ALTERNATIVES TO HYDRAULIC TESTING OF GAS CYLINDERS

IGC Doc 96/03/E

Revision of TN 518/95

EUROPEAN INDUSTRIAL GASES ASSOCIATION

AVENUE DES ARTS 3-5 • B – 1210 BRUSSELS
Tel : +32 2 217 70 98 • Fax : +32 2 219 85 14
E-mail : info@eiga.org • Internet : http://www.eiga.org

IGC Doc 96/03/E

ALTERNATIVES TO HYDRAULIC TESTING OF GAS CYLINDERS

KEYWORDS

- CYLINDER
- APPLICATION
- PRESSURE VESSEL

EUROPEAN INDUSTRIAL GASES ASSOCIATION
Avenue des Arts 3-5 B 1210 Brussels Tel +32 2 217 70 98 Fax +32 2 219 85 14
E-mail: info@eiga.org Internet: http://www.eiga.org

Table of Contents

1 Introduction

Pressure vessels in the form of cylinders for compressed gases were manufactured for the first time in the nineteenth century.

Manufacturing processes with different materials (copper, steel) were developed and introduced.

From the very beginning safety considerations have always been of great concern to the cylinder makers and the gases industry. Each cylinder has to be submitted to a periodic test before re-entering service. The cylinder shall withstand a given test pressure which is usually 1.5 times the working pressure. This hydraulic test procedure, based on the practice of the steam boiler industry, is still used in the gas cylinder industry.

A variant of the above proof pressure test is the "water-jacket test" which is still used in some countries.

Following a number of serious accidents in the 1970's involving carbon monoxide gas cylinders, a new emphasis was given to cylinder retest by the introduction of the ultrasonic inspection technique (UST) which was then already in widespread use in other industries.

The success with the carbon monoxide cylinders enabled UST to be used for hydrogen cylinders. With the help of IGC publication, TN 26/81"Hydrogen cylinders and transport vessels", UST became a mandatory requirement in addition to hydraulic testing by some national authorities, especially for new vessels used in hydrogen trailer service. UST has also been used to re-qualify existing hydrogen cylinders.

Another technique, based on Acoustic Emission Testing (AET), was also initiated for retesting of hydrogen and helium tube vessels at the beginning of the 1980s. This work was carried out mainly in the USA where in 1982 the process was at first officially approved in the form of an exemption from the DOT (United States Department of Transportation).

The major advantage of AET is the ability to perform the test without any disassembly of the tube configuration. Successful tests led to a further expansion of the AET process which is currently used in several countries.

2 Scope and purpose

This document discusses non-destructive test methods for gas cylinders and storage vessels which may be used as an alternative to hydraulic testing in some applications.

There are several methods at different stages of development, which are, in principle, able to meet this requirement.

The ultrasonic test (UST) and the acoustic emission test (AET) are advanced methods compared to the hydraulic test and are already in industrial use.

These two test methods are described in this paper which also provides recommendations for their use and information on the present state of standardisation and the legal status.

In addition to the ultrasonic and the acoustic emission test, there are further test methods which are in principle suitable for some aspects of non-destructive testing (NDT) of gas cylinders (see appendix A).

If the hydraulic test and the visual inspection are no longer necessary or if only some random tests are required, the conditioning (baking out, evacuating, purging) required with certain special gases to remove residual humidity and adsorbed gases may be eliminated.

3 UST and AET: Comparison with hydraulic test

The visual inspection combined with the hydraulic test is a proven, easy to handle and sufficiently effective method, so a question can be asked why it is necessary to introduce new methods?

However, this proven method reveals some weaknesses:

- Grooves, mechanical damage and longitudinal defects in the cylinder wall are sometimes difficult to detect by visual inspection, especially on internal surfaces. However, when submitting the gas pressure vessel to a UST or AET, these defects can usually be detected.

- Lamination in the vessel material can be detected by the hydraulic test only if the vessels fails. With the UST or AET method, these defects may be reliably detected before failure occurs.

- If gas pressure vessels are operated with corrosive gases, any humidity remaining in the cylinder after hydraulic testing will result in an accelerated corrosion rate.

- Very stringent demands on particle cleanliness are required for process gases used for the manufacture of electronic components. The contamination introduced by hydraulic testing cannot be fully avoided even after considerable efforts.

- Water is a relatively viscous fluid so that pinholes and very fine cracks may be difficult to detect.

4 Ultrasonic testing (UST)

4.1 Experience, prospects and legal situation

For some considerable time, the ultrasonic test has been used as a NDT method during the manufacturing process for pipes, cylinders and pressure vessels.

The UST technique is widespread as a supplementary test process, especially for hydrogen cylinders and pressure vessels.

UST has also been considered as an alternative to the hydraulic test during cylinder retest.

Good experience with the substitution of the hydraulic test by the UST in the past few years has resulted in the inclusion of this method in European Standards as an approved method during the periodic inspection cycle for seamless steel and seamless aluminium alloy cylinders.

4.2 Test procedure

UST is a test method that covers the cylindrical part of the cylinder, the transition to the shoulder, the transition at the base and critical zones of the base.

UST is performed by a mechanical test device for the cylindrical part of gas cylinders and for the transition areas to shoulder and base. A manual ultrasonic unit is used for the critical zones of the gas cylinder base.

Where there is a suspicion that cylinders have been damaged by fire, they shall not be examined ultrasonically.

The testing equipment must have at least five ultrasonic probes (one for thickness and four for defects) suitably arranged to scan the entire surface of the cylindrical part of the cylinder, including the adjacent transitions to the base and the shoulders.

The pulse echo method is used to detect defects and measure wall thickness. The testing techniques used are either the contact or the immersion type.

The cylinders to be tested and the search unit with the probes shall go through a rotating motion and translation relative to one another, such that a helical scan is performed on the cylinder. The speeds of translation and rotation shall be constant within ± 10%.

The ultrasonic test unit must have a screen. The installation has an automatic alarm level for each probe which gives an automatic audio and visual indication when a fault signal is registered.

A distinction between internal and external defect signals from a probe is possible by different alarm levels.

The outer and inner surfaces of any gas cylinder to be tested ultrasonically must be in a suitable condition for an accurate and reproducible test result.

In particular the external surface must be free of rust, loose paint, dirt and oil.

The UST equipment must be thoroughly calibrated corresponding to the diameter, wall thickness, external surface finish and material of the gas cylinder. The UST replaces the hydraulic test methods in some countries of Europe.

In some countries it is not required to remove the valve from the cylinder during the UST.

4.3 General

European Standards for periodic inspection and testing of seamless steel and seamless aluminium alloy cylinders are published, see EN 1968 and EN 1802.

5 Acoustic emission testing (AET)

5.1 Experience, prospects and legal situation

Pressure testing procedures backed up by acoustic emission are recognised and accepted by several national authorities as a method for periodic testing of gas cylinders and pressure vessels.

The purpose of the AET is to detect material defects of any kind (e.g. cracks, leaks, oxide layer, corrosion etc.) during a pressure test of cylinders and pressure vessels.

Basically two methods, A and B, are uses and they are described in 3.2.

Since 1983 in the United States, the Department of Transportation (DOT) has approved and issued exemptions which authorise an acoustic emission test (AET) according to method A.

Since 1984 in Canada, Transport Canada (TC) has approved and issued "Permit of Equivalent Level of Safety" that authorises an AET according to method A and B. In France, since 1989 AET is by exemption an approved method for retesting hydrogen tube trailers according to method B, such that the retest period is increased from 5 to 10 years.

Since 1990, a similar exemption has existed in Belgium.

In spite of increasing use, and the positive experience gained, the acoustic emission test is not yet included in international standards as an equivalent alternative to hydrostatic testing, though a draft ISO standard is in preparation.

Since 1993 a special exemption in accordance with the German regulations for transport of dangerous goods has been granted to a German industrial gas producer and then recently extended to the German gas industry.

5.2 Test methods and procedure

This document describes an overview of two methods of AET and for the purpose of differentiation, the methods are addressed as method A and method B.

For detailed information see CGA pamphlet C-18 "Methods for Acoustic Emission Requalification of Seamless Steel Compressed Gas Tubes".

5.2.1 Method A

Method A consists of an AET performed during pneumatic pressurisation to 110-120 percent of the normal working pressure. This test replaces the conventional hydrostatic test with or without water jacket.

5.2.2 Method B

Method B consists of an AET performed during the hydraulic test at normal test pressure of the cylinders. This test allows an increase in the test period from e.g. 5 to 10 years for hydrogen tubes in some countries.

5.2.3 Confirmation of Defects

Methods A and B may require additional ultrasonic verification depending on the AE detection level.

5.3 General

The above description of AE would rely very heavily on following agreed International Standards on the subject, e.g. the imminent ISO standard 16148.

Appendix A: Other NDT-Methods

These methods include:

- The magnetic particle test
- X-ray test (for welded gas cylinders)
- The holographic test
- The ultrasonic test with SH waves (shear wave horizontal)
- The stray flux process
- The eddy current process (only for aluminium alloy and stainless steel cylinders)