INTERNATIONAL STANDARD

ISO 16148

Second edition
2016-04-15

Gas cylinders — Refillable seamless steel gas cylinders and tubes — Acoustic emission examination (AT) and follow-up ultrasonic examination (UT) for periodic inspection and testing

Bouteilles à gaz — Bouteilles à gaz rechargeables en acier sans soudure et tubes — Essais d'émission acoustique et examen ultrasonique complémentaire pour l'inspection périodique et l'essai

Reference number
ISO 16148:2016(E)

Contents

Page

Foreword

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

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

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

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

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

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*.

This second edition cancels and replaces the first edition (ISO 16148:2006), which has been technically revised. The changes include

a) expansion of the scope to include tubes of water capacity up to 3 000 l used for compressed and liquefied gases, and

b) addition of procedures for ultrasonic examination (UT) follow-up during periodic inspection, as described in the new Annex A.

Introduction

In recent years, new non-destructive examination (NDE) techniques have been successfully introduced as an alternative to the conventional testing procedures of gas cylinders, tubes and other cylinders at the time of periodic inspection and testing.

One of the alternative NDE methods for certain applications is acoustic emission examination (AT), which has proved to be an acceptable test method applied during periodic inspection and testing in some countries.

The test method requires pressurization to a level greater than the normal filling pressure.

The pressurization medium can be either gas or liquid.

Acoustic emission (AE) measurements are used to detect and locate emission sources. Other NDE methods are needed to evaluate the significance of AE detected sources. One of the alternative NDE methods used as a follow-up to AT is ultrasonic examination (UT), which has proved to be an acceptable testing method applied during periodic inspection and testing. The purpose of this International Standard is to provide a procedure for locating, detecting and evaluating the relevance of AE indications such as those from longitudinally oriented crack-like discontinuities. The shear wave (angle beam) UT method is intended to be used immediately following AT to evaluate the significance of AE indications.

This International Standard describes two methods of AT, defined as Method A and Method B, and a method of follow-up UT.

With the agreement of the testing and certifying body approved by the competent authority of the country of approval, the hydraulic pressure test of cylinders and tubes can be replaced by an equivalent AT/UT Method A or B.

This International Standard is intended to be used under a variety of national regulatory regimes, but has been written so that it is suitable for the application of Reference.[1] Attention is drawn to requirements in the specified relevant national regulations of the country (countries) where the cylinders are intended to be used that might override the requirements given in this International Standard. Where there is any conflict between this International Standard and any applicable regulation, the regulation always takes precedence.

Gas cylinders — Refillable seamless steel gas cylinders and tubes — Acoustic emission examination (AT) and follow-up ultrasonic examination (UT) for periodic inspection and testing

1 Scope

This International Standard gives procedures for the use of acoustic emission examination (AT) and ultrasonic examination (UT) follow-up during the periodic inspection and testing of seamless steel cylinders and tubes with a water capacity of up to 3 000 l used for compressed and liquefied gases. This examination provides acoustic emission (AE) indications and locations that are evaluated by a secondary examination using UT for a possible flaw in the cylinder or tube. Methods other than UT for the secondary examination are not covered by this International Standard.

This International Standard does not cover composite cylinders.

CAUTION — Some of the tests specified in this International Standard involve the use of processes which could lead to a hazardous situation.

2 Normative references

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

ISO 5577, *Non-destructive testing — Ultrasonic inspection — Vocabulary*

ISO 6406, *Gas cylinders — Seamless steel gas cylinders — Periodic inspection and testing*

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

ISO 12716, *Non-destructive testing — Acoustic emission inspection — Vocabulary*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

EN 13477-1, *Non-destructive testing — Acoustic emission — Equipment characterisation — Part 1: Equipment description*

EN 13477-2, *Non-destructive testing — Acoustic emission — Equipment characterisation — Part 2: Verification of operating characteristic*

ASTM E1419, *Standard Practice for Examination of Seamless, Gas-Filled, Pressure Vessels using Acoustic Emission*

ASNT SNT-TC-1A, *Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 12716 and the following apply.

3.1
critical flaw
imperfection or damage that is large enough to exhibit unstable crack growth under certain service conditions

3.2
working pressure
settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder

Note 1 to entry: In North America service pressure is often used to indicate a similar condition, usually at 21,1 °C (70 °F).

Note 2 to entry: In East Asia, service pressure is often used to indicate a similar condition, usually at 35 °C.

[SOURCE: ISO 10286:2015, definition 736]

3.3
normal filling pressure
level to which a cylinder or tube is pressurized during filling

Note 1 to entry: This is usually greater than the marked working pressure due to the heat of compression.

3.4
acoustic emission test pressure
AT pressure
maximum pressure at which acoustic emission testing is performed

3.5
acoustic emission pressure test range
range of pressure during which acoustic emission is monitored

3.6
Method A
acoustic emission testing performed using pneumatic pressurization to at least 110 % of the normal filling pressure

Note 1 to entry: Normally performed on an assembly of cylinders (e.g. bundle) or tubes (e.g. tube trailer).

3.7
Method B
acoustic emission testing performed during the hydrostatic proof pressurization to the re-test pressure on each cylinder or tube

3.8
secondary AE sources
emissions not generated by actual crack propagation and plastic deformation

Note 1 to entry: Contact between the surfaces of a discontinuity as the cylinder expands, fracture or rubbing of mill scale within a discontinuity as the cylinder expands are examples of secondary AE sources.

3.9
calibration ring
section cut from similar cylinder material used for the calibration of the follow-up UT

3.10
distance amplitude correction curve
DAC curve
curve generated during the standardization process that accounts for the loss of amplitude of the returning signal as a result of signal travel distance

3.11
shear wave ultrasonic search unit
block of material that conforms to the curvature of the surface of the test object and orients the ultrasonic transducer at an angle which transmits and receives shear waves

3.12
ultrasonic couplant
fluid medium that forms a thin, bubble-free layer between the search unit and the test object

3.13
skip distance
in angle beam (shear wave) examination, distance along the test surface from the sound entry point to the point at which the sound returns to the same surface

Note 1 to entry: It can be considered the top surface distance of a complete wave path of sound in the test material.

3.14
modal acoustic emission
MAE
branch of AE (acoustic emission) focused on the detection and analysis of the actual sound waves produced at fracture sites from crack growths or surface rubbing

4 Operational principles

When cylinders or tubes containing discontinuities are pressurized, sound waves (AE) can be produced by several different sources (e.g. secondary sources or actual propagation of cracks). These sources can produce AE indications at pressures less than, equal to or greater than working pressure. The sound waves travel throughout the structure.

Piezoelectric sensors mounted on a cylinder or tube surface respond to sound waves. They are connected to a signal processor, which records the signal parameters associated with the passage of the waves under the sensor. Sound waves travel at assumed constant speeds. With at least two sensors, one mounted at each end of a cylinder or tube, the approximate location of event sources is derived from the measured arrival time of sound waves at the sensors.

If measured emissions exceed the specified levels over a linear distance on the cylinder, then such locations shall undergo a secondary inspection (e.g. by UT) in order to verify the presence of discontinuities and to measure their dimensions. From this secondary inspection, if the depth of the discontinuity exceeds the specified limit (that is, a limit based on a number of factors, i.e. cylinder material, wall thickness, fatigue crack growth rate estimates, fracture critical size calculations and any practical experience), then the cylinder shall be removed from service.

If, after the examination, a recalibration of the AT equipment proves negative, the relevant cylinder shall be re-examined by a non-destructive examination (NDE) method other than AT Method A.

5 Personnel qualification

The AT and UT equipment shall be operated, and its operation supervised, by competent personnel who meet the requirements of ISO 9712 or an equivalent standard (e.g., ASNT SNT TC 1A) as authorized by the Level III operator. The operator shall meet the requirements for Level I and shall be supervised by a Level II person. The testing organization shall retain a Level III operator (company employee or a third party) to oversee the entire AT and UT programme.

6 Special considerations to ensure valid tests

6.1 General

In order to prevent invalid AT when using Method A and to overcome the Kaiser effect, the AT pressure shall exceed that pressure previously exerted on the cylinder or tube during service, i.e. normal filling pressure for compressed gases, and the developed pressure at the maximum service temperature (e.g. 65 °C) for liquefied gases.

NOTE 1 The Kaiser effect is characterized by the absence of AE until the previous maximum applied load level has been exceeded.

If the pressure of the cylinder or tube exceeds 110 % of its normal filling pressure, e.g. exposure to high ambient temperatures, it shall be recorded [see NOTE to Clause 11 d)].

After pressurization to more than the AT pressure, Method A shall not be performed within a time period of less than one year or before a sufficient number of pressurization cycles have occurred, since such practice can decrease the sensitivity of the examination.

NOTE 2 The number of pressurization cycles is related to the design parameters, particularly the material composition, of the cylinder or tube undergoing periodic inspection and testing. This number of pressurization cycles at the working pressure of the cylinder or tube is typically between 75 and 100.

If a pressure greater than the normal filling pressure has been applied and a time period equal to or greater than one year or a sufficient number of pressurization cycles has not elapsed, then the AT shall be 10 % above this excessive pressure, but shall not exceed the design test pressure (TP) of the cylinder or tube. If at any stage a receptacle for liquefied gases has been overfilled, this shall be reported to the re-tester by the cylinder or tube owner or operator. If the AT would result in a pressure greater than TP, then Method A shall not be applied. Only Method B or a hydrostatic proof pressure test shall be performed.

WARNING — Take appropriate measures to ensure safe operation and to contain any energy that could be released during pressure testing. It should be noted that pneumatic pressure tests require more precautions than hydrostatic proof pressure tests since, regardless of the size of the container, any error in carrying out this test is highly likely to lead to a rupture under gas pressure. Therefore, these tests should be carried out only after ensuring that the safety measures satisfy the safety requirements.

6.2 Acoustic emission examination methods

One of the two AT methods (A or B) may be used during periodic inspection and testing of seamless steel cylinders in accordance with this International Standard. In both methods, UT follow-up of the AE indications shall be in accordance with the applicable test method described in Annex A.

Once a method (A or B) has been selected, its result shall be final.

6.3 Pressurization

General practice in the gas industry is to use low pressurization rates. This practice promotes safety and reduces equipment investment. AT should be performed with pressurization rates low enough to allow cylinder deformation to be in equilibrium with the applied load. Pressurization should proceed at rates that do not produce noise from the pressurizing medium. For Method A, typical current practice is to use pressurization rates that approximate 35 bar/h (3,5 MPa/h)[1)] for tubes.

NOTE For smaller cylinders a higher pressurization rate can be suitable provided it is demonstrated that all detrimental defects can be detected and the pressurization rate is slow enough to allow the pressurization to be stopped before bursting of the cylinder. Pressure holds are not necessary; however, they can be useful for reasons other than measurement of AE.

1) 1 bar = 0,1 MPa = 0,1 N/mm^2 = 10^5 N/m^2.

Secondary AE sources can produce emissions throughout pressurization. Crack growth normally produces emissions at pressures higher than the normal filling pressure.

When pressure within a vessel is low and gas is the pressurizing medium, flow velocities are relatively high. Flowing gas (turbulence) can produce measurable emissions. Considering this, acquisition of AE data shall commence at some pressure greater than the starting pressure (for example, one-half of the AT pressure).

Secondary sources in serious flaws can produce more AE than flaw growth. When cylinders are pressurized, flaws can produce emissions at pressures less than normal filling pressure. An AT pressure that is at least 10 % greater than normal filling pressure allows measurement of emissions from secondary sources in flaws and from flaw growth.

Excess background noise can distort AE data or render them useless. Users shall be aware of the following common sources of background noise:

— high gas fill rate (measurable flow noise);

— mechanical contact with the vessel by objects;

— electromagnetic interference and radio frequency interference from nearby broadcasting facilities and from other sources;

— leaks at pipe or hose connections;

— airborne sand particles, insects, rain drops or snow, etc.

An AT shall not be used if background noise cannot be eliminated or sufficiently controlled.

6.4 Safety precautions

When performing the AT (especially pneumatically), safety precautions shall be taken to protect personnel carrying out the examination because of the considerable damage potential from the stored energy that can be released. Additionally, since AT equipment is not explosion-proof, precautions shall be taken when the pressurization medium is a flammable gas due to the possibility of a leakage of flammable gas.

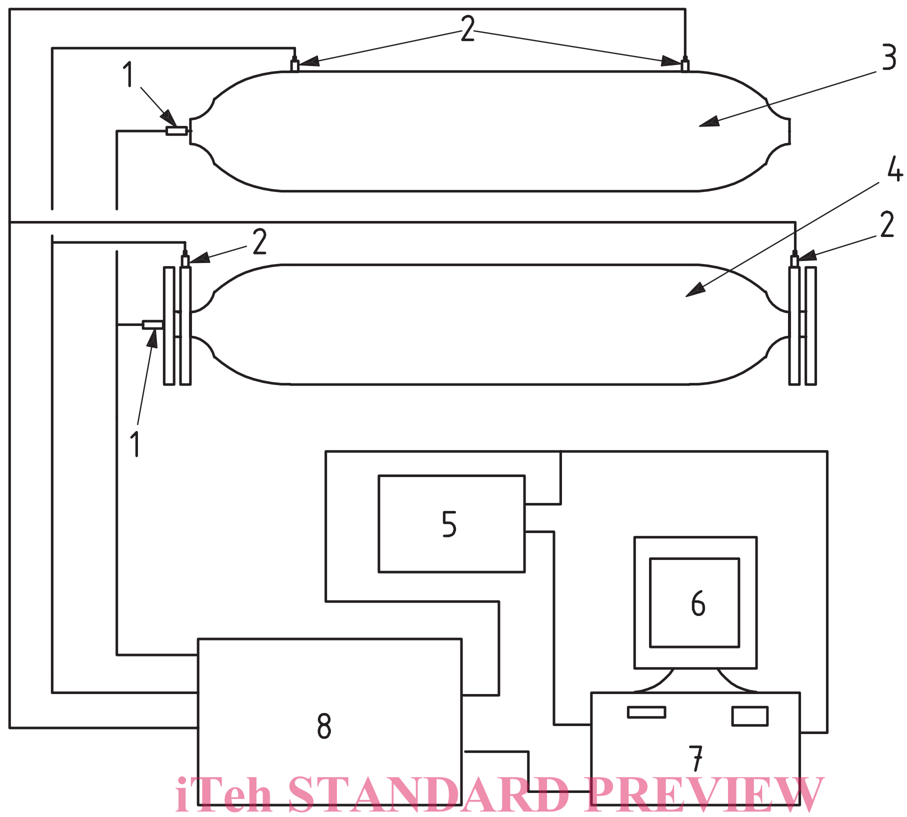
It is essential that good, instantaneous communication exist during manual test operation between the AT operator and the pressurization operator so pressurization can be paused or the pressure reduced if necessary. During automated test operations, this shall be ensured by the automated test equipment.

7 Acoustic emission examination equipment

Typical features of the equipment required for both Method A and B of AT are provided in Figure 1. Full specifications are described in Annex B.

Modal acoustic emission (MAE) can be used for the periodic inspection and testing of refillable seamless steel gas cylinders and tubes in both Method A and Method B. The corresponding specifications for MAE are provided in Annex C.

An optional approach for source location when Method A or B is used is specified in Annex D.



Key

1 pressure transducer

2 acoustic emission sensors with integral preamplifier (two for each tube)

3 tube with sensors mounted on sidewall

4 tube with sensors mounted on end flanges

5 printer

6 video monitor

7 computer

8 acoustic emission signal processor

Figure 1 — Essential features of acoustic emission examination equipment

The area of the cylinder where sensors are placed shall be clean and free from dirt and contamination.

A couplant shall be used to connect sensors acoustically to the cylinder or tube surface. Only adhesives that have acceptable acoustic properties shall be used (see B.3). Sensors shall be held in contact with the cylinder wall to ensure adequate acoustic coupling, e.g. with magnets, adhesive tape or other mechanical means.

A preamplifier may be enclosed in the sensor housing or in a separate enclosure. If a separate preamplifier is used, cable characteristics are critical (see B.4 and EN 13477-1).

Power/signal cable length — i.e. cable between the preamplifier and signal processor — shall not exceed 150 m (see B.5 and EN 13477-1).

Signal processors are computerized instruments with independent channels that filter, measure and convert analogue information into digital form for display and permanent storage. A signal processor shall have speed and capacity to process data independently from all sensors simultaneously. In addition, it shall not stop processing and shall unambiguously identify to the operator, should the situation arise where continuous noise such as from valve leakage, flow noise or high emission rate

