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Hydrogen technologies

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N615 ISO/CD 19884 Gaseous hydrogen -- Cylinders and tubes for stationary storage

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Gaseous hydrogen — Cylinders and tubes for stationary storage

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Foreword

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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 19884 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies.*

Introduction

Requirements covering pressure vessels for stationary storage of compressed gases are normally covered by applicable regulations.

This standard proposes requirements for the safe use of stationary storage of gaseous hydrogen at pressures up to 110 MPa

The principle of this standard is to utilize existing and approved design standards for transportable, fuel vehicle or stationary applications .and to determine how to adapt them for use in stationary storage service.

Gaseous hydrogen — Cylinders and tubes for stationary storage

1 Scope

This International Standard specifies the requirements for assessing cylinders, tubes, and other pressure vessels. These can be of steel, stainless steel, aluminium alloy or non-metallic construction, designed , manufactured and tested in accordance with existing and approved standards or codes for transportable , fuel vehicles or stationary applications which are intended for the stationary storage of gaseous hydrogen of up to a maximum water capacity of 10 000 L and a maximum allowable working pressure not exceeding 110 MPa. These can be of seamless metallic construction (Type 1) or of composite construction (Types 2, 3 and 4) excluding any non-seamless load sharing metallic components. Hereafter they are referred to as pressure vessels.

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This International Standard does not cover pressure vessels used for solid, liquid hydrogen or hybrid cryogenic-high pressure hydrogen storage applications.

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 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 9809-2, *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 9809-4, *Gas cylinders – Refillable seamless steel gas cylinders – Design, construction and testing – Part 4: Cylinders made of stainless steel with an Rm value of less than 1 100 MPa*

ISO 11114-1, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11114-2, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

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 11120, *Gas cylinders — Refillable seamless steel tubes for compressed gas transport, of water capacity between 150 l and 3000 l — Design construction and testing*

ISO 11439, *Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles (to verify if all the necessary requirements are addressed in this standard)*

ISO 11515, *Gas cylinders — Refillable composite reinforced tubes of water capacity between 150 L and 3000 L -- Design, construction and testing*

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

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

ISO 11119-3, *Gas cylinders of composite construction – Specifications and test methods – Part 3: Fully wrapped fibre reinforced composite gas cylinders with non-metallic and non-load-sharing metal liners*

[ISO TS 15869, *Gaseous hydrogen and hydrogen blends – Land vehicle fuel tanks]*

3 Terms and definitions

3.1
maximum allowable temperature
maximum temperature of any part of the pressure vessel for which it is intended to be used

NOTE different limits may apply for maintenance

3.2
maximum allowable working pressure (MAWP)
maximum pressure to which the pressure vessel is allowed to be subjected to

3.3
minimum allowable temperature
minimum temperature of any part of the pressure vessel for which it is intended to be used

3.4
pressure cycle
pressure variation composed of one period of monotonic pressure increase up to a peak pressure followed by one period of monotonic pressure decrease.

3.5
full cycle
cycle of a pressure amplitude as per the reference standard, e.g. between the test pressure and 10 % of the test pressure.

3.6
shallow cycle
cycle with a pressure amplitude less than that of a full cycle.

3.7
Stationary test pressure (TP)
required pressure applied during a pressure test for the pressure vessel used in stationary service l

Note: this is not to be confused with the test pressure Ph used in e.g. ISO 9809 for design purposes as transportable gas cylinder

3.8 **6**
Type 1 pressure vessel
an all metal cylindrical pressure vessel

3.9
Type 2 pressure vessel
a hoop wrapped cylindrical pressure vessel with a load sharing metal liner and composite reinforcement on the cylindrical part only

3.10
Type 3 pressure vessel
a fully wrapped cylindrical pressure vessel with a load sharing metal liner and composite reinforcement on both the cylindrical part and dome ends

3.11
Type 4 pressure vessel
a fully wrapped cylindrical pressure vessel with a non-load sharing liner and composite reinforcement on both the cylindrical part and the dome ends

4 Symbols

MAWP	maximum allowable working pressure
P_h	test pressure
PW	working pressure
n_{eq}	number of cycles equivalent to full cycles (guaranteed in a given standard)
ΔP_i	variation of pressure during a given actual pressure cycle
n_i	number of pressure cycle corresponding to ΔPi
ΔP_{max}	variation of pressure during the pressure test specified in the reference standard
F	design stress factor (ratio of equivalent wall stress at test pressure Ph ,to guaranteed minimum yield strength)

5 Requirements

5.1 General requirements

The pressure vessels covered by this standard shall be designed manufactured and tested to an existing and approved standard or code.

Note: Such cylinders and tubes are normally covered by regulation, e.g. the PED in Europe.

It is recommended to use standards for transportable gas cylinders and tubes such as the ones listed in section 2. National or regional standards can be used if it is demonstrated that they have an acceptable level of safety in the country of use.

In order to qualify a pressure vessel which has already been manufactured designed and tested to an existing and approved standard or which is intended to be manufactured as a stationary pressure vessel ,according to this standard, the requirements of clauses 5.2 to 5.8 shall be met.

5.2 Maximum allowable working pressure (MAWP)

The MAWP shall not exceed the maximum pressure authorized by the existing and approved standard or by regulation, i.e. for transportable cylinders and tubes the test pressure Ph as defined in transportable cylinder standards. If the pressure vessel is designed to ISO 11439 (fuel vehicle applications) the MAWP shall not exceed 1.3 PW (filling pressure).

5.3 Maximum allowable working temperature

The maximum temperature shall not exceed 85℃ for t ype 1, 2, 3 and 4 cylinders.

If these temperatures are intended to be exceeded, it shall be demonstrated by appropriate testing that this is safe .

Note: The maximum temperature for the valves and accessories shall also be considered.

5.4 Minimum allowable working temperature

The minimum temperature shall not be less than the ones specified in the existing and approved standards or regulations.

5.5 Stationary test pressure (TP)

Some regulations require that pressure vessels for stationary storage be tested at a pressure higher than the MAWP, e.g. PED requires at least 1.43 times the MAWP.

In addition to the regulatory requirement, when calculating the stationary test pressure it shall be checked that the following values are not exceeded :

- TP < or= 0.95X1/F times Ph (or equivalent) of the approved standard for type 1 pressure vessels (in order to avoid plastic deformation)
- TP < or= 1.15 times Ph (or equivalent) for type 4 pressure vessels,
- 95% of the autofrettage pressure for types 2 and 3.

Consequently the value of MAWP may result in a value less than the value specified in 5.2

Annex 1 gives examples of calculation of MAWP and stationary test pressure;

5.6 Gas/material compatibility

For hydrogen/material compatibility, the requirements of the reference standard (see 5.1), and the requirements of ISO 11114, parts 1,and 2 shall be followed as applicable .

ISO 11114-4 can also be used when applicable

5.7 Cycle life

Pressure vessels for stationary storage are submitted to many cycles often to shallow cycles, e.g. pressure cycle where the pressure fluctuation does not exceed 20 % of the MAWP.

To determine the cycle life of the pressure vessels for stationary storage the following procedure shall be used to verify the suitability for the intended use.

The user shall specify the predicted maximum number of pressure cycles and the corresponding amplitudes and the pressure cycles that the pressure vessel has already experienced

The following formula enables calculation of the cycle life.

$$n_{eq} = \sum n_i \left(\frac{\Delta Pi}{\Delta P_{max}} \right)^3$$

n_{eq} = number of shallow cycles equivalent to number of full cycles required in a given standard

For pressure vessels to ISO 11120 the number of full cycles shall be taken as 12 000 cycles at Ph

For other standards or codes where no pressure cycle requirements exist, cycle tests with full pressure amplitude shall be carried out

ΔP_i = variation of pressure during a given actual (shallow) pressure cycle

n_i = number of (shallow) pressure cycle corresponding to ΔPi

ΔP_{max} = pressure amplitude during the (full) cycle tests as specified in the reference standard

For some metallic materials hydrogen accelerates crack initiation and crack propagation during fatigue.

This shall be taken into account when calculating the cycle life as follows

An accelerating factors depending on the material and the MAWP shall be used.

This factor is equal to:

- [1] for aluminium alloys and for hydrogen compatible stainless steels (see 5.6)
- [5] for Cr - Mo quenched and tempered steels

For other materials this factor shall be determined by appropriate testing (to be specified at a later stage)

Note :The design life of composite cylinders is often limited by the reference standard. The shortest of the pressure cycle life and design life shall apply.

5.8 Hydraulic pressure test

If the stationary test pressure is higher than the original designed test pressure, the pressure vessels shall be subjected to a pressure test (procedure according to the existing and approved standard) at the stationary test pressure

6 Marking

6.1 Pressure vessels manufactured specifically for stationary service

They shall be marked in accordance with the applicable regulation

6.2 Pressure vessels initially used as a transportable cylinders.

Such pressure vessels shall have additional markings to comply with the applicable regulation for stationary service and they shall at least be specifically marked “ISO 19884 “ and the new MAWP to indicate that they are suitable for stationary service

7 Certificate

The certificate shall indicate

The reference of the existing standard

The new MAWP

The minimum and maximum allowable temperature

The stationary test pressure

The fatigue life calculation

The agreed markings

The certificate confirming that the hydraulic test as been performed if applicable

ANNEX 1 – EXAMPLES OF CALCULATION FOR MAWP STATIONARY TEST PRESSURE AND CYCLE LIFE

1) Type 1 cylinder to ISO 9809 with PW/Ph of 200/300 bar in Europe

TP max = 300 x 0.95 / 0.77 = 370 bar

MAWP max = 370 / 1.43 = 258 bar

2) Type 4 cylinder to ISO 9809 with PW/Ph of 200/300 bar in Europe

TP max = 300 X 1.15 = 345 bar

MAWP max = 345 / 1.43 = 241 bar

3) Type 1 cylinder to ISO 9809 with PW/Ph of 1 000/1 500 bar in Europe

TP max = 1 500 x 0.95 / 0.77 = 1 850 bar

MAWP max = 1 850 / 1.43 = 1 294 bar

4) Type 4 cylinder to ISO 9809 with PW/Ph of 1 000/1 500 bar in Europe

TP max = 1 500 X 1.15 = 1 725 bar

MAWP max = 1 725 / 1.43 = 1 206 bar

5) For example, a cylinder designed to ISO 9809-1 with PW = 700 bar and Ph = 1 050 bar, used as a stationary buffer for filling hydrogen vehicles. If we assume that this buffer is submitted to pressure cycles between 700 and 900 bar (10 000 cycles per year).

For this cylinder:

ΔP_i = 900 – 700 bar = 200 bar

ΔP_{max} = 1 050 – 5 bar = 1 045 bar

n_i = 10 000 cycles/year . For an expected life of 30 years , ni = 300 000 cycles

$$n_{eq} = 300\,000 \times \left(\frac{200}{1\,045}\right)^3 = 2070$$

Taken into account the accelerating factor [5] it comes to 10 350 cycles which is less than 12 000 cycles