Cylinders heated in accordance with these provisions shall not require further testing.

An external heat source shall not be applied (e.g. to dry an external coating) to AA 7XXX heat-treatable (e.g. AA 7032 or AA 7060) seamless aluminium-alloy cylinders and tubes unless approved by the cylinder or tube manufacturer.

Unless otherwise authorized by the cylinder manufacturer, the maximum temperature shall not exceed 80 °C for seamless aluminium-alloy cylinders manufactured from non-heat-treated alloys (e.g. AA 5283). The exposure time shall be limited to 30 min for temperatures between 70 °C and 80 °C. If the heat exposure time exceeds 30 min at temperatures greater than or equal to 70 °C, or if at any time the temperature exceeds 80 °C, then agreement shall be obtained from the manufacturer regarding the further use of the cylinder.

17.2 Re-valving of the cylinder

Before re-valving the cylinder, the thread types (both cylinder and valve) shall be identified. The appropriate valve shall be fitted to the cylinder using a sealing material compatible with the valve, cylinder and gas service. When the cylinder is part of a certified assembly, only replacement components that have been certified for use with the assembly shall be used.

An optimum torque for seamless steel and seamless aluminium-alloy cylinders necessary to ensure a seal between the valve and the cylinder and to prevent over-stressing the neck shall be used as specified, for example in ISO 13341. The torque applied shall take into consideration the size and form of the threads, the material of the valve and the type of sealing material used according to the cylinder/valve manufacturer's recommendations. When the use of lubricants/sealing material is permitted, only those approved for the gas service shall be used taking particular care for oxidizing gas service (see ISO 11114-2).

17.3 Check of cylinder tare

The check of the cylinder tare requirement shall apply only to cylinders for liquefied gases. However, it may be applied to any cylinder when there is doubt. The tare of the cylinders shall be obtained by weighing the cylinders on a scale calibrated with traceability to national or international standards. The scale shall be checked for accuracy at the beginning of each shift. The capacity of the scale shall be suitable for the weight of the cylinders.

The tare is the sum of the “empty weight” plus the mass of any coating (e.g. paint) used in service, the mass of the valve including dip tube when fitted and any fixed valve guard and the mass of all other parts that are permanently attached (e.g. by clamping or bolting) to the cylinder when presented for filling. If the tare of the cylinder differs from the stamped tare by more than the value shown in Table 1 and this is not due to damage, the original tare shall be cancelled. The new correct tare shall be marked in a durable and legible fashion in accordance with ISO 13769. The empty weight shall not be altered.

Table 1 — Maximum differences between scale weight reading to marked tare

Cylinder water capacity *V* l	Maximum permissible deviation in tare weight g
$0,5 \leq V < 1,0$[a]	±25
$1,0 \leq V < 5,0$	±50
$5,0 \leq V \leq 20$	±200
$V > 20$	±400

[a] For cylinders with less than 0,5 l of water capacity, the maximum weight deviation should be reduced to a value less than 25 g.

17.4 Retest marking

17.4.1 General

After satisfactory completion of the periodic inspection and test, each cylinder shall be permanently marked in accordance with the relevant standard, e.g. ISO 13769 (this mark may be applied by means other than stamp marking), with

a) the character(s) identifying the country that authorizes the body performing the periodic inspection and testing as indicated by the distinguishing signs of motor vehicles in international traffic specified in the UN *Model Regulations*,

b) the stamp or symbol of the authorized inspection body or testing facility, followed by

c) the present test date (as either YY/MM or YYYY/MM).

17.4.2 Stamping

These marks shall be in accordance with the relevant standard, e.g. ISO 13769. They may be engraved on a ring made of a material compatible with the gas service and affixed to the cylinder when the valve is installed. The ring can only be removed by disconnecting the valve from the cylinder.

17.5 Reference to next periodic inspection and test date

The next periodic inspection and test date may be shown by an appropriate method such as by a plastic-coloured disc fitted between the valve and the cylinder indicating the year (and the month, when required) of the next periodic inspection and/or tests.

Annex E provides one example of an existing system for indicating retest dates; other systems are in use, and the same systems are used but with different colours for the same year.

17.6 Identification of contents

If the identification of the cylinder's contents is required, then ISO 7225 and ISO 32 may be used as examples for labelling and colour coding, respectively. Care shall be exercised in accordance with 17.1.2.

17.7 Records

After the periodic inspection, the following information shall be recorded on the test certificate:

a) owner's name;

b) serial number of the cylinder;

c) date of manufacture;

d) cylinder weight (empty), or tare, when applicable;

e) type of inspection and test performed;

f) test pressure (if applicable);

g) current retest date — year/month/day (of pressure test or UT) shown as YYYY/MM/DD;

h) identification symbol of the retest body or the testing facility;

i) identification of retester;

j) details of any cylinder repairs made to defects as described in Annex B (see Clause 16);

k) water capacity/size;

l) specification or regulation according to which the periodic inspection/test was performed;

m) cylinder manufacturer's identification;

n) result of inspection and test (pass or fail).

In case of failure, the reason(s) should be recorded.

Records shall be retained by the retester for at least 15 years or until the next periodic inspection date.

18 Rejection and rendering cylinder unserviceable

18.1 General

The decision to reject a cylinder may be taken at any stage during the periodic inspection and test procedure.

18.2 Cylinders with a valve attached

Cylinders rejected during UT that have a valve installed and contain gas under pressure shall be depressurized, purged if required and de-valved in accordance with Clause 8, prior to rendering them unserviceable in accordance with 18.3.

18.3 Cylinders with no valves attached

If a rejected cylinder cannot be recovered, the owner shall be notified and the cylinder shall be condemned. If the owner agrees, the testing facility shall render the cylinder unserviceable for holding gas under pressure by one or more of the methods listed below so that it is impossible for any part of the cylinder, especially the shoulder, to be reintroduced into service. If the owner does not agree with this disposition, at a minimum the markings (e.g. UN marking) that allow the cylinder for legal transport in the country where it is periodically inspected and tested shall be made illegible. In case of any disagreement, ensure that the legal implication of the contemplated action is fully understood.

In some cases, it might be necessary to transport condemned cylinders to a place where they can be scrapped. If there are no specific regulations, the condemned cylinder shall be identified.

The following methods may be used for rendering cylinders unserviceable:

a) crushing or shredding the entire cylinder by mechanical means;

b) burning an irregular hole in the top dome equivalent in area to approximately 10 % of the area of the top dome or, in the case of a thin-walled cylinder, piercing in at least three adjacent places;

c) jagged cutting of the neck and shoulder;

d) irregular cutting of the cylinder in two or more pieces including the shoulder;

e) bursting using a safe method.

Annex A
(informative)

Periodic inspection and test periods

The information shown in Table A.1 includes intervals as outlined in the UN *Model Regulations*[23].

Table A.1 — Intervals for periodic inspections and tests

Gas type	Examples	UN recommended period years
Compressed gases	Ar, N_2, He, etc.	10[a]
	H_2[b]	10[a]
	Air, O_2	10[a]
	Self-contained breathing air, O_2, etc.	[c]
	Gases for underwater breathing apparatus	[c]
	CO[d]	5[e]
Liquefied gases	Refrigerants, CO_2	10[a]
Corrosive gases	[f]	5
Toxic/very toxic gases that are non-corrosive	Sulfuryl fluoride (SO_2F_2), Arsine (AsH_3), Phosphine (PH_3), etc.	5
Gas mixtures	All mixtures	5 years or 10 years according to dangerous properties. Generally toxic or corrosive mixtures have a 5-year interval while other mixtures have a 10-year interval.

These test periods may be used provided the dryness of the product and that of the filled cylinder are such that there is no freestanding water. This condition shall be proven and documented within a quality system of the filler. If this condition cannot be fulfilled, alternative or more frequent testing may be appropriate.

NOTE At all times, certain requirements can necessitate a shorter time interval, e.g. the dew point of the gas, polymerization reactions and decomposition reactions, cylinder design specifications, change of gas service, etc.

[a] Some transport regulations (e.g. ADR) allow the interval between periodic inspections and tests to be extended up to 15 years under specific conditions.

[b] Particular attention shall be paid to the tensile strength and surface condition of such cylinders. Cylinders not in conformance with the special hydrogen requirements shall be withdrawn from hydrogen service. See ISO 11621 for possible additional testing.

[c] Local regulations specify the interval of periodic inspection and testing. In the absence of any regulations, an annual internal inspection should be carried out with a periodic inspection carried out every five years. However, if a risk assessment and the specific use of a cylinder indicate that there is a low risk of internal degradation, then the interval for carrying out an internal examination may be increased to a maximum of 2,5 years.

[d] This product requires very dry gas. See ISO 11114-1.

[e] The interval between periodic inspections and tests may be extended to 10 years for seamless aluminium-alloy cylinders, when the alloy of the cylinder has been subjected to a stress corrosion test as specified in ISO 7866.

[f] Corrosiveness is with reference to human tissue (see ISO 13338) and NOT cylinder material as indicated in Annex C.

Annex B
(normative)

Description, evaluation of defects and conditions for rejection of seamless steel and seamless aluminium-alloy cylinders at the time of periodic inspection

B.1 General

Cylinder defects can be physical, material or due to corrosion as a result of environmental or service conditions to which the cylinder has been subjected during its life. Annex B provides a convenient summary of most of the identified conditions and describes the features for which the cylinder shall be inspected as well as the criteria applied to these features.

Annex B applies to all cylinders, but those that have contained gases with special characteristics may require modified controls.

Any defect in the form of a sharp notch may be removed by mechanical means (e.g. machining or other approved methods) and blended smooth (see Clause 13). After such a repair, the wall thickness shall be checked, e.g. by UT.

If the defect size is such that it has reached limits of depth or extent, the remaining wall thickness shall be checked with an ultrasonic device. The wall thickness may be less than the minimum guaranteed wall thickness, when authorized by the competent authority taking into consideration the severity of the defect and safety factors. ISO/TR 22694 and Figures B.6 and B.7 may be used for guidance to evaluate the acceptable size of the defect.

ISO/TR 22694 was developed as a result of substantial analytical work and verified by experimental tests to establish safe criteria for defects within seamless steel and seamless aluminium-alloy cylinders. ISO/TR 22694 concluded that the criteria developed therein should be incorporated into the next revision of the periodic inspection and testing documents, ISO 6406 and ISO 10461. This document (ISO 18119) is a combined version of ISO 6406 and ISO 10461 and so it is appropriate that the results from ISO/TR 22694 have been incorporated herein. ISO/TR 22694 evaluated cylinders with a water capacity of up to 50 l; therefore, any extension of the rejection criteria of this document to cylinders with a water capacity greater than 50 l or tubes needs to be re-evaluated.

A summary of the data from ISO/TR 22694 had been independently peer reviewed and published in the ASME *Journal of Pressure Vessel Technology*[24].

B.2 Physical or material defects

Evaluation of physical or material defects shall be in accordance with Table B.1.

Permanent attachments (e.g. footrings or neckrings) shall be inspected and shall be suitable for their intended purposes.

Table B.1 — Rejection criteria relating to physical and material defects in the cylinder shell

Type of defect	Definition	Rejection criteria in accordance with Clause 9[a]	Repair or render unserviceable
Bulge	Visible swelling of the cylinder	All cylinders with such a defect	Render unserviceable
Dent	A depression in the cylinder that has neither penetrated nor removed metal and is greater in depth than 1 % of the external diameter	When the depth of the dent exceeds 3 % of the external diameter of the cylinder OR When the diameter of the dent is less than × 15 its depth	Render unserviceable Render unserviceable
Cut or gouge	A sharp impression where metal has been removed, displaced or redistributed and whose depth exceeds 5 % of the cylinder's minimum design wall thickness (see Figure B.1)	When the depth of the cut or gouge exceeds 10 % of the minimum design wall thickness OR When the length exceeds 25 % of the external diameter of the cylinder	Repair possible[b] Repair possible[b, c]
Crack	A split or separation in the metal typically appearing as a line on the surface (see Figure B.2)	All cylinders with such defects	Render unserviceable
Fire/excessive heat damage	Excessive general or localized heating of a cylinder usually indicated by: a) partial melting of the cylinder b) distortion of cylinder c) charring or burning of paint d) fire damage to valve, melting of plastic guard, date ring or fusible plug if fitted	All cylinders in categories a) and b) Cylinders in categories c) and d) may be acceptable after inspection and testing	Render unserviceable Repair possible. In case of doubt, render unserviceable.
Lamination	Layering of the material with a surface breaking imperfection sometimes appearing as a discontinuity, crack, lap or bulge at the surface	All cylinders with such defects	Render unserviceable for internal defects Repair possible for external defects[b]
Neck cracks	A split or separation in the material typically appearing as lines usually running down/up the thread vertically and across the thread (not to be confused with tap marks) (see Figure 5) [d, e]	All cylinders with such defects	Render unserviceable

[a] When applying the rejection criteria given in this table, the conditions of use of the cylinders, the severity of the defect and safety factors in the design shall be taken into consideration.

[b] Repair is possible provided that, after repair by a suitable metal removal technique, the remaining wall thickness is at least equal to the minimum design wall thickness.

[c] If the measured wall thickness is less than the minimum design wall thickness, the cylinder shall either be rendered unserviceable or further action shall be taken as indicated in Table B.3.

[d] Unlike tap marks, cracks can appear on the top face of the cylinder neck.

[e] The following applies only to seamless aluminium-alloy cylinders: some neck cracks (< 1 mm in depth) may be repaired only in accordance with an agreed manufacturer's specification.

[f] If it can be clearly established that the cylinder fully complies with the appropriate specification, altered operational and modified markings may be acceptable and inadequate markings may be corrected, provided there is no possibility of confusion.

Type of defect	Definition	Rejection criteria in accordance with Clause 9[a]	Repair or render unserviceable
Tap marks	Thread machining marks typically appearing as straight lines (not to be confused with neck cracks) (see Figure 4)	Acceptable	No repair necessary
Plug or neck inserts	Additional inserts fitted in the cylinder neck, base or wall	All cylinders unless it can be clearly established that addition is part of approved design	Repair possible
Stamping	Marking by means of a metal punch	All cylinders with illegible, modified or incorrect markings	Render unserviceable[f]
Arc or torch burns	Partial melting of the cylinder, addition of weld metal or removal of metal by scarfing or cratering	All cylinders with such defects	Render unserviceable
Suspicious marks	Marks introduced other than by the cylinder manufacturing process and approved repair	All cylinders with such defects	Continued use possible after additional inspection to eliminate doubt for continued service
Vertical stability		Deviation from verticality that can present a risk during service (especially if fitted with footring)	Repair or render unserviceable

[a] When applying the rejection criteria given in this table, the conditions of use of the cylinders, the severity of the defect and safety factors in the design shall be taken into consideration.

[b] Repair is possible provided that, after repair by a suitable metal removal technique, the remaining wall thickness is at least equal to the minimum design wall thickness.

[c] If the measured wall thickness is less than the minimum design wall thickness, the cylinder shall either be rendered unserviceable or further action shall be taken as indicated in Table B.3.

[d] Unlike tap marks, cracks can appear on the top face of the cylinder neck.

[e] The following applies only to seamless aluminium-alloy cylinders: some neck cracks (< 1 mm in depth) may be repaired only in accordance with an agreed manufacturer's specification.

[f] If it can be clearly established that the cylinder fully complies with the appropriate specification, altered operational and modified markings may be acceptable and inadequate markings may be corrected, provided there is no possibility of confusion.

B.3 Corrosion

B.3.1 General

The cylinder can be subjected to environmental conditions that could cause internal and external corrosion of the metal.

Extensive experience and judgment are required in evaluating whether cylinders that have corroded internally are safe and suitable for return to service. It is important that the surface of the metal is cleaned of corrosion products prior to the inspection of the cylinder.

B.3.2 Types of corrosion

The types of corrosion may be classified generally as in Table B.2.

Table B.2 — Rejection criteria for corrosion of the cylinder wall

Type of corrosion	Definition	Rejection criteria in accordance with Clause 9[a]	Repair or render unserviceable
General corrosion	Loss of wall thickness over an area of more than 20 % of either the interior or the exterior total surface area of the cylinder (see Figure B.3)	If the original surface of the metal is no longer recognizable	Repair possible[b, c]
		OR	
		If the depth of penetration exceeds 10 % of the minimum design wall thickness and the remaining wall thickness is equal to or greater than the minimum design wall thickness	Repair possible[b, c]
		OR	
		If the measured wall thickness is less than the minimum design wall thickness, see Table B.3 requirements	Dependent on outcome of Table B.3 or render unserviceable
Local corrosion	Loss of wall thickness over an area of less than 20 % of either the interior or the exterior total surface area of the cylinder, except for the other types of local corrosion described below	If the depth of penetration exceeds 20 % of the minimum design wall thickness and the remaining wall thickness is equal to or greater than the minimum design wall thickness	Repair possible[b]
		OR	
		If the measured wall thickness is less than the minimum design wall thickness, see Table B.3 requirements	Dependent on outcome of Table B.3 or render unserviceable
Chain pitting or line corrosion	Corrosion forming a narrow longitudinal or circumferential line or strip, or isolated craters or pits that are almost connected (see Figure B.4)	If the total length of corrosion in any direction exceeds the diameter of the cylinder and the depth exceeds 10 % of the minimum design wall thickness	Repair possible[b, c]
		OR	
		If the wall thickness is less than the minimum design wall thickness, see Table B.3 requirements	Dependent on outcome of Table B.3 or render unserviceable

[a] If the bottom of the defect cannot be seen and if its extent cannot be determined using appropriate equipment, the cylinder shall be rendered unserviceable in accordance with Clause 18.

[b] After repair, a cylinder shall meet the requirements given in Clauses 9, 10, and 11.

[c] Repair is possible provided that, after repair by a suitable metal removal technique, the remaining wall thickness is consistent with the requirements of Table B.3.

Type of corrosion	Definition	Rejection criteria in accordance with Clause 9[a]	Repair or render unserviceable
Isolated pits	Corrosion forming isolated craters, without significant alignment (see Figure B.5)	If the diameter of the pits is greater than 5 mm, refer to the “local corrosion” row. If the diameter of the pits is less than 5 mm, the cylinders should be assessed as carefully as possible in order to check that the remaining thickness of the wall or base is adequate for the intended use of the cylinder.	Repair possible[b, c]
		OR If the wall thickness is less than the minimum design wall thickness, see Table B.3 requirements	Acceptance/rejection dependent on requirements of Table B.3 or render unserviceable
Crevice corrosion	Corrosion associated with taking place in, or immediately around, an aperture	If, after thorough cleaning, the depth of penetration exceeds 20 % of the minimum design wall thickness	Repair possible [c]

[a] If the bottom of the defect cannot be seen and if its extent cannot be determined using appropriate equipment, the cylinder shall be rendered unserviceable in accordance with Clause 18.

[b] After repair, a cylinder shall meet the requirements given in Clauses 9, 10, and 11.

[c] Repair is possible provided that, after repair by a suitable metal removal technique, the remaining wall thickness is consistent with the requirements of Table B.3.

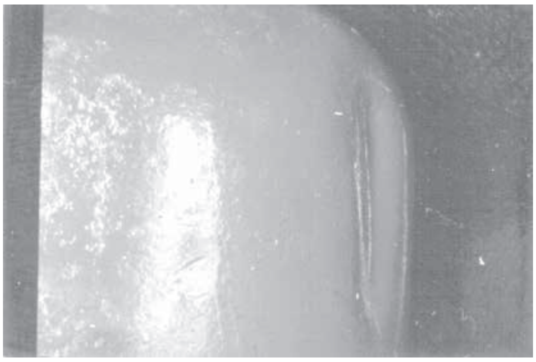


Figure B.1 — Cut or gouge

Figure B.2 — Crack

Figure B.3 — General corrosion

Figure B.4 — Chain pitting or line corrosion

Figure B.5 — Isolated pits

Figures B.1 to B.5 apply to both seamless steel and seamless aluminium-alloy cylinders.

B.3.3 Technical basis for establishing maximum allowable imperfection sizes by UT

The Level III operator shall be knowledgeable about the entire content of ISO/TR 22694 so that the following requirements are correctly applied.

Table B.3 is a summary of criteria relevant to B.3.2 and needs to be read in conjunction with Table B.2. These criteria apply only to work being performed using ultrasonic testing in accordance with 14.4. The two fundamental figures used in the development of this table are Figures B.6 and B.7, which refer to seamless steel and seamless aluminium-alloy cylinders, respectively.

An “X” reference line for flaw location shall be used providing a circumferential orientation reference point from where a flaw can be plotted. This reference line is centred on the cylinder identification stampings and runs down the long axis of the cylinder. The flaw location is the distance measured perpendicular and direction (±) from the “X” line to the centre of the flaw (where “-“ is clockwise and “+” is counter-clockwise when facing to read the stamp marking information).

A “Y” reference point shall be the shoulder of the cylinder (from the marked specification/serial number end for tubes), providing a longitudinal orientation from where a flaw can be plotted down the length of the cylinder. The flaw location is the distance measured from the shoulder to the centre of the flaw. See Figure B.8, which provides an example of an “X” reference point and a “Y” reference point.

The flaw location may be identified by an alternative method, as long as it provides the equivalent accuracy and repeatability.

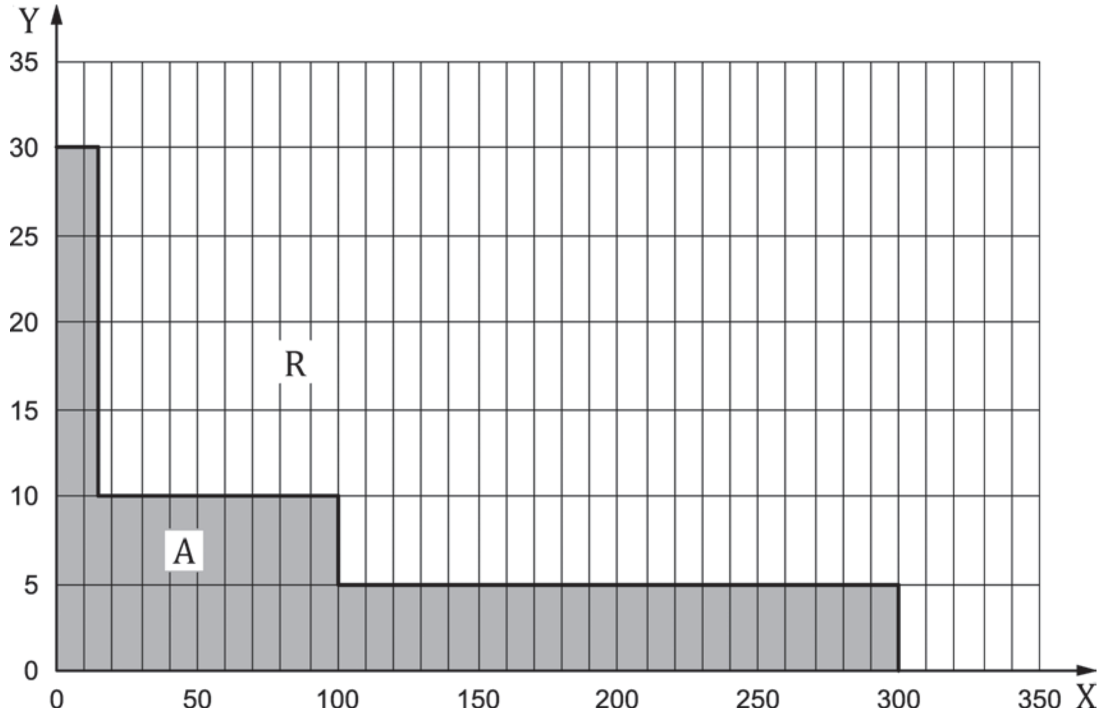
The user of this document can be required to use imperfection sizes that are less than those shown in Table B.3 as maximum allowable imperfection sizes.

Table B.3 — Maximum allowable imperfection sizes for UT acceptance/rejection

Specification	Area of corrosion	Linear flaws (line corrosion, cracks, etc.)	Isolated pit	Sidewall-to-base transition (inside diameter only)
Seamless steel cylinders[a]				
ISO 9809-1, ISO 9809-2, ISO 9809-3	Area less than 1 000 mm^2 and depth less than or equal to 0,10 t_m	Length less than or equal to 100 mm and depth less than or equal to 0,10 t_m	For cylinders with outer diameter (OD) less than or equal to 100 mm: maximum diameter 5 mm and maximum depth 0,33 t_m For cylinders with OD greater than 100 mm but less than or equal to 300 mm: maximum diameter 10 mm and maximum depth 0,33 t_m	Length less than or equal to 25 mm and depth less than or equal to 0,10 t_m
Seamless aluminium-alloy cylinders				
ISO 7866	Area less than 700 mm^2 and depth less than or equal to 0,10 t_m	Length less than or equal to 30 mm and depth less than or equal to 0,10 t_m	For cylinders with OD less than or equal to 100 mm: maximum diameter 5 mm and maximum depth 0,15 t_m For cylinders with OD greater than 100 mm but less than or equal to 300 mm: maximum diameter 10 mm and maximum depth 0,15 t_m	N/A

If corrosion or damage has reached limits of depth or extent of the values in this table, the remaining wall thickness should be checked with an ultrasonic device. With the authorization of the competent authority, the wall thickness may be less than the minimum design wall thickness, e.g. small (depth and extent) isolated pits (see Figure B.5), area corrosion. A more complete description of such imperfections has been evaluated in ISO/TR 22694, which may be used as guidance.

[a] All seamless steel cylinders that fail the design minimum wall thickness shall not be used in embrittling gas service.



Key

X flaw length, in mm

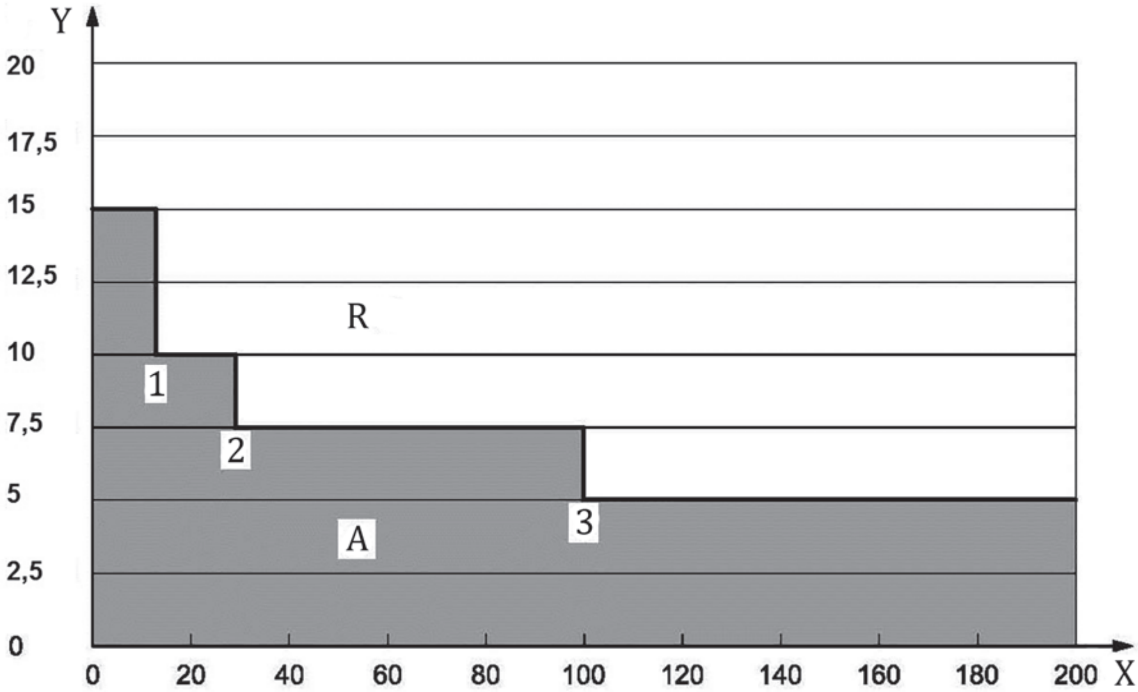
Y flaw depth ratio (a/t), in percent

R reject

A accept

SOURCE: ISO/TR 22694:2008, Figure 19.

Figure B.6 — Maximum allowable imperfection sizes for seamless steel cylinders of various compositions

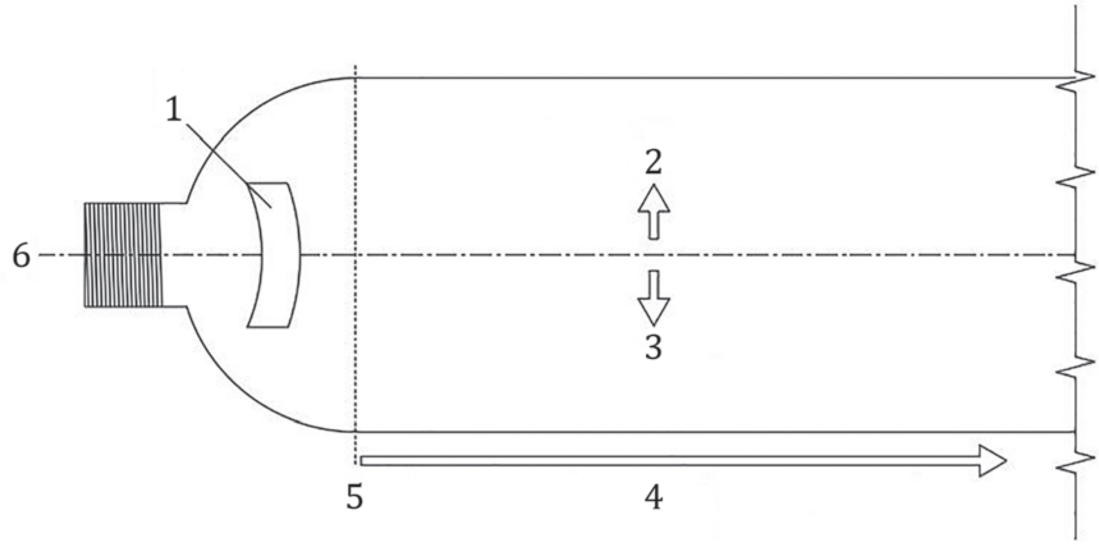


Key

X	flaw length, mm	R	reject
Y	flaw depth ratio (a/t), in percent	A	accept
1	15 mm		
2	30 mm		
3	100 mm		

SOURCE: ISO/TR 22694:2008, Figure 24.

Figure B.7 — Maximum allowable imperfection sizes for seamless aluminium-alloy cylinders



Key

1 identification stamp markings

2 X "+" measurements

3 X "-" measurements

4 Y measurement to flaw centre

5 Y reference point

6 X reference line

Figure B.8 — Example of X and Y reference points for flaw location

B.4 Neck and shoulder cracks

B.4.1 General

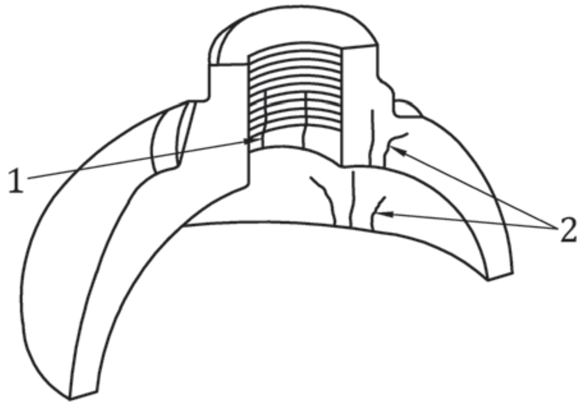
Reject cracks in accordance with Table B.1.

B.4.2 Neck cracks

Some cylinders with taper threads can be subject to neck cracks. After cleaning in a suitable way, cracks can be detected by visual inspection. Figure 4 shows the location and likely propagation of such cracks. Neck cracks should not be confused with tap marks, which normally are visible parallel lines. Figure 5 shows tap marks.

B.4.3 Shoulder cracks

Some cylinders can be subject to shoulder cracks. These cracks might start from folds in the internal shoulder area and propagate into the threaded area or shoulder of the cylinder. Hence, this lower threaded area of the neck shall be very carefully inspected. Figure B.9 shows where shoulder cracks start and how they propagate.



Key

1 shoulder crack propagating into the threads

2 shoulder cracks

Figure B.9 — Shoulder cracks

Figures 4 and B.9 apply only to seamless aluminium-alloy cylinders.

Annex C
(informative)

List of gases corrosive to cylinder material

Table C.1 — Gases corrosive to cylinder material

Gas name	Chemical formula	UN class or division	Subsidiary risk
Boron trichloride	BCl_3	2.3	8
Boron trifluoride	BF_3	2.3	8
Chlorine	Cl_2	2.3	8
Dichlorosilane	SiH_2Cl_2	2.3	2.1, 8
Fluorine	F_2	2.3	5.1, 8
Hydrogen bromide	HBr	2.3	8
Hydrogen chloride	HCl	2.3	8
Hydrogen cyanide	HCN	6.1	3
Hydrogen fluoride	HF	8	6.1
Hydrogen iodide	HI	2.3	8
Methlybromide	CH_3Br (R40B1)	2.3	—
Nitric oxide	NO	2.3	5.1, 8
Nitrogen dioxide	N_2O_4	2.3	5.1, 8
Phosgene	$COCl_2$	2.3	8
Silicon tetrachloride	$SiCl_4$	8	—
Silicon tetrafluoride	SiF_4	2.3	8
Sulfur tetrafluoride	SF_4	2.3	8
Trichlorosilane	$SiHCl_3$	4.3	3, 8
Tungsten hexafluoride	WF_6	2.3	8
Vinyl bromide	C_2H_3Br (R1140B1)	2.1	—
Vinyl chloride	C_2H_3Cl (R1140)	2.1	—
Vinyl fluoride	C_2H_3F (R1141)	2.1	—
Not all mixtures containing these gases are corrosive.			

Annex D
(informative)

Volumetric expansion testing of cylinders

D.1 General

This annex gives details of the three methods for determining the volumetric expansion of seamless steel and seamless aluminium-alloy cylinders:

— two water jacket methods (preferred method);

— the non-water jacket method.

The water jacket volumetric expansion test shall be carried out on equipment with a levelling burette, with a fixed burette or with a scale that contains water.

D.2 Test equipment

The following general requirements shall apply to all three methods of test.

— Hydraulic volumetric expansion test pipelines shall be capable of withstanding a pressure 1,5 times the maximum test pressure of any cylinder that is tested.

— Glass burette at the maximum recorded pressure shall be of sufficient length to contain the full volumetric expansion of the cylinder and shall have bores of uniform diameter such that the expansion can be read to an accuracy of 1 %, or 0,1 ml, whichever is greater.

— Scales shall be capable of providing total expansion measurements to an accuracy of ±1 % or 0,1 g, whichever is greater.

— Pressure gauges shall be at least to an Industrial Class 1 with a scale appropriate to the test pressure, and they shall be calibrated at regular intervals and at least once per month.

— A suitable system control device shall be used to ensure that no cylinder is subjected to a pressure in excess of its test pressure, +3 % or 10 bar, whichever is lower.

— Pipework should utilize long bends in preference to elbow fittings, and pressure pipes should be as short as possible; flexible tubing shall be capable of withstanding 1,5 times the maximum test pressure in the equipment.

— All joints shall be leak tight.

— When installing equipment, care shall be taken to avoid trapping air in the system.

D.3 Water jacket volumetric expansion test

D.3.1 General

This method of test necessitates enclosing the water-filled cylinder in a jacket that is also filled with water. The total and any permanent volumetric expansion of the cylinder are measured as to the amount of water displaced by the expansion of the cylinder when under pressure and after the pressure is released. The PE is calculated as a percentage of the total expansion. The water jacket shall be fitted with a safety device capable of releasing the energy from any cylinder that might burst at test pressure.

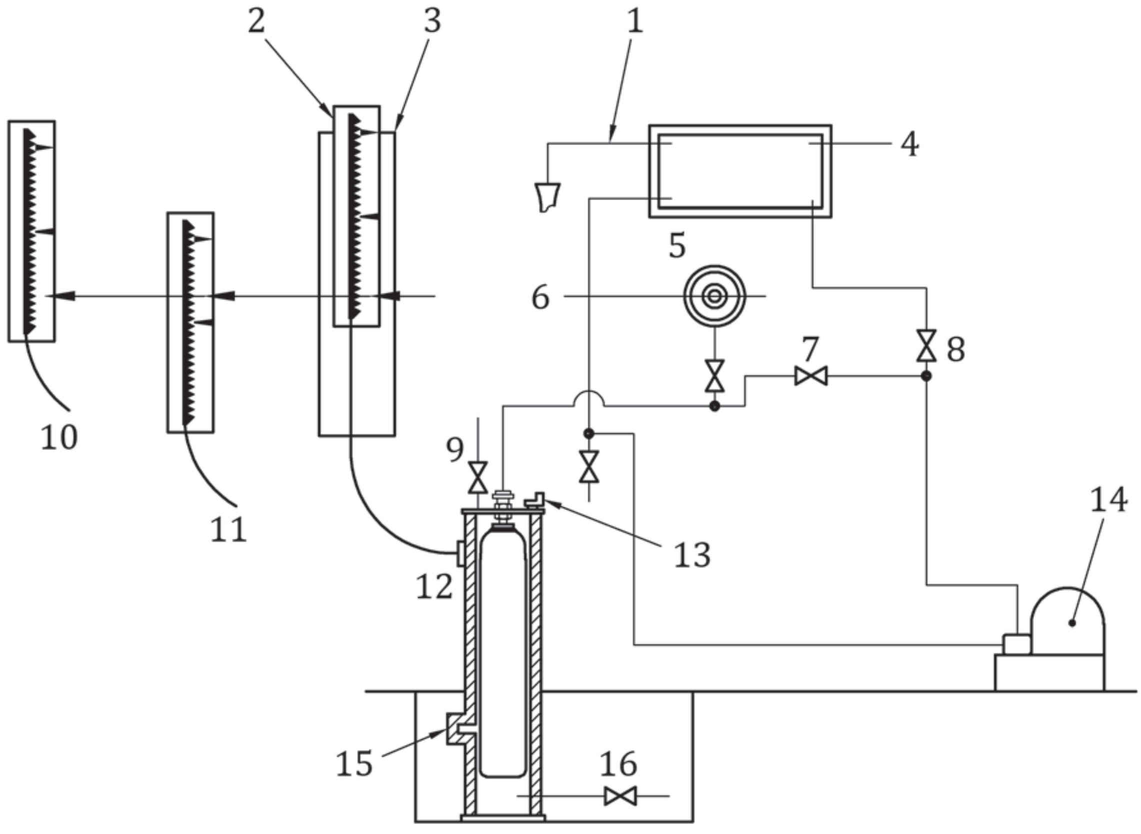
An air-bleed valve should be fitted to the highest point of the jacket.

Two methods for performing this test are described in D.3.2 and D.3.3. Other equivalent methods are acceptable provided they are capable of measuring the total and, if any, permanent volumetric expansion of the cylinder.

D.3.2 Water jacket volumetric expansion test — Levelling burette method

D.3.2.1 General

Equipment should be installed as shown in Figure D.1.



Key

1 overflow
2 calibrated burette sliding in fixed frame
3 fixed frame
4 water supply
5 pressure-measuring device
6 pointer attached to fixed frame at water level
7 hydraulic line valve
8 priming valve
9 jacket filling valve
10 position when pressure is released; reading = PE
11 position at test pressure; reading = total expansion
12 position before pressurization
13 air-bleed valve
14 pump
15 relief device
16 drain

Figure D.1 — Water jacket volumetric expansion test (levelling burette method)

D.3.2.2 Test procedure

The procedure shall be as follows:

a) Fill cylinders with water and attach to water jacket cover.

b) Seal cylinder in jacket and fill jacket with water, allowing air to bleed off through air bleed valve.

c) Connect cylinder to pressure line. Adjust burette to zero level by manipulation of the jacket filling valve and drain valve. Raise pressure to two-thirds of test pressure, stop pumping and close the hydraulic volumetric expansion test supply valve. Check that burette reading remains constant.

d) Re-start pumping and open the hydraulic volumetric expansion test line valve until cylinder test pressure (0 %/+3 % or 10 bar, whichever is lower) is reached. Close the hydraulic volumetric expansion test valve and stop pumping.

e) Lower burette until water level is at zero mark in burette support. Take a reading of the water level in burette at maximum recorded pressure. This reading is the total expansion and shall be recorded on the test certificate.

f) Open hydraulic line drain valve to release pressure from cylinder. Raise burette until water level is at zero on burette support. Check that pressure is at zero and that water level is constant.

g) Read water level in burette. This reading is the PE and, if present, shall be recorded on the test certificate.

h) Check that the PE does not exceed the percentage given in the design specification as determined by using Formula (D.1).

$$\frac{\text{Permanent expansion}}{\text{Total expansion}} \times 100 = \%\text{permanent expansion} \qquad \text{(D.1)}$$

D.3.3 Water jacket volumetric expansion test — Fixed burette method

The equipment should be installed as shown in Figure D.2.

The procedure for this method of test is similar to that described in D.3.2 except that the burette is fixed.

a) Adjust water level to a datum. Apply pressure until test pressure is reached and record the burette reading. The reading above the datum is the total expansion and shall be recorded on the test certificate.

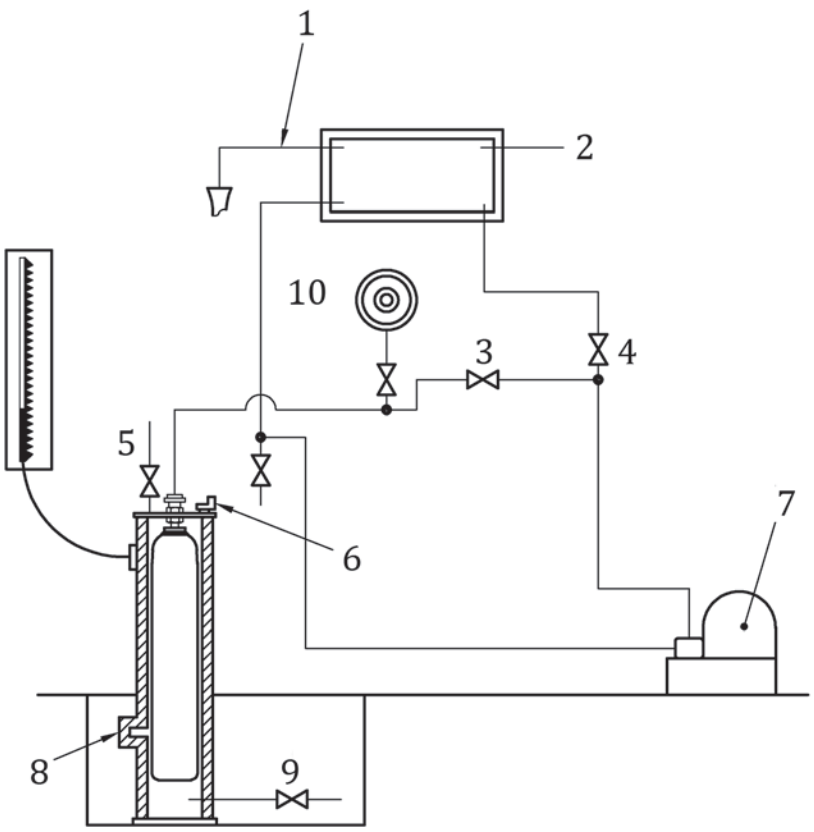
b) Check that the PE does not exceed the percentage given in the design specification, determined by using Formula (D.1).

D.4 Non-water jacket volumetric expansion test

D.4.1 General

This method consists of measuring the amount of water pumped into the cylinder under proof pressure, and on release of this pressure, measuring the water returned to the burette. It is necessary to allow for the compressibility of water and the volume of the cylinder under test to obtain true volumetric expansion. No fall in pressure is permitted under this test.

The water used should be clean and free of dissolved air. Any leakage from the system or the presence of free or dissolved air results in false readings.



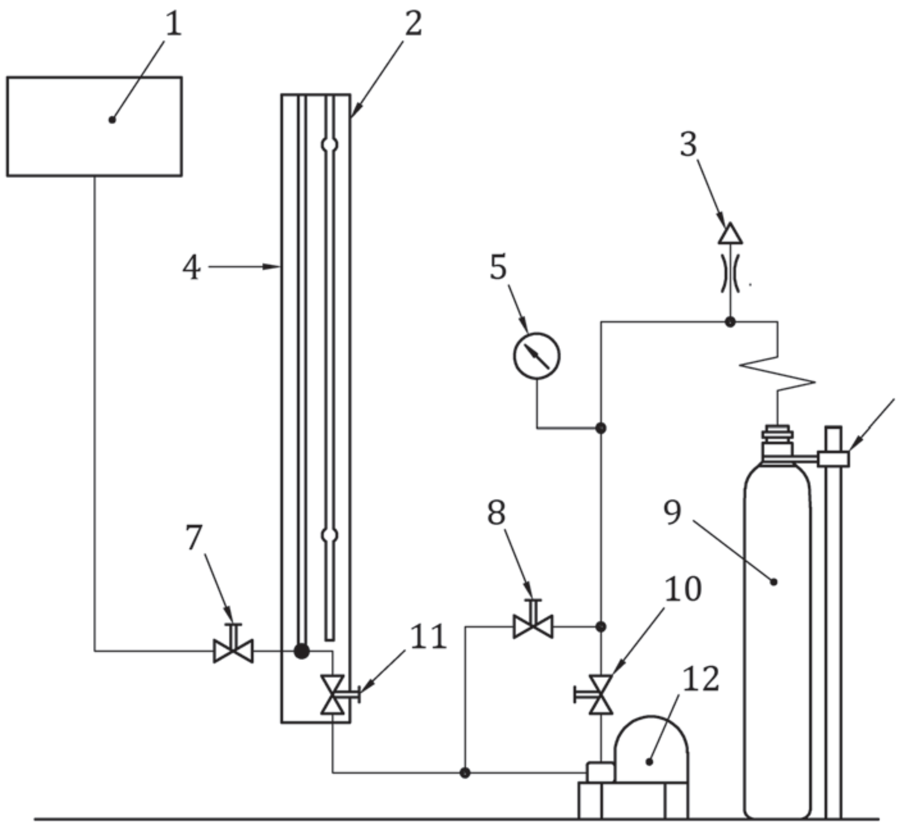
Key

1	overflow
2	water supply
3	hydraulic line valve
4	priming valve
5	jacket filling valve
6	air-bleed valve
7	pump
8	relief device
9	drain
10	pressure-measuring device

Figure D.2 — Water jacket volumetric expansion test (fixed burette method)

The equipment should be installed as shown in Figure D.3. This figure illustrates the different parts of the apparatus. The water supply pipe should be connected to an overhead tank as shown, or to some other supply giving a sufficient head of water.

A temperature-compensating measurement device is also required.



Key

1	supply tank	7	make-up valve
2	calibrated glass burette	8	bypass valve
3	air-bleed valve	9	test cylinder
4	adjustable pointer	10	hydraulic volumetric expansion test line valve
5	main pressure gauge	11	pump suction isolating valve
6	cylinder support	12	pump

Figure D.3 — Non-water jacket method — Diagrammatic layout of cylinder testing apparatus

D.4.2 Requirement for testing

The apparatus shall be arranged such that all air can be removed and that accurate readings can be determined of the volume of water required to pressurize the filled cylinder and of the volume expelled from the cylinder when depressurized. In the case of larger cylinders, it can be necessary to augment the glass tube with metal tubes arranged in the manifold.

If a single-acting hydraulic pump is used, care shall be taken to ensure that the piston is in the "back" position when water levels are noted.

D.4.3 Test method

The test method shall be as follows:

a) Completely fill the cylinder with water and determine the weight of water required.

b) Connect the cylinder to the hydraulic volumetric expansion test pump through the coil and check that all valves are closed.

c) Fill the pump and system with water from the tank by opening valves.

d) To ensure the expulsion of air from the system, close the air-bleed and bypass valves and raise the system pressure to approximately one-third of the test pressure. Open the bleed valve to release the trapped air by reducing the system pressure to zero, and re-close the valve. Repeat if necessary.

e) Continue to fill the system until the level in the glass burette is approximately 300 mm from the top. Close the make-up valve and mark the water level with a pointer, leaving the isolating and air-bleed valves open. Record the level.

f) Close the air-bleed valve. Raise the pressure in the system until the pressure gauge records the required test pressure. Stop the pump and close the hydraulic line valve. After approximately 30 s there should be no change in either the water level or the pressure. A fall in pressure, if there is no leakage, indicates that the cylinder is still expanding under pressure.

g) Record the fall in water level in the glass tube (provided that there has been no leakage, all the water drained from the glass tube will have been pumped into the cylinder to achieve the test pressure). The difference in water level is the total volumetric expansion.

h) Open the hydraulic main and bypass valves slowly to release the pressure in the cylinder and allow the water so released to return to the glass tube. The water level should return to the original level marked by the pointer. Any difference in level will denote the amount of permanent volumetric expansion in the cylinder, neglecting the effect of the compressibility of the water at test pressure. The true permanent volumetric expansion of the cylinder shall be obtained by correcting for the compressibility of the water, which is determined by Formula (D.2).

i) Before disconnecting the cylinder from the test rig, close the isolating valve. This will leave the pump and system full of water for the next test. D.4.3 d) shall, however, be repeated at each subsequent test.

j) If permanent volumetric expansion has occurred, record the temperature of the water in the cylinder.

D.4.4 Calculation of compressibility of water

The compressibility of water shall be calculated using Formula (D.2).

$$C = m \times P \times \left(K - \frac{0,68P}{10^5} \right) \qquad \text{(D.2)}$$

where

C is the compressibility in m^2/Newton (Pa^{-1});

m is the mass of water in kg;

P is the pressure in bar;

K is the factor for individual temperature as listed in Table D.1.

Table D.1 — Values of the factor *K*

Temperature °C	***K***
6	0,049 15
7	0,048 86
8	0,048 60
9	0,048 34
10	0,048 12
11	0,047 92
12	0,047 75
13	0,047 59
14	0,047 42
15	0,047 25
16	0,047 10
17	0,046 95
18	0,046 80
19	0,046 68
20	0,046 54
21	0,046 43
22	0,046 33
23	0,046 23
24	0,046 13
25	0,046 04
26	0,045 94

D.4.5 Calculation example

In this example, allowance for pipe stretch has been neglected.

Test pressure = 232 bar

Mass of water in cylinder at zero gauge pressure = 113,8 kg

Temperature of water = 15 °C

Water forced into cylinder to raise pressure to 232 bar = 1 745 cm^3 (or 1,745 kg)

Total mass of water, *m*, in cylinder at 232 bar = 113,8 + 1,745 = 115,545 kg

Water expelled from cylinder to depressurize = 1 742 cm^3

From Table C.1, *K* factor for 15 °C = 0,047 25

$$\text{If } C = m \times P \times \left(K - \frac{0{,}68\,P}{10^5} \right)$$

$$= 115{,}545 \times 232 \times \left(0{,}047\,25 - \frac{0{,}68 \times 232}{10^5} \right)$$

$$= 1\,224{,}314\ \text{cm}^3$$

Total volumetric expansion, TE

TE = 1 745 − 1 224,314 = 520,686 cm^3

$$\%\text{PE} = \frac{3 \times 100}{520{,}686} = 0{,}58\%$$

Annex E
(informative)

Test date rings for cylinders

NOTE Systems other than the one specified in Table E.1 are in use, and the same system as shown in Table E.1 is used using different colours.

Table E.1 — System using colour and shape of rings to identify periodic inspection dates

Year	Colour	Shape
2013[a]	Red	Circle
2014	Blue	Circle
2015	Yellow	Circle
2016	Green	Circle
2017	Black	Circle
2018	Grey	Circle
2019	Red	Hexagon
2020	Blue	Hexagon
2021	Yellow	Hexagon
2022	Green	Hexagon
2023	Black	Hexagon
2024	Grey	Hexagon
2025	Red	Square
2026	Blue	Square
2027	Yellow	Square
2028	Green	Square
2029	Black	Square
2030	Grey	Square
2031[a]	Red	Circle
2032	Blue	Circle
2033	Yellow	Circle
2034	Green	Circle
2035	Black	Circle
2036	Grey	Circle

[a] The sequence of colour and shape of periodic inspection date rings is to be repeated on an 18-year cycle. Hence, 2031 is a repeat of 2013.

Annex F
(informative)

Cleaning of seamless aluminium-alloy cylinders

WARNING — Ensure the chemical cleaning product is in accordance with the recommendations of the cylinder manufacturer; otherwise serious damage can occur. To ensure gas compatibility, the cleansing agent shall be completely removed or the final cleansing operation shall be compatible with the intended gas service.

F.1 Internal

Seamless aluminium-alloy cylinders in normal service can accumulate internal contamination, which can detrimentally affect use. If internal contamination is detected, the source should be investigated. Table F.1 provides some examples for cleaning the interior of seamless aluminium-alloy cylinders.

Table F.1 — Typical methods for cleaning interiors of seamless aluminium-alloy cylinders

Contamination	**Cleaning method**
Oil and grease	Degrease with suitable solvent Wash with a detergent compatible with aluminium alloy
Odour	Rinse with solution of sodium bicarbonate, then rinse with a 5 % solution of acetic acid
Corrosion	Tumble with aluminium oxide chips, pellets or glass beads Blasting (e.g. with glass beads) (see 11.2.1.3)

For the removal of moisture and loose particles and after each cleaning method, rinse the cylinder with tap water, then rinse with distilled or de-ionised water, then steam clean and dry.

Ensure all traces of cleaning agent have been removed. For temperature limits, see 17.1.2.

F.2 External

Examples of methods for cleaning external surfaces are

— soap and water;

— solvent wipe;

— scouring pad and scrubbing.

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