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Gas cylinders — Service life testing for cylinders and tubes of composite construction

Bouteilles à gaz — Durée de vie des bouteilles et tubes composites

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Contents

Page

Foreword

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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).

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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 Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Introduction

The concept of a service life test programme originated from the United Nation Recommendation on the Transport of dangerous Goods (The Orange Book 19th Revision). The Orange Book requirement for a service life test programme for composite cylinders of more than 15 years will be incorporated into the International Regulation for Transport of Dangerous Goods by sea, air and land.

In the 19th Revision of United Nation Recommendation on the Transport of dangerous Goods (The Orange Book) Note 2 of Section 6.2.2.1.1 is as follows:

*"**NOTE 2:** Composite cylinders with a design life longer than 15 years shall not be filled after 15 years from the date of manufacture, unless the design has successfully passed a service life test programme. The programme shall be part of the initial design type approval and shall specify inspections and tests to demonstrate that cylinders manufactured accordingly remain safe to the end of their design life. The service life test programme and the results shall be approved by the competent authority of the country of approval that is responsible for the initial approval of the cylinder design. The service life of a composite cylinder shall not be extended beyond its initial approved design life."*

To understand what testing programmes are in use by ISO P member countries, competent authorities were asked to provide information regarding the composite cylinder approvals that are accepted in their country and any service life test programmes currently practised.

The information received from the competent authorities has been used to determine the similarities and differences in the service life test programmes in use.

Gas cylinders — Service life testing for cylinders and tubes of composite construction

1 Scope

This document covers composite cylinders and tubes to be used under the International Regulation for Transport of dangerous Goods by sea, air and land:

— with a water capacity up to 3000 l;

— with a design life greater than 15 years.

This document provides:

— information on existing service life test programmes from ISO/TC 58/SC 3 member countries;

— comments (initially for internal committee use only) on similarities and differences;

— recommendations on the feasibility of harmonization and whether it would be appropriate to develop an ISO deliverable.

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 10286, *Gas cylinders — Terminology*

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 http://www.iso.org/obp

3.1
design life
maximum life (in years) for which the composite cylinder is designed and approved in accordance with the applicable standard

3.2
service life
number of years the cylinder is permitted to be in service

Note 1 to entry: In this document for “cylinder/tube” only the term “cylinder” will be used.

4 Information on existing service life test programmes

4.1 General

The concept of a service life test programme is to ensure that an approved cylinder design, with a design life in excess of 15 years, is safe for use beyond 15 years of life. The service life cannot exceed the design life.

According to of United Nations Recommendations on the Transport of Dangerous Goods, the overall programme shall be part of the initial design type approval.

4.2 Information requested

To gather information, a request form and covering letter (see Annex B) were sent to the heads of governmental delegations to the sub-committee of experts on the transport of dangerous goods of the 25 countries who are P Members of ISO TC 58 /SC 3.

4.3 Information received

Information has been received from 11 countries. This information has been collated in Tables 1, 2 and 3 (see Clause 5).

Service life testing on cylinders already in service has been practised in a limited number of countries with different checks, tests and requirements.

4.4 Service life test programmes

Two countries have confirmed that they have service life test programmes (including one response for UN cylinders) in place. One other country has indicated additional requirements to permit the use of the cylinders beyond their 15 years' service and up to the design life (not exceeding 30 years).

5 Commentary on similarities and differences

5.1 General

From the information obtained, the service life test programmes are based on two different approaches:

— Approach 1: Some of the destructive tests performed at the time of the type approvals, as required by the design standard, are carried out on a prescribed number of representative cylinders (see 5.2).

— Approach 2: Some destructive tests are carried out on a number of representative cylinders and using a statistical assessment of the findings is done (see 5.3).

Both approaches can also include non-destructive tests/inspections on each cylinder.

Additional information received from the authorities that is of interest has also been collated (see 5.4).

5.2 Requirements: Approach 1

The requirements of the tests to be performed for the service test programmes may be different from those specified at the type approval stage in the design standard. Table 1 attempts to summarize the sampling procedure and general concepts for the test work. However, full details can be found in the original approval documents.

Table 1 — Sampling and testing for Approach 1

Country	Standard or specification	Cylinder sampling		Tests to be performed	
		Sampling size	Sampling period	Type of tests	Test requirements
United States	*DOT special permits based on: DOT CFFC or* ISO 11119 series	60 off cylinders randomly selected for each design	At 10 years 30 off cylinders At 13 or 15 years 30 off cylinders, as specified	Hydraulic burst Ambient cycle Flaw Drop	Differ from the type approval requirements: aiming to reflect potential degradation of the cylinder over the 10–15 years of use
United Kingdom	HSE specs	This will depend upon the manufacturing or inspection standard, as well as the use to which the cylinder is put.	At 15 years	This will depend upon the manufacturing or inspection standard as well as the use to which the cylinder is put.	This will depend upon the manufacturing or inspection standard, as well as the use to which the cylinder is put.

5.3 Requirements: Approach 2

Test procedure and requirements using the statistical assessment method are described below.

Table 2 attempts to summarize the sampling procedure and general concepts for the test work.

Table 2 — Sampling and testing for Approach 2

Country	Standard or specification	Cylinder sampling		Tests to be performed	
		Sampling size	Sampling period	Type of tests	Test requirements
Germany	Official note of BAM "CAT" (concept additional tests) EN or ISO standard ATR national	≥ 5 randomly selected cylinders per sample (at least 6 samples i.e. ≥ 30 cylinders during service life)	At design type testing; Further 2 dates for sampling during service life are determined by the competent authority dependent from design life (e.g. 10 and 20 years)	Two samples at each date of sampling. (1st: Slow burst testing, 2nd: Load cycle testing to failure)	Dependent from P-V-product; category of gas and LBB-property. Each sample shall demonstrate reliability higher than required (high mean value and low scatter including a safety margin). After 10 … 15 years quantification of degradation and extrapolation of results to EoL. After 20 … 30 years estimated EoL to be confirmed or modified.

For details of the test procedure, criteria and definitions used in Approach 2, see Annex A.

5.4 Other overviews

From the competent authority responses received, the following information has been collected from those countries who do not have service life test programmes and allow the use of non-UN composite cylinders beyond 15 years.

Table 3 — Sampling and testing for other overviews

Country	Standard or specification	Cylinder sampling		Tests to be performed	
		Sampling size	Sampling period	Type of tests	Test requirements
Republic of Korea	KGS AC 415:2014 for LPG cylinders and KGS AC 413:2014 for LPG composite cylinders	2 cylinders in accordance with KGS AC 413:2014	At design stage	High temperature creep	In accordance with KGS AC 413:2014
Republic of South Africa	DOT special permits and ISO standards	In accordance with the relevant manufacturing standard for unlimited design life	At design stage	In accordance with the relevant manufacturing standard for unlimited design life	In accordance with the relevant manufacturing standard for unlimited design life
Sweden	RID/ADR regulation				
Switzerland	EN 12245 ISO 11119 series				
UK	EN 12245 ISO 11119 series				

6 Concluding remarks on feasibility of harmonization

Most participating ISO TC 58/SC 3 P member countries accept composite cylinders designed to ISO standards (and/or EN standards for Europe) with a design life longer than 15 years based on the initial design type approval. In these cases there is no further service life testing programme to be undertaken, other than performing the periodic inspection and pressure test according to the national regulations (see ISO 11623).

Two other approaches for specific design type approvals have been collated and grouped together as described in 5.2 and 5.3.

Additionally, other approaches also exist and these are listed in 5.4. Sustainability should be considered, including the wide range of cylinder applications and design variants.

In the future, if new concepts or techniques show benefit these would need to be further considered.

Annex A
(informative)

Approach 2: Details of test procedure, criteria and definitions

A.1 Test procedure

Dependent on the *cycle fatigue sensitivity* and leak-before-break properties, a key assessment, based on a *slow burst tests* and/or *load cycle tests* is performed on a sample of at least five new cylinders per test. The quality of production is surveyed continuously (on each production batch) by statistics on results of batch tests (key test) to failure.

Before the end of the 15 year period, both tests are repeated on a *sample* of at least 5 cylinders, again on request of the owner. For variants at least the *key test*, depending on the cycle fatigue sensitivity, is performed. In case of a design life of more than 25 years, a second repetition of testing samples coming out of service may be requested.

The appropriate service life time is estimated by comparing development of properties (*degradation* with respect to *mean value* and *scatter* of sample test results) with minimum required *survival rates*.

A.2 Criteria

The service life time will be prolonged to the number of years at which the estimated degradation curve will meet the requested minimum survival rate (SR). The service life may be prolonged up to the design life (usually non-limited).

The minimum requested survival rate for the *population* depends on the pressure-volume-product of the design type. The survival rate against rupture is in no case lower than SR = $1\text{-}10^{-6}$. Leakage may be treated on a level of SR = $1\text{-}10^{-4}$.

In addition, the minimum requested survival rate to be demonstrated by each tested sample and the finally extrapolated curve take into account the size of the relevant sample(s) on the basis of a unilateral confidence interval (*confidence level* of 95 %).

A.3 Definitions with respect to the statistical approach

Confidence level

The probability that the confidence interval contains the true value of the population parameter.

Cycle fatigue sensitivity (CYFAS)

A property of a design type that is used as criterion for choosing the method for quantification of residual strength. For quantification of this property a sample of at least 5 cylinders is tested by load cycle tests (LCT). If none of the 5 specimens ruptures or leaks while performing LCT up to 50 000 LCs, the design type is classified as non-cycle fatigue sensitive. Otherwise, a design is classified as cycle fatigue sensitive. In this case all cylinders of the relevant sample are (continued) cycled to failure independent of the number of cycles of the individual cylinders.

Degradation

A loss of safety during artificial ageing or service; quantified by a loss of slow-burst-strength or a loss of load cycle strength.

Leak-before-break (LBB)

A kind of fail-safe property or damage tolerance in case of leakage. A design is confirmed as a LBB design of a composite cylinder when it is demonstrated by cycle testing of a sample that none of the tested specimens ruptured, after leakage, when cycled to failure at maximum pressure (MAWP or PH). Another criterion is the ratio of failure rates under cyclic and slow burst conditions. It is requested to demonstrate a survival rate against rupture (slow burst) that is at least 100 times the survival rate against first failure by leakage (load cycle).

Load cycle test (LCT)

A hydraulic test of periodically alternating internal pressure at ambient temperature. The inner pressure cycles in a range between a defined lower and upper pressure level. The extreme pressure values of each cycle shall be equal or less than 2 MPa and equal or higher than maximum service pressure or test pressure **(**PH for general service). As a result of LCT, the number of load cycles to first failure (leakage or to rupture) can be evaluated. This test is the preferred test for quantification of residual strength, in the case of a cycle fatigue sensitive design (→ cycle fatigue sensitivity).

Mean (value)

The arithmetic average of experimental results. It is the sum of a collection of test results (→ sample) divided by the number of results in the collection (specimens of the sample). In case of LC test results the mean is calculated on the basis of log-values.

Population

The amount of individual cylinders of a design type (design variant) in service relevant for life time test programme. Usually the life time testing of cylinders coming out of service is related to the population of each owner separately.

Sample

A number of specimens that have identical parameters. Specimens can be grouped to a sample if relevant parameters of production and use are identical (the production date, month in service, etc.). For statistical comparison of two samples all essential parameters of both samples are identical while one of the parameters differs.

Slow burst test (SBT)

A test of constant pressure increase starting at the level of zero or at MAWP (or PH for general service). As result the time to rupture or the pressure at rupture can be evaluated.

This test is the preferred tests for quantification of residual strength in case of a non-cycle fatigue sensitive design. (→ cycle fatigue sensitivity).

Survival rate (SR)

The estimated ratio of specimens, based on sample evaluation, that has survived up to the discussed status of loading (pressure level, number of load cycles, time under load, etc.) without failure.

