INTERNATIONAL STANDARD

ISO 11439

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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

Annexes A and B form a normative part of this International Standard. Annexes C to H are for information only.

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. These requirements are achieved by:

a) specifying service conditions precisely and comprehensively as a firm basis for both cylinder design and use;

b) using an appropriate method to assess cyclic pressure fatigue life and to establish allowable defect sizes in metal cylinders or liners;

c) requiring design qualification tests;

d) requiring non-destructive testing and inspection of all production cylinders;

e) requiring destructive tests on cylinders and cylinder material taken from each batch of cylinders produced;

f) requiring manufacturers to have a comprehensive quality system documented and implemented;

g) requiring periodic re-inspection and, if necessary, retesting in accordance with the manufacturer's instructions;

h) requiring manufacturers to specify as part of their design, the safe service life of their cylinders.

Cylinder designs that meet the requirements of this International Standard:

a) will have a fatigue life which exceeds the specified service life;

b) when pressure cycled to failure, will leak but not rupture;

c) when subject to hydrostatic burst tests, will have factors of "stress at burst pressure" over "stress at working pressure" that exceed the values specified for the type of design and the materials used.

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.

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 serially produced 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 which may arise from vehicle collisions, etc.

This International Standard covers cylinders of any steel, aluminium 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 or of welded construction.

Cylinders covered by this International Standard are designated as follows:

CNG-1 Metal

CNG-2 Metal liner reinforced with resin impregnated continuous filament (hoop wrapped)

CNG-3 Metal liner reinforced with resin impregnated continuous filament (fully wrapped)

CNG-4 Resin impregnated continuous filament with a non-metallic liner (all composite)

NOTE Cylinders designed in accordance with ISO 9809-1, ISO 9809-2, ISO 9809-3 and ISO 7866 can be used for this service provided these designs meet additional requirements as specified in this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983, *Steel — Charpy impact test (V-notch)*.

ISO 306:1994, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*.

ISO 527-2:1993, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics (incorporating Technical Corrigendum 1:1994)*.

ISO 2808:1997, *Paints and varnishes — Determination of film thickness*.

ISO 4624:—[1], *Paints and varnishes — Pull-off test for adhesion*.

ISO 6506-1:1999, *Metallic materials — Brinell hardness test — Part 1: Test method*.

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature*.

ISO 7225, *Gas cylinders — Precautionary labels*.

ISO 7866:1999, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*.

ISO 9227:1990, *Corrosion tests in artificial atmospheres — Salt spray tests*.

ISO 9712:1999, *Non-destructive testing — Qualification and certification of personnel*.

ISO 9809-1:1999, *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 9809-2:2000, *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:—[2], *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*.

ISO 14130:1997, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*.

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

ASTM D1308-87(1998), *Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes*.

ASTM D2794-93(1999)e1, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*.

ASTM D3170-87(1996)e1, *Standard Test Method for Chipping Resistance of Coatings*.

ASTM D3418-99, *Standard Test Method for Transition Temperatures of Polymers by Differential Scanning Calorimetry*.

ASTM G53-93[3], *Standard Practice for Operating Light and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials*.

NACE TM0177-96[4], *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments*.

3 Terms and definitions

For the purposes of this International Standard the following terms and definitions shall apply:

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1) To be published. (Revision of ISO 4624:1978)

2) To be published

3) To be discontinued in 2000 and replaced by G154.

4) NACE standards are available from NACE International, PO Box 218340, Houston, Texas 77218-8340, U.S.A.

3.1
authorized inspection authority
competent inspection authority, approved or recognized by the regulatory authority of the user country, for the supervision of construction and testing of cylinders

3.2
auto-frettage
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

NOTE This results in the liner having compressive stresses and the fibres having tensile stresses at zero internal pressure.

3.3
auto-frettage pressure
pressure within the over-wrapped cylinder at which the required distribution of stresses between the liner and the over-wrap 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
〈of 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, process of manufacture, equipment for manufacture and heat treatment, and conditions of time, temperature and atmosphere during heat treatment

3.6
batch
〈of 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

NOTE Composite cylinders using non-metallic liners are referred to as all-composite cylinders.

3.9
controlled tension winding
process used in manufacturing hoop-wrapped composite cylinders with metal liners by which compressive stresses in the liner and tensile stresses in the over-wrap at zero internal pressure are obtained by winding the reinforcing filaments under significant high tension

3.10
filling pressure
pressure to which a cylinder is filled

3.11
finished cylinders
completed cylinders which are ready for use, typical of normal production, complete with identification marks and external coating including integral insulation specified by the manufacturer, but free from non-integral insulation or protection

3.12
fully-wrapped cylinder
cylinder with an over-wrap having a filament-wound reinforcement both in the circumferential and axial direction of the cylinder

3.13
gas temperature
temperature of gas in a cylinder

3.14
hoop-wrapped cylinder
cylinder with an over-wrap having a filament-wound reinforcement in a substantially circumferential pattern over the cylindrical portion of the liner so that the filament does not carry any significant load in a direction parallel to the cylinder longitudinal axis

3.15
liner
container that is used as a gas-tight, inner shell, on which reinforcing fibres are filament-wound to reach the necessary strength

NOTE Two types of liner are described in this International Standard – metallic liners that are designed to share the load with the reinforcement, and non-metallic liners that do not carry any part of the load.

3.16
manufacturer
person or organization responsible for the design, fabrication and testing of the cylinders

3.18
over-wrap
reinforcement system of filament and resin applied over the liner

3.19
prestress
process of applying auto-frettage or controlled tension winding

3.20
service life
life, in years, during which the cylinders may safely be used in accordance with the standard service conditions

3.21
settled pressure
gas pressure when a given settled temperature is reached

3.22
settled temperature
uniform gas temperature after the dissipation of any change in temperature caused by filling

3.23
test pressure
required pressure applied during a pressure test

3.24
working pressure
settled pressure of 200 bar 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 Use of cylinders

The service conditions specified are also intended to provide information on how cylinders manufactured in accordance with this International Standard may safely be used; this information is intended for

a) manufacturers of cylinders;

b) owners of cylinders;

c) designers or contractors responsible for the installation of cylinders;

d) designers or owners of equipment used to refuel vehicle cylinders;

e) suppliers of natural gas;

f) regulatory authorities who have jurisdiction over cylinder use.

4.1.3 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.

For metal and metal-lined cylinders, the service life shall be based upon the rate of fatigue crack growth. The ultrasonic inspection, or equivalent, of each cylinder or liner shall ensure the absence of flaws which exceed the maximum allowable size. This approach permits the optimized design and manufacture of light weight cylinders for natural gas vehicle service.

For all-composite cylinders with non-metallic non-load bearing liners the service life shall be demonstrated by appropriate design methods, design qualification testing and manufacturing controls.

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 250 bar working pressure system will require pressures to be multiplied by 1,25.

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

a) a pressure that would settle to 200 bar at a settled temperature of 15 °C;

b) the maximum 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 a settled pressure of 200 bar at a settled gas temperature of 15 °C for up to 1 000 times per year of service.

4.4 Temperature range

4.4.1 Gas temperature

Cylinders shall be designed to be suitable for the following gas temperature limits:

a) the settled temperature of gas in cylinders, which may vary from a low of – 40 °C to a high of + 65 °C.

b) the developed gas temperatures during filling and discharge, which may vary beyond these limits.

4.4.2 Cylinder temperatures

Cylinders shall be designed to be suitable for the following material temperature limits:

a) the temperature of the cylinder materials may vary from – 40 °C to + 82 °C.

b) temperatures over + 65 °C shall 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 4.4.1 b).

4.5 Gas composition

4.5.1 General

Cylinders shall be designed to tolerate being filled with natural gas meeting the specification either of dry gas or wet gas as follows. Methanol and/or glycol shall not be deliberately added to the natural gas.

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

This is gas that has a higher water content than that of dry gas.

Constituent maximum limits shall be:

Hydrogen sulfide and other soluble sulfides	23 mg/m^3
Oxygen	1 % (volume fraction)

Carbon dioxide	4 % (volume fraction)
Hydrogen	0,1 % (volume fraction)

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 the following, consistent with installation being carried out in accordance with the instructions to be provided with the cylinder:

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) ultra-violet 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 Approval and certification

5.1 Inspection and testing

Evaluation of conformity is required to be performed in accordance with the relevant regulations of the country(ies) where the cylinders are used.

In order to ensure that the cylinders are in compliance with this International Standard they shall be subject to design approval in accordance with 5.2, and inspection and testing in accordance with either clause 6, 7, 8 or 9 as appropriate to the construction. This shall be carried out by an authorized inspection authority (hereafter referred to as “the Inspector”) recognized in the countries of use. The Inspector shall be competent for inspection of cylinders.

Test procedures are detailed in annex A and annex B. An example of acceptable approval and certification procedures is included in annex C.

5.2 Type approval procedure

5.2.1 General

Type approval consists of 2 parts:

a) design approval, comprising submission of information by the manufacturer to the Inspector, as detailed in 5.2.2.

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 6.5, 7.5, 8.5 or 9.5, 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.

5.2.2 Design approval

Cylinder designs shall be approved by the Inspector. The following information shall be submitted by the manufacturer with a request to the Inspector for approval:

a) statement of service, in accordance with 5.2.3;

b) design data, in accordance with 5.2.4;

c) manufacturing data, in accordance with 5.2.5;

d) quality system, in accordance with 5.2.6;

e) fracture performance and NDE defect size, in accordance with 5.2.7;

f) specification sheet, in accordance with 5.2.8;

g) additional supporting data, in accordance with 5.2.9.

5.2.3 Statement of service

The purpose of this 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) a specification for the minimum in-service test and/or 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.

5.2.4 Design data

5.2.4.1 Drawings

Drawings shall show at least the following:

a) title, 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 dimensions complete with tolerances, including details of end closure shapes with minimum thicknesses and of openings;

d) mass, complete with tolerance, of cylinders;

e) material specifications, complete with minimum mechanical and chemical properties or tolerance ranges and, for metal cylinders or metal liners, the specified hardness range;

f) other data such as, autofrettage pressure range, minimum test pressure, details of the fire protection system and of any exterior protective coating.

5.2.4.2 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.

5.2.4.3 Material property data

A detailed 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.

5.2.4.4 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.

5.2.5 Manufacturing data

Details of all fabrication processes, non-destructive examinations, production tests and batch tests shall be provided.

The tolerances for all production processes such as heat treatment, end forming, resin-mix ratio, filament tension and speed for controlled tension winding, curing times and temperatures, and auto-frettage procedures shall be specified.

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

5.2.6 Quality control programmme

The manufacturer shall specify methods and procedures in accordance with a quality assurance system acceptable to the Inspector and that will comply with any relevant regulations of the country(ies) where the cylinders are to be used.

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

The manufacturer shall specify the maximum defect size for non-destructive examination which will ensure leak before break (LBB) fracture performance and will prevent failure of the cylinder during its service life due to fatigue, or failure of the cylinder by rupture.

The maximum defect size shall be established by a method suitable to the design, an example of a suitable method is given in annex D.

5.2.8 Specification sheet

A summary of the documents providing the information required in 5.2.2 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.