INTERNATIONAL STANDARD

ISO 11439

Second edition
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Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles

Bouteilles à gaz — Bouteilles haute pression pour le stockage de gaz naturel utilisé comme carburant à bord des véhicules automobiles

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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.

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 11439 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition cancels and replaces the first edition (ISO 11439:2000), which has been technically revised. In addition to editorial improvements, the principal technical difference between the first and second editions is the clarification and alteration of the "Change of Design" requirements for the various cylinder types.

Introduction

Cylinders for the on-board storage of fuel for natural gas vehicle service are required to be light-weight, at the same time maintaining or improving on the level of safety currently existing for other pressure vessels.

Owners or users of cylinders designed to this International Standard should note that the cylinders are designed to operate safely if used in accordance with specified service conditions for a specified finite service life only. The expiry date is marked on each cylinder and it is the responsibility of owners and users to ensure that cylinders are not used after that date, and that they are inspected in accordance with the manufacturer's instructions.

Users of this International Standard are encouraged to consider the environmental impacts associated with performing certain tests.

Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles

1 Scope

This International Standard specifies minimum requirements for light-weight refillable gas cylinders intended only for the on-board storage of high pressure compressed natural gas as a fuel for automotive vehicles to which the cylinders are to be fixed. The service conditions do not cover external loadings that can arise from vehicle collisions, etc.

This International Standard covers cylinders of any seamless steel, seamless aluminium alloy or non-metallic material construction, using any design or method of manufacture suitable for the specified service conditions. This International Standard does not cover cylinders of stainless steel. Although this standard uses 200 bar as a reference working pressure, other working pressures can be used.

Cylinders covered by this International Standard are designated Type 1, Type 2, Type 3 and Type 4.

2 Normative references

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

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7866, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

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

ISO 9809-1, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

ISO 9809-2, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

ISO 9809-3, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*

ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*

ISO 15403-1, *Natural gas — Natural gas for use as a compressed fuel for vehicles — Part 1: Designation of the quality*

ISO/TR 15403-2, *Natural gas — Natural gas for use as a compressed fuel for vehicles — Part 2: Specification of the quality*

ISO 15500-13, *Road vehicles — Compressed natural gas (CNG) fuel system components — Part 13: Pressure relief device (PRD)*

ASTM D522-93a, *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*

ASTM D1308-87, *Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes*

ASTM D2794-93, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*

ASTM D3170-87, *Standard Test Method for Chipping Resistance of Coatings*

ASTM D3359, *Standard Test Methods for Measuring Adhesion by Tape Test*

ASTM D3418, *Standard Test Method for Transition Temperatures of Polymers by Differential Scanning Calorimetry*

ASTM G154:2006[1)], *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*

NACE/TM 0177-96, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
authorized inspection body
authorized inspection body, approved or recognized by the regulatory authority of the user country, for the supervision of construction and testing of cylinders used for the on-board storage of natural gas

3.2
autofrettage
pressure application procedure used in manufacturing composite cylinders with metal liners, which strains the liner past its yield point sufficient to cause permanent plastic deformation

3.3
autofrettage pressure
pressure within the overwrapped cylinder at which the required distribution of stresses between the liner and the overwrap is established

3.4
batch – composite cylinders
group of not more than 200 cylinders plus cylinders for destructive testing, or if greater, one shift of successive production of cylinders, successively produced from qualified liners having the same size, design, specified materials of construction and process of manufacture

3.5
batch – metal cylinders/liners
group of not more than 200 cylinders/liners plus cylinders/liners for destructive testing, or if greater, one shift of successive production of metal cylinders/liners, successively produced having the same nominal diameter, wall thickness, design, specified material of construction, material cast, process of manufacture, equipment for manufacture and heat treatment, and conditions of time, temperature and atmosphere during heat treatment

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1) Most recent version is ASTM G154-12a, 2012.

3.6
batch – non-metallic liners
group of not more than 200 liners plus liners for destructive testing, or if greater, one shift of successive production of non-metallic liners, successively produced having the same nominal diameter, wall thickness, design, specified material of construction and process of manufacture

3.7
burst pressure
highest pressure reached in a cylinder during a burst test

3.8
composite cylinder
cylinder made of resin-impregnated continuous filament wound over a metallic or non-metallic liner

3.9
destroyed
cylinder in a state of alteration which makes it physically unusable for its purpose

3.10
finished cylinders
completed cylinders which are ready for use, complete with identification marks and external coating including integral insulation and/or protection as specified by the manufacturer on the design drawing for the cylinder

3.11
liner
inner portion of the composite cylinder, comprising of a metallic or non-metallic vessel

3.12
manufacturer
person or organization responsible for the design, fabrication and testing of the cylinders

3.13
overwrap
reinforcement system of filament and resin applied over the liner

3.14
pre-stress
process of applying autofrettage or controlled tension winding

3.15
service life
life, in years, during which the cylinders can be used in accordance with the standard service conditions

3.16
settled pressure
gas pressure when a given settled temperature is reached

3.17
settled temperature
uniform gas temperature in the cylinder after the dissipation of any heat caused by filling

3.18
test pressure
required pressure applied during a pressure test

3.19
type 1 design
an all metal cylinder

3.20
type 2 design
a hoop wrapped cylinder with a load sharing metal liner and composite reinforcement on the cylindrical part only

3.21
type 3 design
a fully wrapped cylinder with a load sharing metal liner and composite reinforcement on both the cylindrical part and dome ends

3.22
type 4 design
a fully wrapped cylinder with a non-load sharing liner and composite reinforcement on both the cylindrical part and dome ends

3.23
working pressure
settled pressure of a fully filled cylinder at a uniform temperature of 15 °C

4 Service conditions

4.1 General

4.1.1 Standard service conditions

The standard service conditions specified in this clause are provided as the basis for the design, manufacture, inspection, testing and approval of cylinders that are to be mounted permanently on vehicles and used to store natural gas at ambient temperatures for use as a fuel on the vehicles.

4.1.2 Service life

The service life for which cylinders are safe shall be specified by the cylinder manufacturer on the basis of use under service conditions specified herein. The maximum service life shall be 20 years.

4.2 Maximum pressures

This International Standard is based upon a working pressure of 200 bar settled at 15 °C for natural gas as a fuel with a maximum filling pressure of 260 bar. Other working pressures may be accommodated by adjusting the pressure by the appropriate factor (ratio); e.g. a 240 bar working pressure system will require pressures to be multiplied by 1,20. See also Annex E.

Except where pressures have been adjusted in this way, the cylinder shall be designed to be suitable for:

a) a pressure of 200 bar at a settled temperature of 15 °C;

b) a maximum pressure shall not exceed 260 bar, regardless of filling conditions or temperature.

4.3 Design number of filling cycles

Cylinders shall be designed to be filled up to 1 000 times per year of service.

4.4 Temperature range

4.4.1 Settled gas temperature

Settled temperature of gas in cylinders, which may vary from a minimum of –40 °C to a maximum of +65 °C.

4.4.2 Cylinder temperatures

Cylinders shall be designed for service conditions involving temperatures of between –40 °C and +82 °C. Cylinder material temperatures over +65 °C are expected to be sufficiently local, or of short enough duration, that the temperature of gas in the cylinder never exceeds +65 °C, except under the conditions of 4.4.3.

4.4.3 Transient temperatures

Developed gas temperatures in the cylinders during filling and discharge may vary beyond the limits of 4.4.1.

4.5 Gas composition

4.5.1 General

Cylinders shall be designed to tolerate being filled with natural gas meeting the specification of ISO 15403-1 and ISO/TR 15403-2, and either of dry gas or wet gas as described in 4.5.2 or 4.5.3, respectively. Methanol and/or glycol shall not be deliberately added to the natural gas.

NOTE Where it is suspected that wet-gas conditions may exist, it has been found that a minimum of 1 mg of compressor oil per kg of gas has prevented the corrosion of steel cylinders.

4.5.2 Dry gas

Water vapour shall be limited to less than 32 mg/m^3 (i.e. a pressure dewpoint of –9 °C at 200 bar). Constituent maximum limits shall be:

Hydrogen sulfide and other soluble sulfides	23 mg/m^3
Oxygen	1 % (volume fraction)
Hydrogen, when cylinders are manufactured from a steel with an ultimate tensile strength exceeding 950 MPa	2 % (volume fraction)

4.5.3 Wet gas

For gas that has a higher water content than that of dry gas, constituent limits shall be:

Hydrogen sulfide and other soluble sulfides	23 mg/m^3 maximum
Oxygen	1 % (volume fraction) maximum
Carbon dioxide	3 % (volume fraction) maximum
Hydrogen	0,1 % (volume fraction) maximum
Compressor oil	1 mg/kg natural gas minimum (see Note 4.5.1)

4.6 External surfaces

It is not necessary for cylinders to be designed for continuous exposure to mechanical or chemical attack (e.g. leakage from cargo that may be carried on vehicles or severe abrasion damage from road conditions). However, cylinder external surfaces shall be designed to withstand inadvertent exposure to mechanical or chemical attack consistent with their installation being carried out in accordance with the instructions to be provided with the cylinder.

Mechanical or chemical attack may result from environments such as:

a) water, either by intermittent immersion or road spray;

b) salt, due to the operation of the vehicle near the ocean or where ice-melting salt is used;

c) ultraviolet radiation from sunlight;

d) impact of gravel;

e) solvents, acids and alkalis, fertilizers;

f) automotive fluids, including petrol, hydraulic fluids, battery acid, glycol and oils;

g) exhaust gases.

5 Inspection and testing

Evaluation of conformity can be carried out in accordance with the relevant regulations recognized by the country(ies) where the cylinders are intended to be used.

To ensure that cylinders are in conformance to this International Standard, they shall be subject to inspection and testing in accordance with Clauses 7, 8, 9, or 10 and Annex A as appropriate to the construction. This shall be carried out by an authorized inspection body, hereafter referred to as "the Inspector", recognized in the countries of use. The Inspector shall be competent for inspection of cylinders.

6 Type approval procedure

6.1 General

Type approval consists of two parts:

a) design approval, comprising submission of information by the manufacturer to the Inspector, as detailed in 6.3.

b) prototype testing, comprising testing carried out under the supervision of the Inspector. The cylinder material, design, manufacture and examination shall be proved to be adequate for their intended service by meeting the requirements of the prototype tests specified in 7.5, 8.5, 9.5 or 10.5, and Annex A, as appropriate for the particular cylinder design.

The test data shall also document the dimensions, wall thicknesses and weights of each of the test cylinders.

6.2 Type approval

Cylinder designs shall be approved by the Inspector. Information shall be submitted by the manufacturer with a request to the Inspector for approval, and shall include:

a) statement of service, in accordance with 6.3;

b) design data, in accordance with 6.4;

c) manufacturing data, in accordance with 6.5;

d) fracture performance and NDE defect size, in accordance with 6.6;

e) specification sheet, in accordance with 6.7;

f) additional supporting data, in accordance with 6.8.

6.3 Statement of service

The purpose of the statement of service is to guide users and installers of cylinders as well as to inform the Inspector. The statement of service shall include:

a) a statement that the cylinder design is suitable for use in the service conditions defined in Clause 4 for the service life of the cylinder;

b) a statement of the service life;

c) the minimum periodic inspection requirements;

d) a specification for the pressure relief devices, and insulation if provided;

e) a specification for the support methods, protective coatings and any other items required but not provided;

f) a description of the cylinder design;

g) any other information and instructions necessary to ensure the safe use and inspection of the cylinder.

6.4 Design data

6.4.1 Drawings

Drawings shall include, as a minimum:

a) title, manufacturer, reference number, date of issue, and revision numbers with dates of issue if applicable;

b) reference to this International Standard and the cylinder type;

c) all cylinder dimensions complete with tolerances, including details of end closure shapes, openings, and neck threads;

d) water capacity and mass (including any permanent attachments), complete with tolerance, of cylinders;

e) material specifications, mechanical properties (including tolerances where applicable) and, for metal cylinders or metal liners, the specified hardness range;

f) other data such as, working pressure, autofrettage pressure, test pressure, minimum design burst pressure, design life;

g) details of the fire protection system and of any exterior protective coating.

6.4.2 Stress analysis report

A finite element stress analysis or other stress analysis shall be carried out. A table summarizing the calculated stresses shall be provided.

6.4.3 Material property data

A description of the materials and tolerances of the material properties used in the design shall be provided. Test data shall also be presented characterizing the mechanical properties and the suitability of the materials for service under the conditions specified in Clause 4.

6.4.4 Fire protection

The arrangement of pressure relief devices, and insulation if provided, that will protect the cylinder from sudden rupture when exposed to the fire conditions in A.15 shall be specified. Test data shall substantiate the effectiveness of the specified fire protection system.

NOTE A manufacturer may specify alternative PRD locations for specific vehicle installations.

6.5 Manufacturing data

Details of fabrication processes, non-destructive examinations, production tests and batch tests shall be provided. Production processes such as heat treatment, end forming, resin-mix ratio, filament tension and speed for controlled tension winding, curing times and temperatures, and autofrettage procedures shall be specified.

Surface finish, thread details, acceptance criteria for ultrasonic examination (or equivalent), and maximum lot sizes for batch tests shall also be specified.

6.6 Fracture performance and non-destructive examination (NDE) defect size

The manufacturer shall specify the maximum defect size for non-destructive examination that will ensure leak before break (LBB) fracture performance, and will prevent failure by leakage or rupture of the cylinder during its service life. The maximum defect size shall be established by a method suitable to the design.

NOTE An example of a suitable method is given in Annex C.

6.7 Specification sheet

A summary of the documents providing the information required in 6.2 shall be listed on a specification sheet for each cylinder design. The title, reference number, revision numbers and dates of original issue and version issues of each document shall be given. All documents shall be signed or initialled by the issuer.

6.8 Additional supporting data

Additional data that would support the application may be provided.

6.9 Type approval certificate

If the results of the type approval according to 6.1 and the prototype testing according to 7.5, 8.5, 9.5 or 10.5, and Annex A, as appropriate to the particular cylinder design, are satisfactory, the Inspector shall issue a test type approval certificate.

NOTE An example of a type approval certificate is given in Annex D.

7 Requirements for type 1 metal cylinders

7.1 General

This International Standard does not provide design formulae, nor list permissible stresses or strains, but requires the adequacy of the design to be established by appropriate calculations and demonstrated by testing to show that cylinders shall pass the materials, design qualification, production and batch tests specified.

The design shall ensure a “leak-before-break” failure mode during normal service.