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Gas cylinders — Refillable seamless steel gas cylinders — Acoustic emission testing (AT) for periodic inspection

Bouteilles à gaz — Bouteilles à gaz rechargeables sans soudure — Essais d'émmision acoustique pour contrôle périodique

Reference number
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Contents

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16148 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*, in collaboration with Technical Committee CEN/TC 23, *Transportable gas cylinders*, of the European Committee for Standardization.

Introduction

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

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

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

The pressurization medium may 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. Procedures for other NDE techniques are beyond the scope of this International Standard. For example, shear wave, angle beam ultrasonic inspection is commonly used to establish the exact position and dimensions of flaws that produce AE.

This International Standard includes two methods of AT and, for the purpose of differentiation, the methods are addressed as Method A and Method B (see Clause 3).

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 may be replaced by an equivalent method based on acoustic emission.

Gas cylinders — Refillable seamless steel gas cylinders — Acoustic emission testing (AT) for periodic inspection

1 Scope

This International Standard is a guideline for using acoustic emission testing (AT) during re-qualification of seamless steel cylinders and tubes of water capacity up to 3 000 l used for compressed and liquefied gases. For cylinders below 20 l additional precautions may be taken due to the potential reflections from the ends. This examination provides indications and locations that should be evaluated by another examination for a possible flaw in the cylinder. This International Standard covers monolithic steel cylinders.

2 Normative references

The following referenced documents are indispensable for the application 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 6406, *Gas cylinders — Seamless steel gas cylinders — Periodic inspection and testing*

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

EN 1330-9, *Non-destructive testing — Terminology — Part 9: Terms used in acoustic emission testing*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-9 and the following apply.

3.1
fracture critical flaw
defect that is large enough to exhibit unstable crack growth under certain service conditions

3.2
working pressure
settled pressure at a uniform temperature of 288 K (15 °C) for a full gas cylinder with the maximum permissible charge of compressed gas

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

NOTE 2 For compressed gases, this value is usually stamped on the cylinder.

3.3
normal filling pressure
level to which a receptacle is pressurized during filling

NOTE This is usually greater than the marked working pressure due to the heat of compression.

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

3.5
maximum allowable pressure
maximum pressure a receptacle may experience

NOTE For liquefied gases, this is the developed pressure at the maximum service temperature (e.g. 65 °C).

3.6
acoustic emission pressure test range
range of pressure during which acoustic emission is monitored

3.7
Method A
acoustic emission testing performed during pneumatic pressurization to at least 110 % of the normal filling pressure

3.8
Method B
acoustic emission testing performed during the hydrostatic proof pressurization to the re-test pressure

3.9
secondary AE sources
emissions other than actual crack propagation and plastic deformation

NOTE Contact between flaw surfaces as the cylinder expands, fracture or rubbing of mill scale within a flaw as the cylinder expands are examples of secondary AE sources.

4 Operational principles

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

Piezoelectric sensors mounted on a cylinder surface respond to stress waves. They are connected to a signal processor, which records AE signal parameters associated with the passage of the waves under the sensor. Stress waves travel at average speeds. With at least two sensors, one mounted at each end of a cylinder, the approximate location of AE sources is derived from the measured arrival time of stress 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 (for example, ultrasonic examination) in order to verify the presence of flaws and to measure flaw dimensions. From this secondary inspection, if the flaw depth exceeds the specified limit (that is, a limit based on a number of factors, i.e. cylinder material, wall thickness, fatigue crack growth estimates, fracture critical flaw depth calculations and any practical experience), then the cylinder shall be removed from service.

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

5 Personnel qualification

Properly qualified and capable personnel shall perform AT. In order to prove this qualification, the personnel shall be certified in accordance with relevant standards as approved by the national authority (e.g. ISO 9712, EN 473, ASNT TC 1A).

6 Special considerations to ensure valid tests

6.1 General

In order to prevent invalid AE examinations when using Method A and to overcome the Kaiser effect (see NOTE 1), the AE test pressure shall exceed that pressure previously exerted on the receptacle during service, i.e. normal filling pressure for compressed gases and maximum allowable pressure for liquefied gases.

After pressurization to more than the AE test pressure, Method A shall not be performed within a time period less than one year or before a sufficient number of pressurization cycles (see NOTE 2) have occurred, since such practice can decrease the sensitivity of the examination.

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 AE examination shall be 10 % above this excessive pressure, but shall not exceed the design test pressure (TP) of the receptacle. If at any stage a receptacle for liquefied gases has been overfilled, this shall be reported to the re-tester by the receptacle owner or operator. If the AE examination would result in a pressure greater than TP, then Method A shall not be applied. Only Method B or a conventional re-test shall be performed.

WARNING —Take appropriate measures to ensure safe operation and to contain any energy that may be released during the hydraulic test. It should be noted that pneumatic pressure tests require more precautions than water 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 only be carried out after ensuring that the safety measures satisfy the safety requirements.

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

NOTE 2 A sufficient number of pressurization cycles are dependent upon the design parameters of the receptacle undergoing periodic inspection, particularly the material composition.

6.2 Pressurization

General practice in the gas industry is to use low pressurization rates. This practice promotes safety and reduces equipment investment. AE examinations should be performed with low enough pressurization rates 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 practices use pressurization rates that approximate 35 bar/h (3,5 MPa/h) for tubes.

NOTE For smaller cylinders a higher pressurization rate may 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.

Secondary AE sources can produce emissions throughout pressurization. Flaw 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) and impact by entrained particles 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 AE test pressure).

NOTE According to Clause 3, AE test pressure means the maximum pressure at which AT is performed.

Serious flaws can produce more AE from secondary sources than from flaw growth. When cylinders are pressurized, flaws can produce emissions at pressures less than normal filling pressure. An AE test 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.

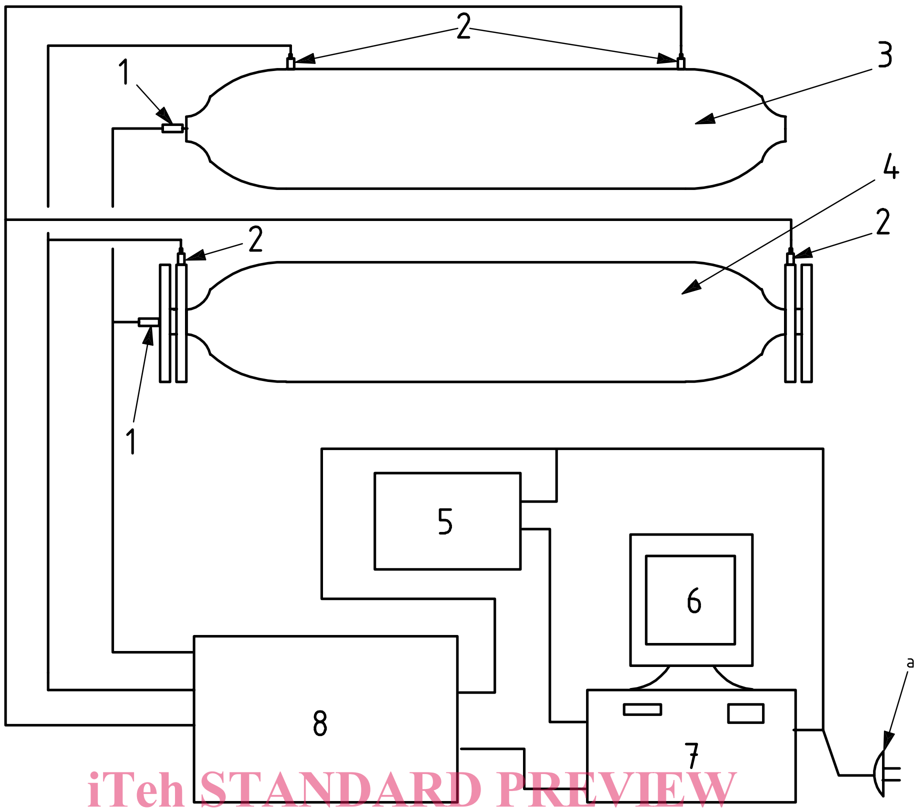
AT shall not be used if background noise cannot be eliminated or sufficiently controlled.

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 exists during manual test operation between the AT operator and the pressurization operator so pressurization can be paused or the pressure reduced if necessary. During automatic test operations, this shall be ensured by the automatic test equipment.

7 Apparatus

Typical features of the apparatus required for this test method are provided in Figure 1. Full specifications are in Annex A. An optional approach for source location is described in Annexes B and C.



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

[a] Power.

Figure 1 — Essential features of acoustic emission examination equipment

The cylinder surface at sensor places shall be cleaned (see Clause 9).

The couplant shall be used to connect sensors acoustically to the receptacle surface. Only adhesives that have acceptable acoustic properties shall be used (see A.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 A.4 and EN 13477-1).

Power/signal cable length (that is, cable between preamplifier and signal processor) shall not exceed 150 m (see A.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