TECHNICAL SPECIFICATION

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Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride

Appareils de stockage de gaz transportables — Hydrogène absorbé dans un hydrure métallique réversible

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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 16111 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

Introduction

As the utilization of gaseous hydrogen evolves from the chemical industry into a fuel for various emerging applications, the importance of new and improved storage techniques has become essential. One of these techniques employs the absorption of hydrogen into specially formulated alloys. The material can be stored and transported in a solid form, and later released and used under specific thermodynamic conditions. This Technical Specification describes the service conditions, design criteria, type tests and routine tests for these canisters.

Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride

1 Scope

This Technical Specification defines the requirements applicable to the safe design and use of transportable hydrogen gas storage canisters, including all necessary shut-off valve, pressure-relief devices (PRD), and appurtenances, intended for use with reversible metal hydride hydrogen storage systems. This Technical Specification only applies to refillable storage canisters where hydrogen is the only transferred media. Storage canisters intended to be used as fixed fuel storage onboard hydrogen fuelled vehicles are excluded.

2 Normative references

The following referenced documents are indispensable for the application 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 7225, *Gas cylinders — Precautionary labels*

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

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

ISO 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 11119-1, *Gas cylinders of composite construction — Specification and test methods — Part 1: Hoop wrapped composite gas cylinders*

ISO 11119-2, *Gas cylinders of composite construction — Specification and test methods — Part 2: Fully wrapped fibre reinforced composite gas cylinders with load-sharing metal liners*

ISO 14687, *Hydrogen fuel — Product specification*

ISO 16528 (all parts)[1)], *Boilers and pressure vessels*

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1) To be published.

3 Terms and definitions

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

3.1
absorbed
taken and held through the formation of bonding interactions within the bulk of the material

3.2
canister
single complete hydrogen storage system, including shell, metal hydride, **PRD**, shut-off valve and other appurtenances (e.g. for heat exchange, to prevent excessive stress on the shell walls due to hydride expansion, etc.)

NOTE The canister extends only to, and includes, the first shut-off valve.

3.3
design stress limit
total stress loading allowed on the shell wall, according to the standard to which the shell was designed

3.4
full flow capacity pressure
gas pressure at which the pressure relief device is fully open

3.5
hydrogen absorbing alloy
material capable of combining directly with hydrogen gas to form a reversible metal hydride

3.6
maximum developed pressure
MDP
highest gas gauge pressure for a canister at rated capacity and equilibrated at the maximum service temperature

NOTE The MDP term was specifically selected for metal hydride systems to avoid confusion with the MAWP and the service pressure used in other ISO International Standards. In metal hydride systems, the shell design takes to take into account the gas pressure plus the pressure exerted by the hydrogen absorbing alloy expansion.

3.7
metal hydride
solid material formed by reaction between hydrogen and hydrogen absorbing alloy

3.8
normal operating conditions
range of conditions such as pressure, temperature, hydrogen flow rate, hydrogen impurities, etc. that the product may be exposed to during all use and filling operations

3.9
normal service conditions
range of conditions, such as pressure, temperature, hydrogen flow rate, hydrogen impurities, etc. that the product may be exposed to during normal operating, transportation and storage conditions

3.10
pressure relief device
PRD
basic safety device used to relieve excessive pressure within the canister before damage to the canister can occur

NOTE A pressure relief device may be “pressure-activated”, set to activate at a certain pressure. Alternately, a pressure relief device may be “thermally-activated”, set to activate at a certain temperature. A pressure relief device may also be both “pressure-activated” and “thermally-activated”.

3.11
pressure relief valve
PRV
PRD that includes a valve that will open at a set pressure and reclose once the pressure drops below a set pressure

NOTE Pressure relief valves are typically spring-loaded valves.

3.12
rated capacity
stated deliverable quantity of hydrogen specified by the manufacturer

3.13
rated charging pressure
RCP
maximum pressure allowed to be applied to the product for refilling

3.14
reversible metal hydride
metal hydride for which there exists an equilibrium condition where the hydrogen absorbing alloy, hydrogen gas and the metal hydride co-exist

NOTE Changes in pressure or temperature will shift the equilibrium favouring the formation or decomposition of the metal hydride with respect to the hydrogen absorbing alloy and hydrogen gas.

3.15
rupture
structural failure of a shell resulting in the rapid and violent release of the stored energy in such a manner that it may pose a safety hazard to people or property

3.16
shell
enclosure designed to contain the hydrogen gas, metal hydride and other internal components of the canister

NOTE A shell may be a cylinder, a pressure vessel or other type of container.

3.17
stress level at MDP
sum of all the stresses on the shell wall caused by the metal hydride material at rated capacity, hydrogen gas at **MDP** and any other applicable mechanical loadings

3.18
transportable
designed to be mobile and not intended to be used in a fixed, permanent installation

4 Service conditions

4.1 Pressures

4.1.1 Maximum developed pressure (MDP)

The MDP shall be determined by the manufacturer from the metal hydride's temperature-pressure characteristics at the maximum service temperature.

4.1.2 Rated charging pressure (RCP)

The RCP shall be specified by the manufacturer in order to prevent charging at a pressure that could result in the shell wall stress exceeding the design stress limit.

4.1.3 Stress level at MDP

The stress level at MDP shall be determined by the manufacturer from the hydrogen absorbing alloy's packing and expansion properties, the MDP within the canister, and other applicable mechanical loadings.

4.1.4 PRD activation pressure

The pressure of actuation of pressure-activated PRD shall be specified by the manufacturer and shall be greater than the MDP. For pressure-relief valves (PRV), the full flow capacity pressure shall also be specified.

4.2 Rated capacity

The manufacturer shall state the rated capacity of the canister by units of mass of hydrogen.

4.3 Temperature ranges

4.3.1 Operating temperature range

The minimum and maximum temperature for normal operating conditions to which the canister is rated shall be specified by the manufacturer.

4.3.2 Service temperature range

The minimum and maximum temperature for normal service conditions to which the canister is rated shall be specified by the manufacturer. At a minimum this range shall be of at least from −40 °C to +65 °C and shall include the entire operating temperature range.

4.3.3 PRD activation temperature

The temperature at which any thermally actuated PRD is set to activate shall be specified by the manufacturer and it shall be greater than the maximum service temperature. The PRD shall have a pressure rating of greater than the MDP at all temperatures less than or equal to 10 °C above the maximum service temperature.

NOTE Exposure to higher temperatures may be expected in some geographical regions and should be considered.

4.4 Environmental conditions

The canisters are expected to be exposed to a number of environmental conditions over their service life, such as vibration and shock, varying humidity levels, and corrosive environments. The manufacturer shall specify the environmental conditions for which the canister was designed.

4.5 Service life

The service life for the canisters shall be specified by the manufacturer on the basis of use under service conditions specified herein. The service life shall not exceed that specified by the standard to which the shell is designed as per 5.1 and in no case shall exceed 20 years.

4.6 Requalification procedures

The canister may be requalified in accordance with the requirements of the standard to which the shell was originally designed, or in accordance with a method acceptable to the authority having jurisdiction.

NOTE Caution should be taken, as certain procedures (e.g. hydrostatic testing) allowed for cylinder or pressure vessel requalification may not be appropriate for metal hydride canisters. In such cases, an alternative method (e.g. ultrasonic examination) may be applicable.

If requalification is authorized, the manufacturer shall specify the minimum requalification procedures.

4.7 Hydrogen quality

The quality of the hydrogen gas that shall be used to fill a canister shall be specified by the manufacturer according to ISO 14687 or as appropriate.

NOTE If the quality of the hydrogen gas is considered a critical issue, the manufacturer may consider including the information on the product label.

4.8 Special service conditions

Any additional service conditions that shall be met for the safe operation, handling and usage of the canister shall be specified by the manufacturer.

5 Design considerations

5.1 Shell design

The canister shell shall be designed according to ISO 7866, ISO 9809-1, ISO 9809-3, ISO 11119-1, ISO 11119-2 or standards registered in accordance with ISO 16528, as applicable, or as required by the authority having jurisdiction. The shell shall not exceed 150 litres water capacity, and the MDP shall not exceed 25 MPa. The stress level at MDP, including contributors listed in 5.2, shall be less than or equal to the design stress limit allowed by the standard to which the shell is designed (e.g. the shell's maximum allowable working pressure or maximum permissible working pressure). The operating and service temperature ranges for the canister shall be less than or equal to that of the standard to which the shell is designed.

Alternatively for canisters with an internal volume of less than 0,12 litres, the shell design shall be deemed to be appropriate if the canister design meets all the other requirements of this Technical specification, successfully passes all tests specified in Clause 6 and meets the following design criteria:

a) the pressure in the canister shall not exceed 5 MPa at 55 °C when the canister is filled to its rated capacity; and

b) the canister design shall withstand, without leaking or bursting, a minimum shell burst pressure of 2 times the pressure in the canister at 55 °C when filled to rated capacity, or 200 kPa more than the pressure in the canister at 55 °C when filled to rated capacity, whichever is greater.

5.2 Design strength

The shell design shall take into account the stress level at MDP. Consideration of components contributing to the stress level at MDP shall include but not be limited to:

— the MDP;

— thermal stress, including dissimilar rates of thermal expansion and contraction;

— weight of internals in any possible canister orientation;

— shock and vibration loading;

— maximum stress due to hydrogen absorbing alloy expansion;

— other mechanical loadings.

To verify that the design stress limit is not exceeded, the canister design shall be subjected to the hydrogen cycling and strain measurement test described in 6.5.

NOTE The process of introducing and subsequently removing hydrogen in the hydrogen absorbing alloy causes it to expand and contract. In turn, this can result in large stresses inside the alloy's particles that cause them to fragment into smaller particles, a phenomenon known as decrepitation. After several charge/discharge cycles, the average particle size may have significantly decreased. Stresses on the canister walls may be derived from expansion of the hydrogen absorbing alloy during hydrogenation and from changes in the packing configuration due to decrepitation over the service life of the canister. The magnitude of the expansion/contraction phenomena will vary greatly as a function of the hydrogen absorbing alloy used.

5.3 Material selection

5.3.1 General

The canister components shall be made of materials that are suitable for the range of conditions expected during normal service conditions over the service life of the canister. Components that are in contact with gaseous hydrogen and/or metal hydride material shall be sufficiently resistant to their chemical and physical action under normal service conditions to maintain operational and pressure containment integrity.

Metal hydride material that is capable of rapid disassociation or explosion when exposed to prolonged heating shall not be used in a canister.

5.3.2 External surfaces

The canister shell, shut-off valve, PRDs and other appurtenances shall be resistant to the environmental conditions specified in 4.4. Resistance to these environmental conditions may be provided by using materials inherently resistant to the environment or by applying resistant coatings to the components. Exterior protection may be provided by using a surface finish giving adequate corrosion protection (e.g. metal sprayed on aluminium or anodizing); or a protective coating (e.g. organic coating or paint). If an exterior coating is part of the design, the coating shall be evaluated using the test methods acceptable to the authority having jurisdiction. Any coatings applied to canisters shall be such that the application process does not adversely affect the mechanical properties of the shell or performance and operation of other components. The coatings shall be designed to facilitate subsequent in-service inspection and the manufacturer shall provide guidance on coating treatment during such inspections to ensure the continued integrity of the canister.

5.3.3 Compatibility

The compatibility of canister materials with process fluids and solids, specifically embrittlement due to the exposure to hydrogen, shall be considered. Materials necessary for the pressure containment and structural integrity of the canister and its internal and external appurtenances shall be resistant to hydrogen embrittlement, hydrogen attack and reactivity with contained materials and maintain their required integrity for the service life of the canister. Recognized test methods, such as those specified in ISO 11114-4, shall be used to select metallic materials resistant to hydrogen embrittlement where required for pressure or structural integrity. Consideration shall be given to the impact that temperature may have on hydrogen embrittlement. Alternatively, materials known to be resistant to hydrogen embrittlement may be used.

If charged with gases or materials that are capable of combining chemically with each other or with the canister material, the materials shall be selected so as the combination does not endanger the canister integrity.

NOTE The susceptibility to hydrogen embrittlement of some commonly used metals is summarized in ISO/TR 15916. Additional guidance regarding hydrogen compatibility is found in Annex A.

5.3.4 Temperature

The canister materials shall be suitable for the normal service temperature range of 4.3.2.

