
**Gas cylinders — Service life
performance of composite cylinders
and tubes**

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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).

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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*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Composite gas cylinders have been manufactured for more than 50 years. Over that time, several specifications have been developed at the national, regional and international levels.

The following ISO standards cover the design of composites cylinders and tubes:

- ISO 11119 series (cylinders and tubes up to 450 l);
- ISO 11515 (tubes from 450 l to 3 000 l).

When the above-mentioned standards were proposed for reference in the UN Model Regulations, a lot of discussion took place because the two main regions using composite gas cylinders (Europe and North America) had different approaches. In Europe, regulations permitted non-limited lifetime for composite cylinders, while in North America, the lifetime was limited to 15 years by the US Department of Transportation.

To reach consensus, the concept of a service life test programme for composite cylinders and composite tubes of more than 15 years design life time was incorporated into the United Nations Recommendations on the Transport of Dangerous Goods (The Orange Book), as adopted in the 19th revision, in NOTE 2 of 6.2.2.1.1 and 6.2.2.1.2. This statement has raised several questions over the years:

- When are the tests to be performed?
- On which cylinders are the tests to be performed? How will the sampling be established?
- What tests are to be performed?
- Are all the tests really needed?
- Can the service life test programme be included in the design standard?

To answer these questions, ISO/TC 58/SC 3/WG 36 developed ISO/TR 19811. Indeed, 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 practiced.

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

In 2018, ISO/TC 58/SC 3/AHG 1 concluded that there is no standardized global test protocol, and the worldwide feasibility of such programmes was difficult to put in place.

Finally in 2019, taking into account the previous work of ISO/TC 58/SC 3/WG 36 and ISO/TC 58/SC 3/AHG 1, ISO/TC 58/SC 3 asked WG 36 to develop a document to support the removal of service life test programme from the UN Model Regulations.

The aim of this proposed Technical Report was to build a rationale to answer the following question:

“Is a service life test programme needed to guarantee the safe and reliable performance of cylinders with a design life longer than 15 years?”

It is important to note that the current document deals only with the need (or not) of having a service life test programme for a cylinder with design life of more than 15 years or non-limited life to guarantee its “safety”.

NOTE The aim of the current document is not to discuss the merit of the tests performed to extend the life beyond its design life nor the frequency of periodic inspections

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Gas cylinders — Service life performance of composite cylinders and tubes

1 Scope

This document collects history and experience of composite cylinders and tubes to be used under the International Regulations for the Transport of Dangerous Goods:

- with a water capacity up to 3 000 l;
- with a design life greater than 15 years.

In particular the document reviews the topic of the service life performance of existing composite cylinders and tubes and provides information and data for the following items:

- history of cylinder design;
- current testing regimes;
- significance of the tests on their performance;
- service performance including pre-fill and periodic inspection and tests.

NOTE In this document, for “cylinder/tube”, only the term “cylinder” is used.

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 — Vocabulary*

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 terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://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

4 History of composite cylinder design

Composite cylinders have been used in commercial service for over 50 years. The first well-known standards were:

- DOT FRP-1, type 3FC composite cylinders published in 1981;
- DOT FRP-2, type 3HW composite cylinders published in 1982.

Both of the above were developed by the Compressed Gas Association (CGA) in cooperation with DOT. DOT FRP-1 and FRP-2 were limited to a service life of 15 years.

- HSE-AL-FW1, 1st published in January 1991. 15-year service life with possibility to extend;
- HSE-AL-HW1, 1st published in January 1991. 15-year service life with possibility to extend;
- DOT-CFFC, published on 1996 with the possibility of extending the 15-year service life up to a total service life of 30 years;
- ISO 11119, Parts 1, 2 & 3, published in 2002;
- EN 12245 and EN 12257, both published in 2002;
- ISO 11515, published in 2013.

ISO 11119 series, ISO 11515, EN 12245 and 12257 are for limited life and non-limited life designs.

Technical reports collected data and specific design factors, test protocols and cylinder performance are summarized in the ISO/TR 13086 series of documents.

Approximately 12 million composite cylinders have been manufactured for compressed gases and 20 million for liquefied gases (mainly liquid propane gas (LPG)).

The vast majority of cylinders with a design life in excess of 15 years have been designed, manufactured and tested as non-UN approved cylinders thus allowing a service life greater than 15 years without a service life test programme.

The initial limitation of service life to 15 years was imposed in some countries because of lack of service experience of composite materials and cylinders.

5 Current testing regimes

5.1 General

The UN Model Regulations refer to ISO standards for the design, construction, testing, pre-fill inspection and periodic inspection and testing for composite cylinders and tubes:

- At the manufacturing stages the relevant standards are ISO 11119 (series) and ISO 11515.
- At time of filling the relevant standard is ISO 24431.
- At periodic inspection and testing the relevant standard is ISO 11623.

5.2 Requirements at the design, construction and testing stage

Tests are carried out during Type Approval, during production on a batch-by batch basis and on individual cylinders to ensure that the cylinders will provide satisfactory in-service performance.

The tests and the main requirements specified in the ISO 11119 series are summarised in [Tables 1 and 2](#).

Table 1 — Type approval testing ISO 11119

Test	ISO 11119-1	ISO 11119-2-	ISO 11119-3	ISO 11119-4	Sampling Rate
Liner material tests	X	X	X	X	1
Liner integrity test	N/A	N/A	N/A	X	1
Composite material tests	X	X	X	X	1
Proof pressure test or hydraulic expansion test	X	X	X	X	100 %
Liner burst test	X	X	X	X	1
Hydraulic burst test	X	X	X	X	3/30
Ambient cycle test	X	X	X	X	2/30
Environmental cycling test	X	X	X	X	1/30
Flaw test	N/A	X	X	X	2/30
Drop test	O	X	X	X	2/30
Torque test	X	X	X	X	1/30
High velocity impact	O	X	X	X	1/30
Fire resistance test	O	O	O	O	2/30
Saltwater test	O	O	O	O	2/30
Stress rupture test	O	O	O	O	2/30
Leak test	N/A	N/A	X	X	4/30
Permeability test	N/A	N/A	O	N/A	1/30
Vacuum	N/A	N/A	O	N/A	1/30
Pneumatic cycle test	N/A	N/A	X	N/A	1/30
Key X = Test required O = Test optional depending on design and intended use N/A = Test not required					

Table 2 — Batch Testing Requirements for ISO 11119 series

Tests	ISO 11119-1, ISO 11119-2, ISO 11119-3	ISO 11119-4	Sampling Rate
Liner tensile test	X	X	1 per batch
Liner hardness testing	X	X	5 % or 100 %
Liner compliance	X	X	100 %
Liner integrity test	N/A	X	100 %
Liner burst test	N/A	X	1 per batch
Composite materials compliance	X	X	100 %
Cylinder compliance	X	X	100 %
Hydraulic proof test or volumetric expansion test	X	X	100 %
Key X = Test required N/A = Test not required			

Table 2 (continued)

Tests	ISO 11119-1, ISO 11119-2, ISO 11119-3	ISO 11119-4	Sampling Rate
Dimensional check	X	X	100 %
Visual examination	X	X	100 %
Hydraulic burst test	X	X	1 per batch
Ambient cycle test	X	X	1 per batch up to 1 per 5 batches
Key			
X = Test required			
N/A = Test not required			

The tests and the main requirements specified in ISO 11515 are summarised in [Tables 3](#) and [4](#).

Table 3 — Type Approval Testing ISO 11515

Design Tests	Type 2	Type 3	Type 4	Sampling Rate
Liner material tests	X	X	X	1
Composite material tests	X	X	X	1
Proof pressure test, or Hydraulic expansion test	X	X	X	100 % ^c
Liner burst test	X	X	N/A	1
Tube burst test	X	X	X	3
Ambient temperature cycling test	X	X	X	2
Environmental cycling test	X	X	X	1
Flaw test	N/A	X	X	1
Blunt impact test	X	X	X	1
Fire resistance test	X	X	X	1
Neck strength test	N/A	N/A	X	1
Leak test	N/A	N/A	X	100 %
Accelerated stress rupture test	O	O	O	1
Permeability test	N/A	N/A	O	1
Gas cycling test	N/A	N/A	X	1
Coatings test ^a (where applicable) ^b	O	O	O	1
Salt Spray test	O	O	O	1
Acid environment test	O	O	O	1
Vacuum test	N/A	N/A	O	1
Key				
X = Test required				
O = Test optional depending on design and intended use				
N/A = Test not required				
^a Tubes being used for other tests can be used.				
^b Coating tests can be carried out on sections/domes of tubes as appropriate.				
^c Sufficient number of test samples for Prototype testing				

Table 4 — Batch Testing Requirements for ISO 11515

Tests	Type 2	Type 3	Type 4	Sampling Rate
Ultrasonic examination of liner tube	X	X	N/A	100 %
Ultrasonic examination of steel liners	X	X	N/A	100 %
Liner and boss tensile test	X	X	X	1 per batch
Liner and boss hardness testing	X	X	X	5 % or 100 %
Liner compliance	X	X	X	100 %
Composite materials compliance	X	X	X	100 %
Cylinder compliance	X	X	X	100 %
Hydraulic proof test or volumetric expansion test	X	X	X	100 %
Dimensional check	X	X	X	100 %
Visual examination	X	X	X	100 %
Hydraulic burst test	X	X	X	1 per batch
Ambient cycle test	X	X	X	1 per batch up to 1 per 5 batches
Key X = Test required N/A = Test not required				

5.3 Requirements at Pre-fill inspection

The inspections specified in ISO 24431 at the time of filling the cylinder are summarized in [Table 5](#).

Table 5 — Pre-fill inspection checks (ISO 24431)

Inspections	Description	Sampling
External condition	Visual inspection for external corrosion of some metallic liners (Type 2) or metallic end bosses	100 %
	Visual inspection of composite cylinders for damage: — Abrasion damage — Damage from cuts — Impact damage — Delamination — Heat or fire damage — Chemical attack	100 %
Neck inspection	Types 3 and 4 cylinders to be inspected for deformation & damage	100 %
Internal condition	A visual internal inspection of the cylinder to be performed if liquid is detected or whenever the valve is removed.	when applicable

Table 5 (continued)

Inspections	Description	Sampling
Cylinder tare	The validity of the tare to be verified for cylinders which are required by regulation to be filled by weight.	100 % for cylinders to be filled by weight
Cylinders fitted with coverings	Visual inspection	100 %
Verification of gas tightness	For Type 4 composite cylinders, the filler ensures that the cylinder is free from leaks at the boss-composite interface and around the dome of the cylinder	100 %

5.4 Requirements at Periodic inspection and testing

The inspections and tests specified in ISO 11623 at the time of periodic inspection and testing are summarized in [Table 6](#).

Table 6 — Periodic Inspection and testing (ISO 11623)

Inspections and tests	Description	Sampling
External visual inspection	The external surface to be inspected for damage to the composite overwrap.	100 %
Internal visual inspection	The whole of the internal surface of each cylinder to be inspected using an adequate technique and illumination to identify imperfections present.	100 %
Pressure test	Each cylinder to be proof pressure tested using a suitable fluid, normally water, as the test medium at its test (design) pressure.	100 %
Leak test	Leak test to be performed when indicated by the nature of the imperfections found during the internal inspection.	when applicable

6 Significance of cylinder test on their performance

The UN Model Regulations in 6.2.2.1.1 to 6.2.2.1.2 have requirements to demonstrate that composite cylinders remain safe to the end of their design life. The concept of “remain safe” relates to the potential degradation of the structure of the cylinder.

The main potential causes of composite cylinder degradation are:

- materials ageing;
- structural damage (e.g., fire, mechanical impacts, corrosion chemical attack).

For each of the potential causes listed above, their impact on cylinder’s performance can be measured by one or more of the descriptors listed below:

- reduction in burst pressure to test pressure ratio;
- reduction in the number of ambient pressure cycles to failure;
- liner collapse /blistering (Type 4 only);
- leak (i.e. escape of gas or liquid).

For each of the potential degradation effects the current tests and inspections prescribed in ISO standards (see [Clause 5](#) of this document) were considered to determine whether cylinder degradation could be detected (see [Table 7](#)).