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Gaseous hydrogen and hydrogen blends — Land vehicule fuel tanks —

Part 4:
Particular requirements for fully wrapped composite tanks with metal liner (Type 3)

Hydrogène gazeux et mélanges d'hydrogène gazeux — Réservoirs de carburant pour véhicules terrestres —

Partie 4: Exigences particulières pour les réservoirs composites entièrement bobinés avec liner métallique (Type 3)

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Member bodies are reminded to consult relevant national interests in each of the technical fields concerned [*Hidrogen technologies* (ISO/TC 197), *Gas cylinder* (ISO/TC 58/SC 3) and *Road vehicles* (ISO/TC 22) and before returning their ballot to the Central Secretariat.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

In accordance with the provisions of Council Resolution 15/1993 this document is circulated in the English language only.

Conformément aux dispositions de la Résolution du Conseil 15/1993, ce document est distribué en version anglaise seulement.

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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.

International Standard ISO 15869-4 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*, and Technical Committee ISO/TC 58 Subcommittee SC 3, *Gas cylinder design*.

This is the first edition.

ISO 15869 consists of the following parts, under the general title *Gaseous hydrogen and hydrogen blends — Land vehicle fuel tanks*:

— *Part 1: General requirements*

— *Part 2: Particular requirements for metal tanks (type 1)*

— *Part 3: Particular requirements for hoop wrapped composite tanks with a metal liner (type 2)*

— *Part 4: Particular requirements for fully wrapped composite tanks with a metal liner (type 3)*

— *Part 5: Particular requirements for fully wrapped composite tanks with a non metallic liner (type 4)*

Gaseous hydrogen and hydrogen blends — Land vehicule fuel tanks —

Part 4:
Particular requirements for fully wrapped composite tanks with metal liner (Type 3)

1 Scope

This part of ISO 15869 defines the specific aspects of fully wrapped composite fuel tanks with a metal liner used for the on-board storage of high pressure compressed gaseous hydrogen or hydrogen blends. It modifies or supplements the common aspects that are defined in ISO 15869-1.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 15869. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15869 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 7866:1999, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

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 15869-1: *Gaseous hydrogen and hydrogen blends — Land vehicle fuel tanks — Part 1: General requirements*

3 Terms and definitions

For the purposes of this part of ISO 15869, the terms and definitions given in ISO 15869-1 apply.

4 General requirements

Tanks conforming to this part of ISO 15869 shall meet the general requirements specified in ISO 15869-1. Should there be a conflict between this part of ISO 15869 and ISO 15869-1, the requirements specified in this part of ISO 15869 shall prevail.

5 Materials

5.1 General

Materials used shall be suitable for the service conditions specified in ISO 15869-1, clause 4. The design shall not have incompatible materials in contact.

5.2 Steel

Steels shall conform to the materials requirements of clauses 6.1 to 6.4 of ISO 9809-1:1999, or clauses 6.1 to 6.3 of ISO 9809-2;2000 as appropriate.

5.3 Aluminium

Aluminium alloys shall conform to the materials requirements of ISO 7866:1999, clauses 6.1 and 6.2. Other aluminium alloys may be used provided that hydrogen compatibility is demonstrated as per 8.1.2.

5.4 Resins

The material for impregnation may be thermosetting or thermoplastic resins. Examples of suitable matrix materials are epoxy, modified epoxy, polyester and vinylester thermosetting plastics, as well as polyethylene and polyamide thermoplastic material.

5.5 Fibres

Structural reinforcing filament material types shall be glass fibre, aramid fibre or carbon fibre. If carbon fibre reinforcement is used, the design shall incorporate means to prevent galvanic corrosion of metallic components of the tank.

The tank manufacturer shall keep on file for the intended life of the tank design the published specifications for composite materials, the material manufacturer's recommendations for storage, conditions and shelf life. The tank manufacturer shall keep on file, for the intended life of each batch of tanks, the fibre manufacturer's certification that the fibre material properties of each shipment conform to the manufacturer's specifications for the product.

6 Design requirements

6.1 General

The design shall ensure a «leakage before break» failure mode under feasible degradation of pressure parts during normal service. If leakage of the metal liner occurs, it shall be only by the growth of a fatigue crack.

NOTE This part of ISO 15869 does not provide design formulas nor permissible stresses or strains, but requires the adequacy of the design to be established by appropriate calculations and demonstrated by tanks being capable of consistently passing the materials, prototype and batch tests as well as the tests on every tank specified in this part of ISO 15869. During pressurization, this type of tank design has a behaviour in which the displacements of the composite overwrap and the metal liner are linearly superimposed. Due to different techniques of manufacture, this part of ISO 15869 does not give a definite method for design.

6.2 Test pressure

The minimum test pressure used in manufacture shall be 1,5 times working pressure.

6.3 Burst pressure and fibre stress ratio

The minimum actual burst pressure shall not be less than the values given in Table 1. The composite overwrap shall be designed for high reliability under sustained loading and cyclic loading. This reliability shall be achieved by meeting or exceeding the composite reinforcement stress ratio values given in Table 1.

The stress ratio calculations shall include:

a) an analysis method with capability for non-linear materials (special purpose computer program or finite element analysis program);

b) correct modelling of the elastic-plastic stress-strain curve for liner material;

c) correct modelling of the mechanical properties of the composite;

d) calculations at autofrettage pressure, zero pressure after autofrettage, working pressure, and minimum burst pressure;

e) account for the prestresses from winding tension;

f) the minimum burst pressure, chosen such that the calculated stress at minimum burst pressure divided by the calculated stress at working pressure meets the stress ratio requirements for the fibre used;

g) when analyzing tanks with hybrid reinforcement (two or more different fibres), consideration of the load share between the different fibres based on the different elastic modulii of the fibres. The stress ratio requirements for each individual fibre type shall be in accordance with the values given in Table 1.

Verification of the stress ratios may also be performed using strain gauges. An acceptable method is outlined in ISO 15869-1, Annex A.

Table 1 — Minimum actual burst pressure and stress ratios

Fibre type	Stress ratio	Burst pressure
Glass	3,65	3,5 times working pressure[a]
Aramid	3,10	3 times working pressure
Carbon	2,35	2,35 times working pressure
Hybrid		[b]

[a] Minimum actual burst pressure. In addition, calculations shall be performed in accordance with 6.3 to confirm that the minimum stress ratio requirements are also met.

[b] Stress ratios and burst pressures shall be calculated in accordance with 6.3g).

6.4 Stress analysis

A stress analysis shall be performed to justify the minimum design wall thickness. It shall include the determination of the stresses in liners and fibres of composite designs.

The stresses in the composite and in the liner after prestress shall be calculated in the tangential and longitudinal direction of the tank at zero pressure, working pressure, test pressure and design burst pressure. The calculations shall use suitable analysis taking account of non-linear material behaviour of the liner to establish stress distributions.

The limits within which the autofrettage pressure shall fall shall be calculated.

6.5 Maximum defect size

The tank manufacturer shall specify the maximum defect size at any location in the metal liner.

The allowable defect size for NDE shall be determined by an appropriate method, e.g. as per ISO 15869-1, Annex B. This method shall demonstrate that a tank with defects of the specified maximum defect size will meet the ambient pressure cycling requirements of 8.1.4.

6.6 Fire protection

The tank, its materials, pressure relief devices and any added insulation or protective material shall be designed collectively to ensure adequate safety during fire conditions in the test specified in 8.1.6. A manufacturer may specify alternative pressure relief device locations for specific land vehicle installations to optimize safety considerations.

7 Construction and workmanship

7.1 General

The composite tank shall be fabricated from a liner over-wrapped with continuous filament windings. Fibre winding operations shall be computer or mechanically controlled. The fibres shall be applied under controlled tension during winding. After winding is complete, thermosetting resins shall be cured by heating, using a predetermined and controlled time-temperature profile.

7.2 Liner

The compressive stress in the liner at zero pressure and the service temperature range shall not cause the liner to buckle or crease.

7.3 Neck threads

Threads shall be clean cut, even, without surface discontinuities, to gauge, and conform to international standards.

7.4 Fibre winding

The tanks shall be fabricated by a fibre winding technique. During winding the significant variables shall be monitored to demonstrate that they remain within specified tolerances. The results shall be documented in a winding record that shall be retained by the tank manufacturer for the intended life of each batch of tanks. These variables can include but are not limited to:

a) fibre type including sizing;

b) manner of impregnation;

c) winding tension;

d) winding speed;

e) number of rovings;

f) band width;

g) type of resin and composition;

h) temperature of the resin;

i) temperature of the liner;

j) winding angle.

7.5 Curing of thermosetting resins

If a thermosetting resin is used, the resin shall be cured after filament winding. During the curing, the curing cycle (i.e. the time-temperature profile) shall be documented and retained by the tank manufacturer for the intended life of each batch of tanks.

The maximum curing time and temperature for tanks with aluminium alloy liners shall be below the time and temperature that adversely affect metal, resin and fibre properties.

7.6 Auto-frettage

Auto-frettage, if used, shall be carried out before the hydraulic test specified in 10 f). The auto-frettage pressure shall be within the limits established in 6.4. The tank manufacturer shall establish the method to verify that the appropriate pressure is applied. Records of auto-frettage pressure shall be retained by the tank manufacturer for the intended life of each batch of tanks.

7.7 Exterior environmental protection

The exterior of tanks shall meet the requirements of the chemical exposure test of ISO 15869-1, clause C.10. Exterior protection may be provided by using any of the following:

a) a surface finish giving adequate protection (e.g. metal sprayed on aluminium, anodizing); or

b) the use of a suitable fibre and matrix material (e.g. carbon fibre in resin); or

c) a protective coating (e.g. organic coating, paint). If exterior coating is part of the design, the requirements of ISO 15869-1, clause C.7 shall be met; or

d) a covering impervious to the chemicals of ISO 15869-1, clause C.10.

Any coatings applied to tanks shall be such that the application process does not adversely affect the mechanical properties of the tank. The coating shall be designed to facilitate subsequent in-service inspection and the manufacturer shall provide guidance on coating treatment during such inspection to ensure the continued integrity of the tank.

8 Prototype tests

8.1 Qualification testing of new designs

8.1.1 Material tests for steel liners

If the liner of the tank is made of steel, material tests as required in clauses 10.2, 10.3 and 10.4 of ISO 9809-1:1999, , or clauses 10.2, 10.3 and 10.4 of ISO 9809-2:2000 as appropriate, shall be carried out on one liner. The tensile strength and elongation shall meet the manufacturer’s design specifications.

The hydrogen compatibility of metallic materials in contact with hydrogen shall be demonstrated in accordance with ISO 15869-1, clause C.22. Steels that conform to paragraph 6.3 and 7.2.2 of ISO 9809-1:1999 are exempted from this test.

8.1.2 Material tests for aluminium alloy liners

If the liner of the tank is made of aluminium alloy, the material properties of the aluminium alloy in the finished liner shall be determined by having one liner subjected to the tests defined in ISO 7866:1999, clause 10.2 and 10.3 as well as Annexes A and B. The elongation shall meet the manufacturer’s design specification.

The hydrogen compatibility of metallic materials in contact with hydrogen shall be demonstrated in accordance with ISO 15869-1, clause C.22. Aluminium alloys that conform to paragraphs 6.1 and 6.2 of ISO 7866:1999 are exempted from this test.

8.1.3 Hydrostatic burst pressure test

Three tanks shall be hydrostatically pressurized to failure in accordance with ISO 15869-1, clause C.14. The tank burst pressure shall exceed the specified minimum burst pressure specified in Table 1, and in no case be less than the value necessary to meet the stress ratio requirements of 6.3.