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New Zealand Standard

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Standards New Zealand

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Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas
Energy Resources Aotearoa
Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
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New Zealand Standard

Transportable gas cylinders − Compatibility of cylinder and valve materials with gas contents

Part 4: Test methods for selecting steels resistant to hydrogen embrittlement

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the test methods and the evaluation of results from these tests in order to qualify steels suitable for use in the manufacture of gas cylinders (up to 3000 litres) for hydrogen and hydrogen bearing embrittling gases.

This document only applies to seamless steel gas cylinders.
The requirements of this document are not applicable if at least one of the following conditions for the intended gas service is fulfilled:

(a) The working pressure of the filled embrittling gas is less than 20% of the test pressure of the cylinder;
(b) The partial pressure of the filled embrittling gas of a gas mixture is less than 5 MPa (50 bar) in the case of hydrogen and other embrittling gases, except for hydrogen sulphide and methyl mercaptan (in such cases, the partial pressure shall not exceed 0.25 MPa [2.5 bar]).

NOTE − In such cases, it is possible to design the cylinder as for ordinary (non-embrittling) gases.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 11114-4:2017 *Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 4: Test methods for selecting steels resistant to hydrogen embrittlement*.

As this standard is reproduced from an international standard, the following applies:

(c) In the source text, 'this International Standard' should read 'this New Zealand standard';
(d) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 11114-4

Second edition
2017-04

Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents —

Part 4:
Test methods for selecting steels resistant to hydrogen embrittlement

Bouteilles à gaz transportables — Compatibilité des matériaux et des robinets avec les contenus gazeux —

Partie 4: Méthodes d'essai pour le choix des aciers résistants à la fragilisation par l'hydrogène

Reference number
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 58, *Gas cylinders*.

This second edition cancels and replaces the first edition (ISO 11114-4:2005), which has been technically revised with the following changes:

- improvement of the procedure corresponding to Method C and adjustment of acceptance criteria;
- light modifications on procedures corresponding to Method A and Method B.

A list of parts in the ISO 11114 series can be found on the ISO website.

Introduction

It is widely recognized that compressed hydrogen and some hydrogen bearing gases can have an embrittling effect on steels. This embrittling effect has resulted in the failure of hydrogen gas cylinders (including some bursts) that has led gas cylinder users and manufacturers to adopt specific measures.

The adoption of these measures has eliminated all known failures of hydrogen cylinders from this embrittlement phenomenon as far has been reported.

The basic recommendation is to limit the tensile strength of the steels (see ISO 11114-1) and eliminate manufacturing defects.

This tensile strength limit of 950 MPa was developed for quenched and tempered gas cylinders of 34 Cr Mo 4 type steels using steelmaking practices, chemistry and manufacturing techniques typical of those used during the early 1980's and successfully used for filling pressures up to 300 bar. This practice has been in widescale use up to the current time. Other higher pressures, although at lower tensile strength limits, have also been used.

In recent years, improvements in steelmaking, e.g. by reducing the sulphur and phosphorus contents, have indicated the possibility of increasing the tensile strength limit of 950 MPa for embrittling gas service. Experimental work has shown that the relevant parameters affecting hydrogen embrittlement are the following:

a) microstructure resulting from the combination of the chemistry and the heat treatment;

b) mechanical properties of the material;

c) applied stress;

d) internal surface imperfections resulting in local stress concentrations;

e) characteristics of the gas contained (composition, quality, pressure, etc.).

When developing this document, only the material aspects, a) and b) and the characteristics of the gas e) above, were considered. Other essential features, c) and d), are covered by the relevant parts of ISO 9809.

Some low alloy steels other than 34 Cr Mo 4 may require tensile strength to be lower than 950 MPa, or may be permitted to be higher than 950 MPa, to be suitable for the manufacture of gas cylinders for embrittling gas service.

This document specifies test methods to identify steels which, when combined with the cylinder manufacturing requirements specified in ISO 9809 (all parts), will result in cylinders suitable for use in embrittling gas service.

These tests have been developed following an extensive world-wide programme which incorporated laboratory and full scale tests. See also AFNOR FD E29-753.

Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents —

Part 4:
Test methods for selecting steels resistant to hydrogen embrittlement

1 Scope

This document specifies test methods and the evaluation of results from these tests in order to qualify steels suitable for use in the manufacture of gas cylinders (up to 3 000 l) for hydrogen and hydrogen bearing embrittling gases.

This document only applies to seamless steel gas cylinders.

The requirements of this document are not applicable if at least one of the following conditions for the intended gas service is fulfilled:

— the working pressure of the filled embrittling gas is less than 20 % of the test pressure of the cylinder;

— the partial pressure of the filled embrittling gas of a gas mixture is less than 5 MPa (50 bar) in the case of hydrogen and other embrittling gases, with the exception of hydrogen sulphide and methyl mercaptan; in such cases, the partial pressure shall not exceed 0,25 MPa (2,5 bar).

NOTE In such cases, it is possible to design the cylinder as for ordinary (non-embrittling) gases.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7539-1, *Corrosion of metals and alloys — Stress corrosion testing — Part 1: General guidance on testing procedures*

ISO 7539-6:2011, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of precracked specimens for tests under constant load or constant displacement*

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 11114-1:2012, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

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

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply. Some of the definitions used are based upon those in ISO 7539-1 and ISO 7539-6.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
embrittling gases
gases which can cause cracking of metal due to the combined action of stress and hydrogen atoms

Note 1 to entry: Embrittling gases are listed as groups 2 and 11 in ISO 11114-1:2012, A.4.

3.1.2
hydrogen rupture pressure
P_{H2}
maximum pressure recorded during the hydrogen rupture pressure test

3.1.3
helium rupture pressure
P_{He}
maximum pressure recorded during the helium rupture pressure test

3.1.4
hydrogen embrittlement index
maximum value of the ratio P_{He}/P_{H2} as a function of the pressure rise rate

3.1.5
environmentally-assisted cracking
synergistic effect on a metal caused by the simultaneous action of a particular environment and a nominally static tensile stress, which results in the formation of cracking

3.1.6
threshold stress
stress above which a crack will initiate and grow, for the specified test conditions

3.1.7
plane strain stress intensity factor
K_1
function of applied load, crack length and specimen geometry having dimensions of stress × $\sqrt{\text{length}}$ which uniquely define the elastic-stress field intensification at the tip of a crack subjected to opening mode displacements (mode I)

Note 1 to entry: K_1 uniquely defines the elastic stress field intensification at the tip of a crack subjected to opening mode displacements.

3.1.8
threshold stress intensity factor for susceptibility to environmentally-assisted cracking
K_{1H}
stress intensity factor above which an environmentally-assisted crack will initiate and grow, for the specified test conditions under conditions of high constraint to plastic deformation, i.e. under essentially plane strain conditions

3.2 Symbols and abbreviated terms

a	effective crack length measured from the crack tip to the loading plane
a_0	average value of a
B	specimen thickness
e_m	mean disc thickness
E	modulus of elasticity
K_IAPP	applied elastic stress-intensity factor
K_1H	threshold stress intensity factor
m	elastic displacement per unit load
P	applied load
P_r	actual rupture pressure
P_r'	corrected rupture pressure
${P_\mathrm{r}}'_\mathrm{H2}$	corrected hydrogen rupture pressure
${P_\mathrm{r}}'_\mathrm{He}$	theoretical helium rupture pressure corresponding to the same pressure rise rate as for the hydrogen test, calculated by regression from the corrected helium rupture pressure
R_m	actual value of tensile strength
V	crack-mouth opening displacement (CMOD) defined as the mode 1 (also called opening-mode) component of crack displacement due to elastic and plastic deformation, measured at the location on a crack surface that has the greatest elastic displacement per unit load, m
W	effective width of a compact specimen, measured from the back face to the loading plane
Y	stress intensity factor coefficient derived from the stress analysis for a particular specimen geometry, which relates the stress intensity factor for a given crack length to the load and specimen dimensions
HAC	hydrogen assisted cracking

4 General requirements

The test methods as described in Clause 5 are valid for all designed working pressures. The test shall be performed at room temperature at not less than the designed working pressure. All tests shall be conducted to evaluate the hydrogen embrittlement taking into account conditions that will be found in the intended application. The composition of the tested gas shall have a concentration of embrittling gas not less than the maximum concentration in the intended application. The tests shall be performed for selecting steels for hydrogen/embrittling gases and mixtures cylinders. Chromium-molybdenum steels, quenched and tempered with a guaranteed maximum actual ultimate tensile strength of 950 MPa, do not need to be tested and can safely be used for the construction of hydrogen/embrittling gases cylinders; however, H_2S mixtures at more than 100 bar working pressure need to be tested. For carbon-manganese steels, different limits on ultimate tensile strength apply (as described in ISO 9809-1).

The tests described in Clause 5 are "qualification tests" for a given steel composition and heat treatment. This means that the tests need not be repeated for each type, as defined in ISO 9809 (all parts), of cylinder once a steel has been qualified for a specific design strength level.

The test samples shall be taken from a representative cylinder or from a piece of tube (for long cylinders, according to ISO 11120), representative of the relevant manufacturing process including heat treatment.

The test samples shall have a mechanical strength not lower than the maximum intended tensile strength to be used for the cylinders to be manufactured. If it is intended later to increase the maximum strength of the steel, a new qualification test shall be performed.

With respect to the possible variation of the chemical composition, the chemistry of the steel tested shall be recorded in the qualification test report and the difference in chemistry for the steels actually used for the cylinders shall not exceed the "permissible difference" according to ISO 9809-2. In addition, for sulphur and phosphorus, these permissible differences are limited to 0,005 % and 0,010 %, respectively. In no case shall the phosphorus content of either the qualification or the production cylinders exceed 0,015 %.

With respect to the heat treatment, the manufacturer shall specify the relevant temperatures and times, and the quenching conditions (if relevant). Any modification to the heat treatment needing a new type approval according to ISO 9809-2 requires a new qualification test.

For the qualification of a given steel for the manufacturing of gas cylinders, method A, B, or C can be used (see 5.1, 5.2 and 5.3, respectively). Additionally, tensile tests shall be carried out (see 5.4).

5 Test methods

5.1 Disc test (method A)

5.1.1 Principle of test

A mounted test piece in the shape of a disc is subjected to an increasing gas pressure at constant rate to burst or to crack. The embrittling effect of hydrogen (or other embrittling gas) is evidenced by comparing the hydrogen rupture pressures, P_{H2}, with the helium rupture pressures, P_{He}, helium being chosen as a reference gas.

The ratio $P_{\mathrm{He}}/P_{\mathrm{H2}}$ shall be determined.

The lower the ratio, the less susceptible the steel will be to embrittlement. This ratio is dependent on the pressure rise rate, which shall remain constant during the whole test.

NOTE Hydrogen/embrittling gases rupture pressures also depend on the hydrogen purity. Oxygen or traces of water vapour can partially inhibit the hydrogen embrittlement effect.

5.1.2 Test conditions and procedure

5.1.2.1 Sample disc

The sample disc shall be flat and ground (or machined to an equivalent surface finish), and shall have the following characteristics.

Dimensions:

- diameter: $58\,^{0}_{-0,05}$ mm;
- thickness: 0,75 mm ± 0,01 mm;
- flatness: less than 1/10 mm deflection.

NOTE 1 The hydrogen rupture pressures are in the range of 300 bar. If it is intended to evaluate the steel for higher working pressure, thickness higher than 0,75 mm can be used.

NOTE 2 For gases intended to be used at maximum working pressure less than 100 bar, the test results could be conservative. In such case, the test could be repeated with disk at thickness such that the failure pressure is no more than service pressure.

Surface condition (both sides):

- roughness: *Ra* value (see ISO 4287) less than 0,001 mm; the roughness of the samples used for both H_2 and He tests shall be equivalent;
- no visible oxides.

The following operations shall be performed to verify the sample quality.

- Immediately after the final preparation and prior to the testing, store the samples in a dry atmosphere, i.e. a desiccator.
- Degrease the sample and check thickness at 4 points taken 90° apart to define a mean thickness.
- Determine the disc's hardness (e.g. Vickers) over its outer circumference (outside the O-ring zone) to verify that machining has not altered the original material properties.

5.1.2.2 Cell and other apparatus

The cell (see Figure 2) is composed of two stainless steel flanges embedding the disc. A volume of approximately 5 cm^3 is provided below the disc. Above the disc, a high-strength steel ring is mounted ($R_\text{m} \geq 1\ 100$ MPa). The internal diameter is 25,5 mm and the ring curvature radius where it meets the disc is $0{,}5^{0{,}25}_{-0{,}05}\ \text{mm}$.

Gas discharges can occur after disc bursting either through the lower flange or upper flange discharge port to the atmosphere. This permits the evacuation of the installation and a check of the hydrogen purity and freedom from either oxygen ($O_2 < 1$ µl/l) or water vapour ($H_2O < 3$ µl/l). It also permits regulation of the gas flow and adjustment of the pressure rise rate.

NOTE 1 µl/l= 1 ppm. The use of ppm is deprecated.

The sealing device shall be an elastomer O-ring for helium testing, and for hydrogen testing at rates of more than 10 bar/min. For hydrogen testing at rates not exceeding 10 bar/min, indium O-rings shall be used (to eliminate oxygen retrodifusion).

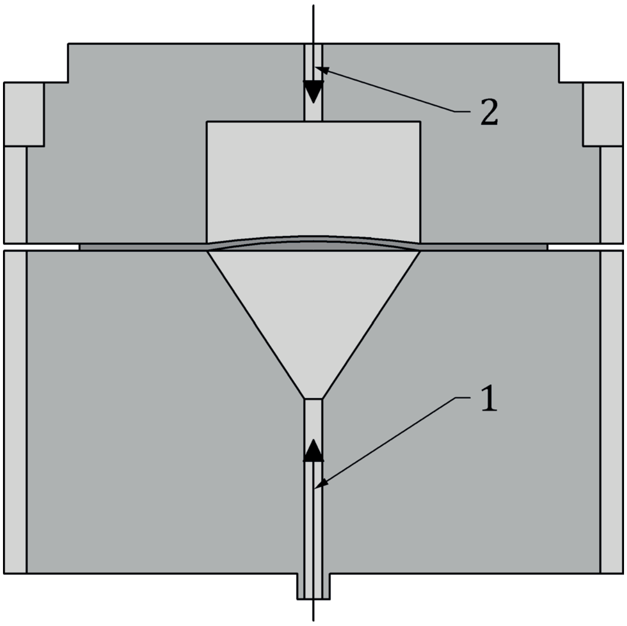
For the flange assembly, ten high-strength steel bolts should be used, size M10 or equivalent. The tightening torque shall be 30 Nm for elastomer O-rings and 100 Nm for indium O-rings.

Hydrogen and helium shall be stored in high-pressure containers connected to the test cells. A flow control valve between the high-pressure container and the cell shall be used to adjust the pressure rise rate.

5.1.2.3 Test procedure

For a satisfactory outcome of the test performances, operations in the following sequences shall be carried out.

- Evacuation of the cell by pumping to eliminate any traces of air or moisture absorbed by the walls. Purging with the gas to be used, followed by vacuum pumping, can also be used to improve the cleaning efficiency.
- Check the purity of the gas flowing out of the cell before testing to ensure absence of trace of air or moisture absorbed by the walls and the gas specification has been met.
- Adjustment of the gas flow to achieve the appropriate pressure rise rate (if necessary).
- Isolation of the cell (at the start of pressure rise).



Key

1 disc is subjected to P_{H2} on the lower side

2 disc is subjected to P_{N2} on the upper side

NOTE The disc is loaded with $\Delta P = P_{H2} - P_{N2}$.

Figure 1 — Compensating pressure disc test principle

The rate of pressure rise shall be regular and kept as constant as possible, neglecting the gas compressibility factor with pressure.

To evaluate the behaviour of steels at pressure higher than 300 bar, either a thicker disc shall be used (see 5.1.2.1) or a compensating pressure of inert gas (see Figure 1) shall be introduced progressively in the upper part of the disc cell at the same rate and pressure as hydrogen (e.g. up to 400 bar). Then, the hydrogen pressure is further increased as indicated in 5.1.1 at a constant rate to burst or to crack (e.g. at 700 bar) to evaluate the behaviour of the steel at about 700 bar).

The rupture pressures shall be noted from the recorded readings at the end of the test. The pressure gauge shall be accurate to ±2 % for the intended measured rupture pressure.

The tests shall be carried out with hydrogen (for quality, see 5.2.2.3) and with helium (H_2O < 3 µl/l) for a range of pressure rise rates evenly distributed between 0,1 bar/min and 1 000 bar/min. Once a range of pressure rise rates showing maximum hydrogen sensitivity has been established, three additional tests shall be conducted within this area, in order to establish the minimum value for the rupture pressure (see Figure 3). Six helium tests and nine hydrogen tests (i.e. 15 tests in total) are enough for a thorough material evaluation.

5.1.3 Treatment and interpretation of test results

5.1.3.1 Disc thickness

Rupture pressure P_r shall be systematically corrected for deviation from the “ideal” value corresponding to the test of a standard thickness disc.

The corrected rupture pressure, P_r', shall be given by Formula (1):

$$P_r' = \frac{P_r \times 0{,}75}{e_m} \tag{1}$$

where

e_m is the mean disc thickness.

5.1.3.2 Presentation and interpretation of test results

Rupture pressures, corrected as indicated in 5.1.3.1, shall be plotted against the pressure rise rate (actual rupture pressure divided by the test duration) expressed in bar/min (see Figure 3).

For each hydrogen test, calculate the ratio given in Formula (2):

$$P_r'{}_{\text{He}} \big/ P_r'{}_{\text{H2}} \tag{2}$$

where

$P_r'{}_{\text{He}}$ is the theoretical helium rupture pressure corresponding to the same pressure rise rate as for the hydrogen test, calculated by regression from the corrected helium rupture pressure;

$P_r'{}_{\text{H2}}$ is the corrected hydrogen rupture pressure.

Ratios of $P_r'{}_{\text{He}}/P_r'{}_{\text{H2}}$ shall be plotted against the pressure rise rate (see Figure 4).

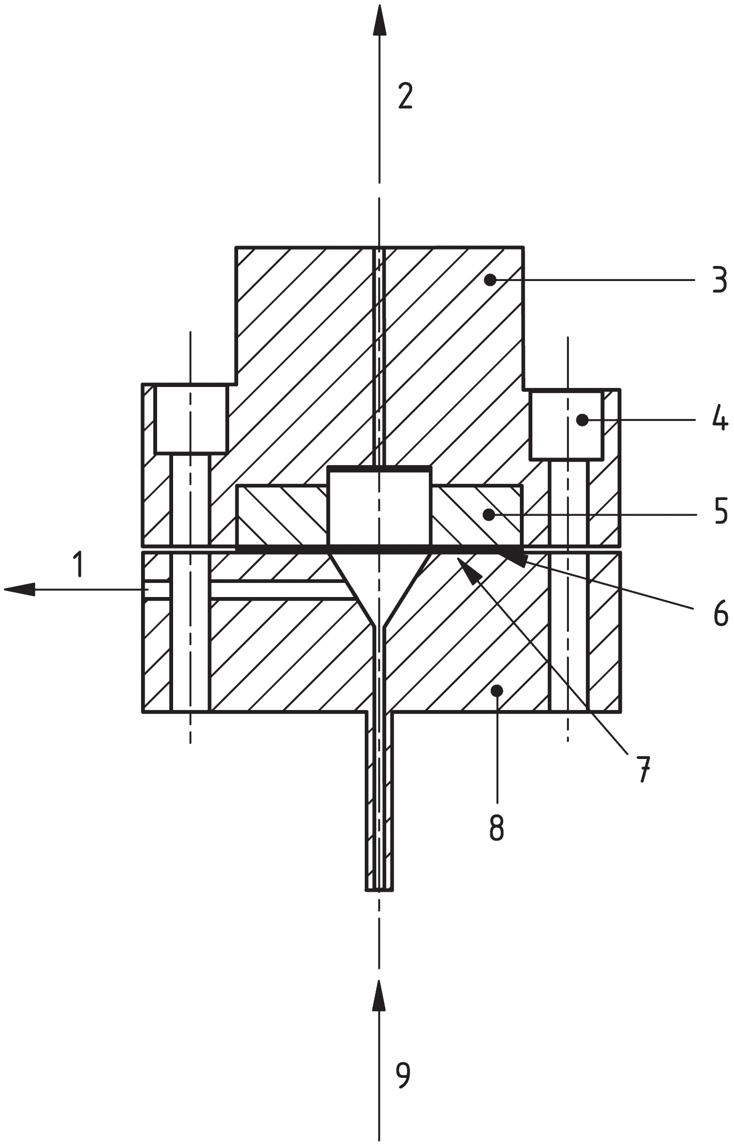
The embrittlement index of a material is the maximum value of the above-mentioned ratio. The material shall be considered as suitable for compressed hydrogen/embrittling gas cylinders if the index is less than or equal to two.

5.1.4 Failure in conducting test

If it is found that a failure occurred during the conduction of a test (e.g. inappropriate surface condition, abnormal hardness, irregular pressure rise), the test shall be repeated.

5.1.5 Test report

The detailed test conditions (gas purity, rupture pressure, hardness of the specimen, ratio $P_r'{}_{\text{He}}/P_r'{}_{\text{H2}}$, embrittlement index) and the cylinder design drawing including the material properties, chemical composition and heat treatment conditions of the tested cylinder shall be reported.

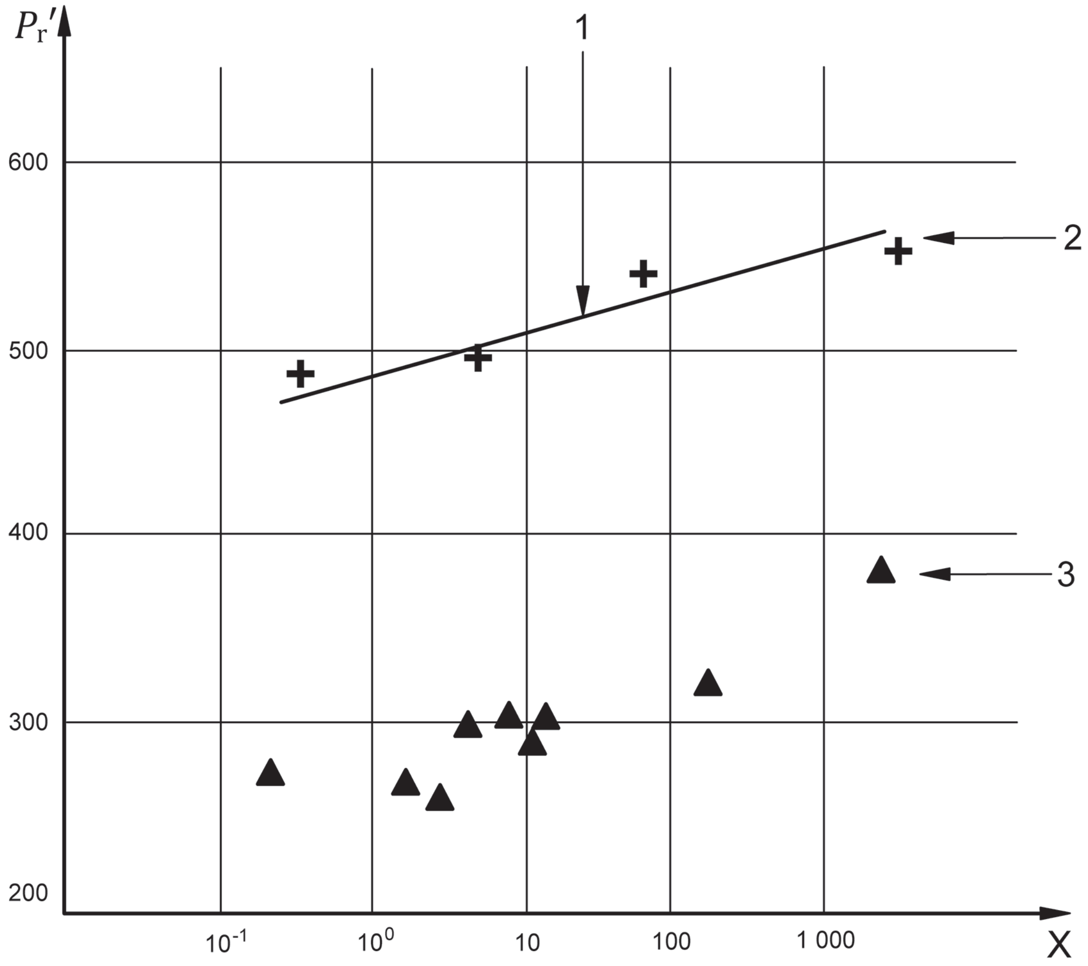


Key

1	port for evacuation and flow adjustment	6	disc
2	discharge port	7	O-ring
3	upper flange	8	lower flange
4	bolt hole	9	gas inlet
5	high-strength steel ring		

NOTE This figure is not to scale. See dimensions in 5.1.2.1 and 5.1.2.2.

Figure 2 — Schematic test installation (test cell)



Key

1 regression curve

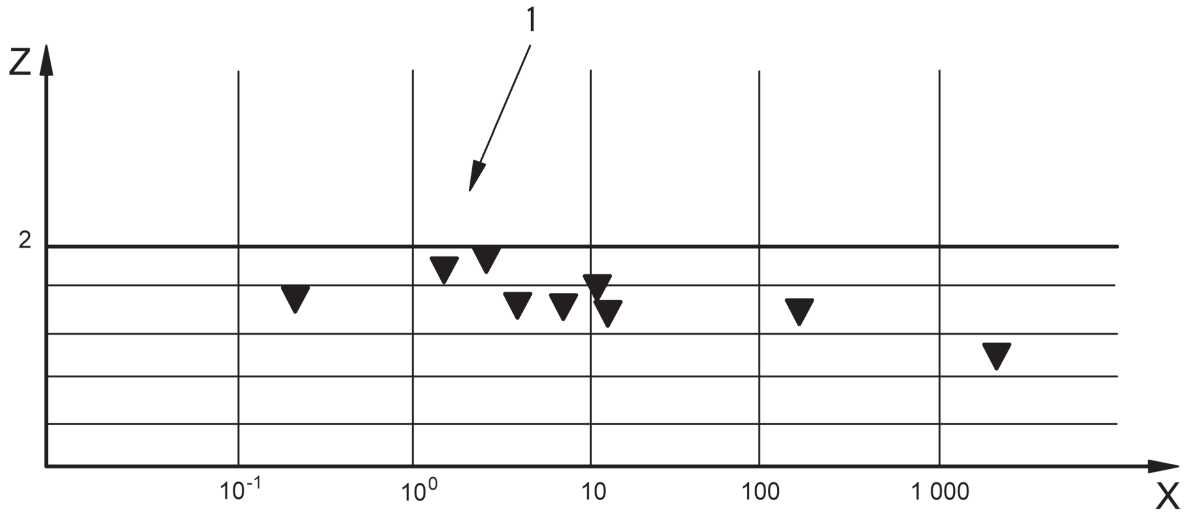
2 helium corrected rupture pressures ($P_r'_{He}$)

3 hydrogen corrected rupture pressures ($P_r'_{H2}$)

X pressure rise rate (bar/min)

P_r' corrected rupture pressure (bar)

Figure 3 — Examples of hydrogen and helium corrected rupture pressures as a function of the pressure rise rate



Key

1 hydrogen embrittlement index

X pressure rise rate (bar/min)

Z $P_{r}'_{He}/P_{r}'_{H2}$

Figure 4 — Examples of the ratio $P_{r}'_{He}/P_{r}'_{H2}$ as a function of the pressure rise rate

5.2 Fracture mechanics test (method B)

5.2.1 Principle of the test method

This specifies a method for the determination of the threshold stress intensity factor (K_{1H}) for susceptibility to cracking of metallic materials in gaseous hydrogen (or other embrittling gases).

The procedure covers the use of machined compact tension test pieces, as described in ISO 7539-6, for the determination of the threshold stress intensity factor, as described in ISO 7539-1.

The test involves a specimen containing a machined notch. This notch is extended by fatigue cracking and then subjected to an incrementally increasing tensile load during exposure to a pressurised, gaseous hydrogen environment. The objective is to quantify the conditions under which environmentally-assisted crack propagation can occur.

If the specimens pass the test requirements, then the material is characterized as suitable for gas cylinders filled with compressed hydrogen.

NOTE The test can be carried out with any other embrittling gas or gas mixture (e.g. H_2S, hydrides). The acceptance criteria of the considered gas will then be defined similarly.

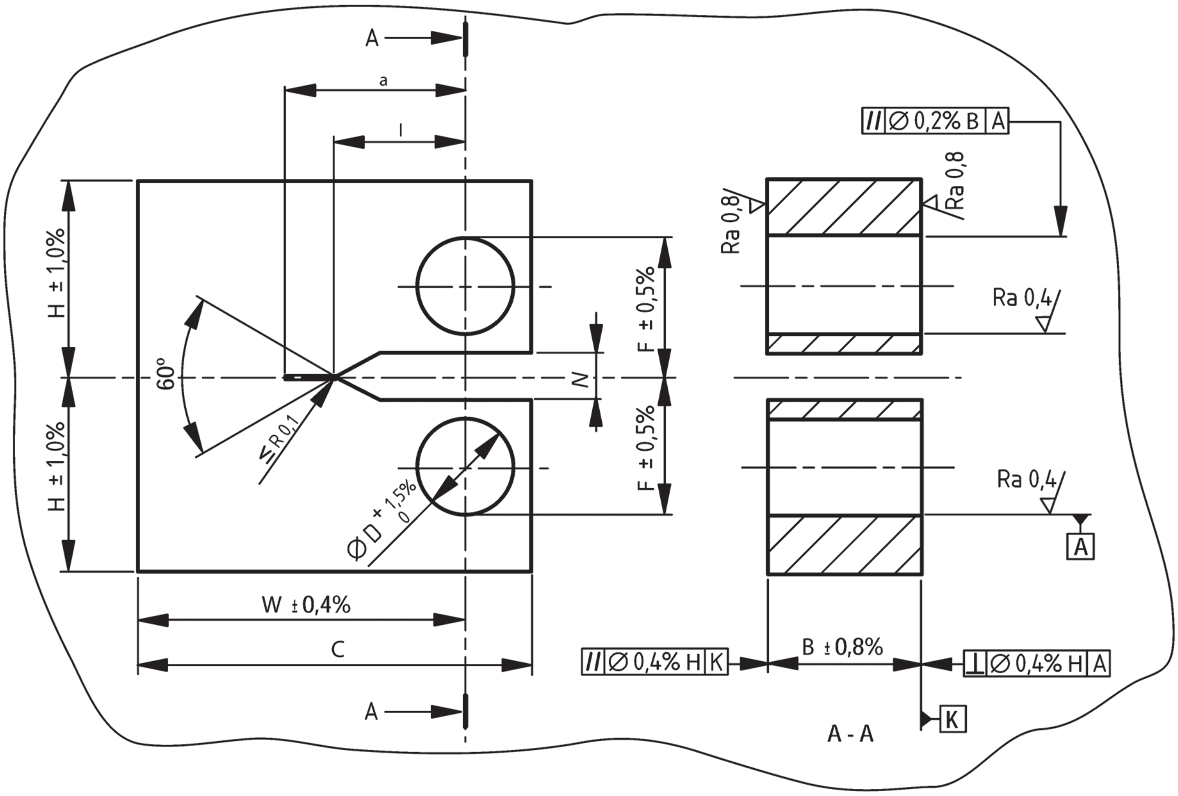
5.2.2 Test procedure

5.2.2.1 Specimen type

The test involves the use of a compact tension (CT) type specimen, according to the geometry given in Figure 5 (ISO 7539-6:2011, Figure 3), with a *W* dimension of 26 mm and *B* equal to the greatest thickness allowed by the cylinder wall curvature and thickness, but not less than 85 % of the design thickness of the cylinder being qualified. The specimen orientation (Y-X) relative to the cylinder axis is shown in Figure 6.

At least three specimens taken 120° apart from the cylindrical wall shall be tested. Flattening of specimen blanks is not allowed. If the test specimen thickness cannot meet the validity requirements of ISO 7539-6, then the thickest possible specimen as specified above shall be tested.

Dimensions in millimetres
Surface roughness values in micrometres



Key

W	net width
C	total width, 1,25 *W* minimum
B	thickness, 0,5 *W*
H	half height, 0,6 *W*
D	hole diameter, 0,25 *W*
F	half distance between hole outer edges, 1,6 *D*
N	notch width, 0,065 *W* maximum
l	effective notch length, 0,25 *W* to 0,40 *W*
a	effective crack length, 0,45 *W* to 0,55 *W*

Figure 5 — Proportional dimensions and tolerances for compact tension test pieces

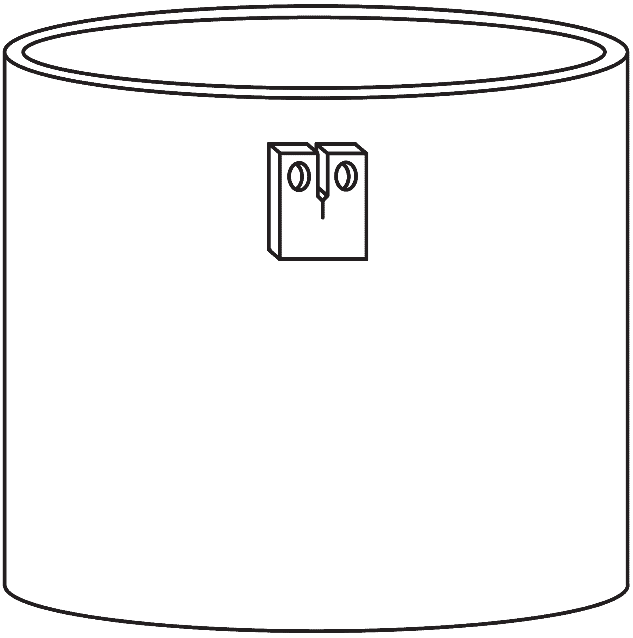


Figure 6 — Test piece: type and orientation

5.2.2.2 Specimen preparation

Prior to fatigue pre-cracking, all necessary electrical contacts and wires required for crack monitoring shall be attached to the specimen. The specimen shall be thoroughly degreased, with particular attention paid to the notch tip region.

During all subsequent operations, especially the fatigue pre-crack, the specimen shall not be contaminated in order to ensure a clean crack front.

Fatigue pre-cracking shall be conducted to meet the general requirements detailed in ISO 7539-6:2011, Clause 6 for the initiation and propagation of fatigue cracks. The final maximum pre-cracking load shall give a final maximum stress intensity lower than the initial stress intensity required for the test.

On completion of fatigue pre-cracking, the specimen shall be measured as detailed in ISO 7539-6:2011, Clause 7 to determine the thickness, B, width, W, and average length of the fatigue pre-crack on the specimen surfaces. The last of these values shall be used in assessing the load necessary to produce the required initial stress intensity.

To prevent oxidation of the crack tip, the specimen shall now be put on test. If, for any reason, this is not possible, the specimen shall be stored in a clean, desiccated environment until ready for testing.

5.2.2.3 Gas purity and pressure

The gas pressure in the test chamber shall be not less than the working pressure at which the cylinder needs to be evaluated. In the case of hydrogen, a purity of at least 99,999 5 %, and $O_2 \leq 1$ µl/l and $H_2O \leq 3$ µl/l. For other gases, the purity shall be equivalent to that of the gas being used. This gas shall be covered by a batch certificate of conformity. As an alternative, gas with a 99,999 9 % purity ($O_2 \leq 0{,}1$ µl/l and $H_2O \leq 0{,}5$ µl/l) and covered by an individual certificate of conformity may be used.

5.2.2.4 Test apparatus

The tests shall be conducted in a stainless steel chamber such as shown together with the loading bars and specimen in Figure 7, and installed on a servo-hydraulic test machine (Figure 8).

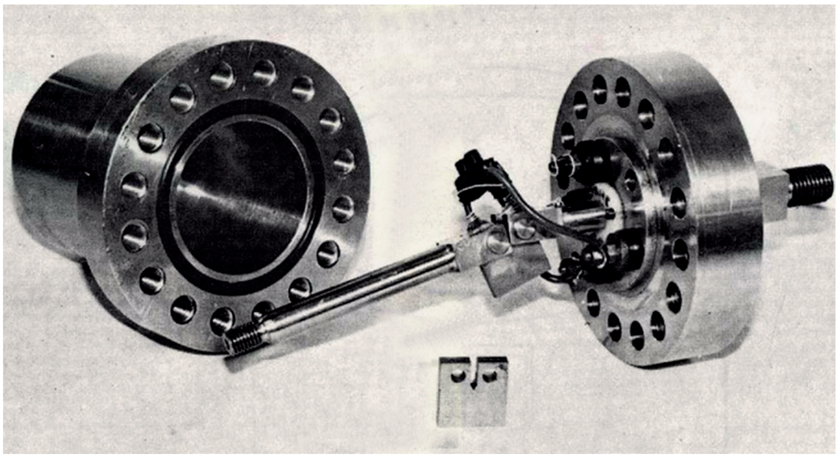


Figure 7 — Stainless steel chamber, showing loading bars and specimen

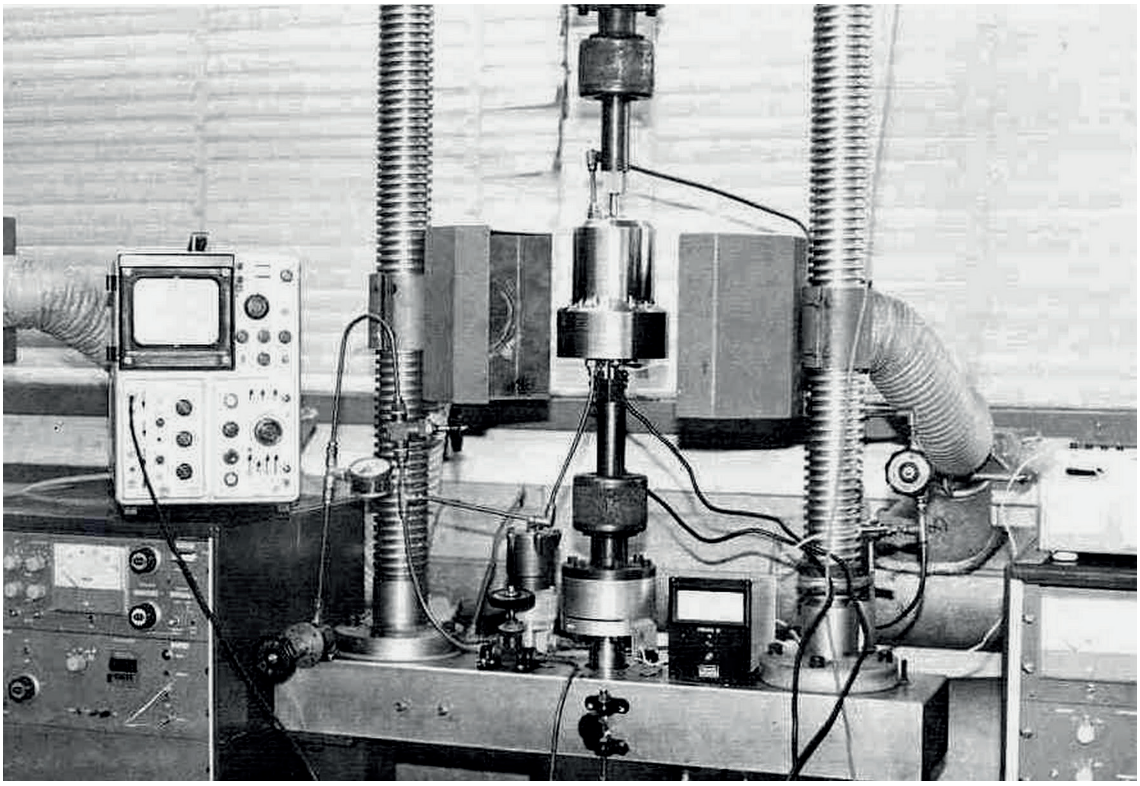


Figure 8 — Servo-hydraulic test machine

After installation of the specimen, it is recommended that the test chamber be evacuated to a pressure of <130 Pa prior to the introduction of gaseous hydrogen. The purity of the gaseous environment in the test chamber shall be as specified in 5.2.2.3.

Crack initiation and any subsequent growth shall be detected and monitored using a direct current potential drop (DCPD) method.

5.2.2.5 Test method

If there is no prior knowledge of the material's threshold stress intensity factor, then the test shall be started using a load which produces a stress intensity factor of 1 MPa·m^{0,5} at the crack tip (for calculation of the load, see ISO 7539-6). Otherwise, the test may be started at a stress intensity factor equivalent to, but not exceeding, 50 % of the stress intensity factor derived from previous work.

The applied load shall be recorded continuously. The specimen shall be held at the initial load for a period of at least 20 min to allow for crack growth at room temperature. If no crack growth is detected by the end of the hold period, as evidenced by a plateau in the potential drop curve, the load shall be increased at a controlled rate in a step equivalent to a crack tip stress intensity factor increase of 1 MPa·$m^{0,5}$, and held for a further 20 min. This procedure shall be continued until failure occurs, with the appropriate load being recorded on the test data sheet.

The load shall be increased at the end of a hold period, by means of a servo-controller, at a constant rate of 2×10^{-3} kN·s^{-1}, until attainment of the crack tip stress intensity required for the subsequent hold period. This would result in a controlled crack tip stress intensity factor increase totalling 1 MPa·$m^{0,5}$ over a time interval of approximately 1 min, assuming a test piece of thickness 7 mm and with an a/W of 0,5.

5.2.2.6 Specimen measurement

After the test, the specimen shall be inspected in accordance with ISO 7539-6, with the appropriate measurements to ±0,01 mm being made using a travelling microscope.

5.2.3 Test results

5.2.3.1 Analysis and acceptance criteria

Calculation of the test result shall be as stated in ISO 7539-6, through a relationship of the form as given by Formula (3):

$$K_{1\mathrm{H}} = YP/BW^{0,5} \qquad (3)$$

The load, P, used in the calculation is that applied to the specimen before the final increment that caused failure.

Provided that the $K_{1\mathrm{H}}$ values of both CT specimens are greater than or equal to (60/950) × R_m (MPa·$m^{0,5}$), then the material is qualified for a maximum tensile strength (R_m) equal to the average of the two tensile strength values obtained in 5.4. If the constraint validity requirement of 5.2.2.1 is not met, then the material is suitable up to the design thickness of the cylinder tested.

5.2.3.2 Failure in conducting test

If it is found that a failure occurred during the conduction of a test (e.g. inappropriate surface condition, abnormal hardness, irregular pressure rise), the test shall be repeated.

5.2.3.3 Test report

The detailed test conditions [gas purity and pressure, record of the direct current potential drop (DCPD) measurements, location and dimension of the specimen, $K_{1\mathrm{H}}$ and R_m (see 5.4) and the cylinder design drawing], including the material properties and chemical composition and the heat treatment conditions of the tested cylinder, shall be reported.

5.3 Test method to determine the resistance to hydrogen assisted cracking of steel cylinders (method C)

5.3.1 General

A fatigue precracked specimen is loaded by a constant displacement method to a stress intensity $\mathrm{K}_{\mathrm{IAPP}}$ in pressurized hydrogen gas or other embrittling gas at room temperature. After the test period, the specimen is examined to assess whether the initial fatigue crack did or did not grow. To determine the extent of crack propagation, calculate the K value at arrest condition. If the test specimen exhibits less than or equal to a specified amount of crack growth at a K_{arrest} value that is less than the acceptable threshold, then the material is characterized as suitable for gas cylinders with respect to the hydrogen assisted cracking (HAC) resistance requirement.

Testing shall be conducted using applicable rules of ISO 7539-6 and additional rules specified in this document. Rules provided in ISO 7539-6 on corrosive environment need not be satisfied. Some symbols used in this method are to be found in ISO 7539-6:2011, Clause 3.

NOTE The test can be carried out with any other embrittling gas or gas mixture (e.g. H_2S, hydrides). The acceptance criteria of the considered gas will then be defined similarly.

5.3.2 Specimen configurations and numbers of tests

5.3.2.1 Fracture specimens

5.3.2.1.1 The compact tension (CT) specimen geometry given in Figure 5 (ISO 7539-6:2011, Figure 3) shall be used. The specimen thickness shall not be less than 85 % of the design thickness of the cylinder which is being qualified.

5.3.2.1.2 Specimen orientation shall be Y-X in ISO 7539-6:2011, Figure 15, for rectangular section.

5.3.2.1.3 At least three specimens taken 120° apart from the cylindrical wall shall be tested. Flattening of specimen blanks is not allowed.

5.3.2.1.4 If test specimen thickness cannot be obtained from the specified location or locations to meet the validity requirements of 5.3.4.5, then the thickest possible specimen shall be tested.

5.3.2.2 Tensile specimens

Three longitudinal tensile specimens taken adjacent to the CT specimens from the cylindrical wall area shall be used according to ISO 9809-1.

5.3.3 Fatigue precracking

All rules provided in ISO 7539-6:2011, Clause 6 shall be met.

5.3.4 Specimen testing procedure

5.3.4.1 All rules in ISO 7539-6:2011, Clause 7 shall be satisfied, except for those in ISO 7539-6:2011, 7.2.2, 7.2.6, 7.5.1, 7.5.2, 7.5.4, and 7.5.5.

5.3.4.2 Load the fatigue-precracked specimens to a stress-intensity K_{IAPP} determined from Formula (4):

$$K_{\text{IAPP}} = 1{,}5\left(60\right)\times\left(R_{\text{m}}/950\right) \tag{4}$$

Specimens may be loaded by a suitable constant displacement method.

5.3.4.3 Constant displacement loading

For testing of CT specimens at a constant displacement loading, use Formula (5):

$$V = \frac{\left(K_{\text{IAPP}}\right)\sqrt{w}}{E\left[f\left(x\right)\right]\left(\sqrt{B/B_{\text{N}}}\right)} \tag{5}$$

where

$f(x) = (1 - x)^{0,5}\,(0{,}748 - 2{,}176\,x + 3{,}56\,x^2 - 2{,}55\,x^3 + 0{,}62\,x^4)$

$x = \frac{a}{w}$

5.3.4.4 For specimens loaded by constant displacement method, the loading shall be determined by the following method.

a) At the end of the test, record the crack mouth opening displacement (CMOD) before unloading.

b) Unload the specimen.

c) Reload the specimen up to the measured CMOD in a device suitable for load measurement. Record the load and use this load in the K_{IAPP} calculations. This calculated K_{IAPP} shall be equal to or greater than the calculated K_{IAPP} value from 5.3.4.2.

5.3.4.5 All specimens shall meet the validity requirements specified in ISO 7539-6:2011, 7.6.6 e), except as exempted in 5.3.4.1 above.

5.3.5 Test procedure

5.3.5.1 Place the test specimens in a high-pressure test chamber.

NOTE Extended periods of time after loading and before exposure to hydrogen gas can affect the final results.

For a satisfactory outcome of the test performances, the following operations shall be carried out.

- Evacuation of the cell by pumping to eliminate any traces of air or moisture absorbed by the walls. Purging with the gas to be used, followed by vacuum pumping, can also be used to improve the cleaning efficiency.
- Check the purity of the gas flowing out of the cell before testing to ensure absence of trace of air or moisture absorbed by the walls and the gas specification has been met.
- The O_2 content in the hydrogen gas shall not exceed 1 µl/l and H_2O content shall not exceed 3 µl/l. Pressurize the test chamber with hydrogen gas to the pressure at which the steel needs to be evaluated.

5.3.5.2 The specimens shall be tested for at least 1 000 h at room temperature.

5.3.6 Crack growth examination

5.3.6.1 After the specified test period, unload the specimen and mark the HAC advance using one of the following methods.

a) Heat tinting the specimen at about 300 °C for 30 min.

b) Fatigue cycling at maximum stress-intensity factor not exceeding 0,6 K_{IAPP}. Advance the crack by at least 1 mm.

followed by:

c) Fracturing the specimen at very low temperature such as that of liquid nitrogen.

5.3.6.2 Measure the crack growth, using a scanning electron microscope. Measurements shall be taken at locations perpendicular to the pre-crack at 25 %, 50 % and 75 % of B. Calculate the average of these three values.

5.3.6.3 If the average measured crack growth does not exceed 0,25 mm**,** the specimen passes the tests. If the measured values exceed 0,25 mm, calculate the new K_I. If this new K_I is greater or equal to (60) × (Rm/950), the specimen will also pass the test.

5.3.7 Cylinder material qualification

5.3.7.1 If all specimens pass, the material is qualified for maximum tensile strength equal to the average of the three tensile strength values obtained in 5.3.2.2.

5.3.7.2 If the constraint validity requirement of 5.3.4.5 is not met, then the material is suitable up to the design thickness of the cylinder wall.

5.3.8 Failure in conducting test

If it is found that a failure occurred during the conduction of a test (e.g. inappropriate surface condition, abnormal hardness, irregular pressure rise), the test shall be repeated.

5.3.9 Test report

The information described in ISO 7539-6:2011, Clause 8, with the exception of 8 e), shall be reported. The report shall indicate if the validity criteria are met or not and shall include scanning electron microscope micrographs. The report should be kept on file permanently as a record that the cylinder material has been tested and found acceptable.

5.4 Tensile tests

Two longitudinal tensile specimens taken adjacent to the CT specimens (if applicable) from the cylindrical wall area shall be tested in accordance with test procedures of the ISO 9809 series.

Bibliography

[1] ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

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

[3] ISO 9809-4, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa*

[4] AFNOR FD E29-753, *Gas cylinders — Hydrogen compatibility testing for metals*

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Committee representation

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The committee consisted of representatives of the following nominating organisations:

Coregas

Energy Resources Aotearoa

Fabrum

Fonterra Co-operative Group

Gas Appliance Industry

GasNZ

GNS

Hiringa Energy

HW Richardson Group

HyPotential

Methanex

New Zealand Hydrogen Council

PEC

WorkSafe New Zealand − Energy Safety

Z Energy

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New Zealand Standard

Hydrogen fuel quality – Product specification

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

ISO 14687 *Hydrogen fuel quality − Product specification* is seen as an important standard for adoption in New Zealand. It sets out maximum permissible concentrations for many key impurities depending on the application and specifies the minimum quality characteristics of hydrogen fuel as distributed for use in vehicular and stationary applications. It also provides more detailed requirements on fuel purity for specific applications. An impurity's impact varies according to its physio-chemical nature (inert impurities such as nitrogen, for example, are usually less harmful than reactive species such as hydrogen sulphide) and the equipment being used (for example, a boiler that combusts hydrogen will generally tolerate a higher concentration of impurities than would a vehicle using polymer electrolyte membrane fuel cell [PEMFC] technology).

ISO 14687 is already being used in many global jurisdictions. In Europe, for example, Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, states that the hydrogen purity dispensed by hydrogen refuelling points shall comply with the technical specifications included in ISO 14687. And in California, the state is using the ISO values as the SAE's J2719 *Hydrogen fuel quality for fuel cell vehicles* is being revised.

This standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 14687:2019 *Hydrogen fuel quality – Product specification.*

As this standard is reproduced from an international standard, the following applies:
(a) In the source text, 'this International Standard' should read 'this New Zealand standard';
(b) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL
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Qualité du carburant hydrogène — Spécification de produit

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This first edition of ISO 14687 cancels and replaces ISO 14687-1:1999, ISO 14687-2:2012 and ISO 14687-3:2014. It also incorporates the Technical Corrigenda ISO 14687-1:1999/Cor 1:2001 and ISO 14687-1:1999/Cor 2:2008.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

As mentioned in the Foreword, this document is a combination of three former standards for the specifications of hydrogen fuel, ISO 14687-1, ISO 14687-2 and ISO 14687-3, incorporating their revisions at the same time.

In recent years, PEM (proton exchange membrane) fuel cell technologies have shown a remarkable progress such as lowering of platinum (Pt)-loading, thinned electrolyte membrane, operation with high current density and operation under low humidity. With this progress, it has become necessary to reconsider the tolerances of hydrogen impurities for the PEM fuel cells which were previously specified in ISO 14687-2 and ISO 14687-3.

Therefore, this document has been mainly revised based on the research and development of PEM fuel cells focusing on the following items[1], [3] to [15]:

- PEM fuel cell catalyst and fuel cell tolerance to hydrogen fuel impurities;
- effects/mechanisms of impurities on fuel cell power systems and components;
- impurity detection and measurement techniques for laboratory, production and in-field operations;
- fuel cell vehicle demonstration and stationary fuel cell demonstration results.

The grade D and the grade E of this document are intended to apply to PEM fuel cells for road vehicles and stationary appliances respectively. These aim to facilitate the provision of hydrogen of reliable quality balanced with acceptable lower cost for the hydrogen fuel supply.

This document reflects the state of the art at the date of its publication, but since the quality requirements for hydrogen technology applications are developing rapidly, this document may need to be further revised in the future according to technological progress.

Hydrogen fuel quality — Product specification

1 Scope

This document specifies the minimum quality characteristics of hydrogen fuel as distributed for utilization in vehicular and stationary applications.

It is applicable to hydrogen fuelling applications, which are listed in Table 1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 19880-8, *Gaseous Hydrogen — Fuelling stations — Part 8: Fuel Quality Control*

ISO 21087, *Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
boundary point
<PEM *fuel cell* (3.7) for stationary applications> point between the *hydrogen fuel supply equipment* (3.13) and the PEM *fuel cell power system* (3.9) at which the quality characteristics of the hydrogen fuel are to be determined

3.2
constituent
component (or compound) found within a hydrogen fuel mixture

3.3
contaminant
impurity that adversely affects the components within the *fuel cell system* (3.8), the *fuel cell power system* (3.9) or the hydrogen storage system

Note 1 to entry: An adverse effect can be reversible or irreversible.

3.4
customer
<PEM *fuel cell* (3.7) for stationary applications> party responsible for sourcing hydrogen fuel in order to operate the *fuel cell power system* (3.9)

3.5
detection limit
lowest quantity of a substance that can be distinguished from the absence of that substance with a stated confidence limit

3.6

determination limit

lowest quantity which can be measured at a given acceptable level of uncertainty

3.7

fuel cell

electrochemical device that converts the chemical energy of a fuel and an oxidant to electrical energy (DC power), heat and other reaction products

3.8

fuel cell system

<PEM *fuel cell* (3.7) for road vehicle applications> power system used for the generation of electricity on a fuel cell vehicle

Note 1 to entry: The fuel cell system typically contains the following subsystems: fuel cell stack, air processing, fuel processing, thermal management and water management.

3.9

fuel cell power system

<PEM *fuel cell* (3.7) for stationary applications> self-contained fuel cell assembly used for the generation of electricity which is fixed in a place in a specific location

Note 1 to entry: The fuel cell power system typically contains the following subsystems: fuel cell stack, air processing, thermal management, water management and automatic control system. It is used in applications such as: distributed power generation, back-up power generation, remote power generation, electricity and heat co-generation for residential and commercial applications.

Note 2 to entry: For the purposes of the applications, the fuel cell power system does not contain a fuel processing system due to the location of the *boundary point* (3.1).

3.10

gaseous hydrogen

hydrogen under gaseous form, purified to a minimum mole fraction as specified in tables in this document

3.11

hydrogen-based fuel

<PEM *fuel cell* (3.7) for stationary applications> gas containing a concentration of hydrogen as specified in tables in this document used for PEM fuel cell for stationary applications

3.12

hydrogen fuel index

mole fraction of a fuel mixture that is hydrogen

3.13

hydrogen fuel supply equipment

equipment used for the transportation or on-site generation of hydrogen fuel, and subsequently for the delivery to the *fuel cell power system* (3.9), including additional storage, vaporization and pressure regulation as appropriate

3.14

irreversible effect

effect, which results in a permanent degradation of *the fuel cell system* (3.8) or the *fuel cell power system* (3.9) performance that cannot be restored by practical changes of operational conditions and/or gas composition

3.15

liquid hydrogen

hydrogen that has been liquefied, i.e. brought to a liquid state

3.16

particulate

solid or liquid such as oil mist that can be entrained somewhere in the production, delivery, storage or transfer of the hydrogen fuel to a *fuel cell system* (3.8) or a *fuel cell power system* (3.9)

3.17

reversible effect

effect, which results in a temporary degradation of *the fuel cell system* (3.8) or the *fuel cell power system* (3.9) performance that can be restored by practical changes of operational conditions and/or gas composition

3.18

slush hydrogen

hydrogen that is a mixture of solid and liquid at the eutectic (triple-point) temperature

3.19

system integrator

<PEM *fuel cell* (3.7) for stationary applications> integrator of equipment between the PEM *fuel cell power system* (3.9) and the hydrogen supply

4 Classification and application

4.1 Classification

Hydrogen fuel shall be classified according to the following types and grade designations:

a) Type I (grades A, B, C, D and E): gaseous hydrogen and hydrogen-based fuel.

b) Type II (grades C and D): liquid hydrogen.

c) Type III: slush hydrogen.

4.2 Application

Table 1 characterizes representative applications of each type and grade of hydrogen fuel.

Table 1 — Hydrogen and hydrogen-based fuel classification by application

Type	Grade	Category	Applications	Clause
I Gas	A	—	Gaseous hydrogen; internal combustion engines for transportation; residential/commercial combustion appliances (e.g. boilers, cookers and similar applications)	7
	B	—	Gaseous hydrogen; industrial fuel for power generation and heat generation except PEM fuel cell applications	7
	C	—	Gaseous hydrogen; aircraft and space-vehicle ground support systems except PEM fuel cell applications	7
	D[a,b]	—	Gaseous hydrogen; PEM fuel cells for road vehicles	5
	E	PEM fuel cells for stationary appliances		6
		1	Hydrogen-based fuel; high efficiency/low power applications	
		2	Hydrogen-based fuel; high power applications	
		3	Gaseous hydrogen; high power/high efficiency applications	

[a] Grade D may be used for other fuel cell applications for transportation including forklifts and other industrial trucks if agreed upon between supplier and customer.

[b] Grade D may be used for PEM fuel cell stationary appliances alternative to grade E category 3.

Table 1 *(continued)*

Type	Grade	Category	Applications	Clause
II Liquid	C	—	Aircraft and space-vehicle on-board propulsion and electrical energy requirements; off-road vehicles	7
	D[a,b]	—	PEM fuel cells for road vehicles	5
III Slush	—	—	Aircraft and space-vehicle on-board propulsion	7

[a] Grade D may be used for other fuel cell applications for transportation including forklifts and other industrial trucks if agreed upon between supplier and customer.

[b] Grade D may be used for PEM fuel cell stationary appliances alternative to grade E category 3.

NOTE Biological sources of hydrogen can contain additional constituents (e.g. siloxanes or mercury) that can affect the performance of the various applications, particularly PEM fuel cells. However, these are not included in most of the following specifications due to insufficient information.

5 Hydrogen quality requirements for PEM fuel cell road vehicle application

5.1 Fuel quality specification

The quality of hydrogen at dispenser nozzle for grade D hydrogen (see Table 1) shall meet the requirements of Table 2. The fuel specifications are not process-dependent or feed-stock-specific. Non-listed contaminants have no guarantee of being benign.

NOTE ISO 19880-8:2019, Annex A provides the rationale for the selection of the impurities specified in Table 2.

Table 2 — Fuel quality specification for PEM fuel cell road vehicle application

Constituents[a] (assay)	**Type I, Type II** **grade D**
Hydrogen fuel index (minimum mole fraction)[b]	99,97 %
Total non-hydrogen gases (maximum)	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbons except methane[c] (C1 equivalent)	2 µmol/mol
Methane (CH_4)	100 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmol/mol).

[d] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[e] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[f] All halogenated compounds which could potentially be in the hydrogen gas [for example, hydrogen chloride (HCl) and organic chlorides (R-Cl)] should be determined by the hydrogen quality control plan discussed in ISO 19880-8. Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

[g] Particulate includes solid and liquid particulates comprises of oil mist. Large particulates can cause issues with vehicle components and should be limited by using filter as specified in ISO 19880-1. No visible oil shall be found in fuel at a nozzle.

Table 2 *(continued)*

Constituents[a] (assay)	**Type I, Type II** **grade D**
Nitrogen (N_2)	300 µmol/mol
Argon (Ar)	300 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)[d]	0,2 µmol/mol
Total sulphur compounds[e] (S1 equivalent)	0,004 µmol/mol
Formaldehyde (HCHO)[d]	0,2 µmol/mol
Formic acid (HCOOH)[d]	0,2 µmol/mol
Ammonia (NH_3)	0,1 µmol/mol
Halogenated compounds[f] (Halogen ion equivalent)	0,05 µmol/mol
Maximum particulate concentration[g]	1 mg/kg

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmol/mol).

[d] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[e] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[f] All halogenated compounds which could potentially be in the hydrogen gas [for example, hydrogen chloride (HCl) and organic chlorides (R-Cl)] should be determined by the hydrogen quality control plan discussed in ISO 19880-8. Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

[g] Particulate includes solid and liquid particulates comprises of oil mist. Large particulates can cause issues with vehicle components and should be limited by using filter as specified in ISO 19880-1. No visible oil shall be found in fuel at a nozzle.

5.2 Analytical method

The analytical methods for measuring constituents in Table 2 shall meet the requirements of ISO 21087.

5.3 Sampling

Guidance on hydrogen sampling methods for gaseous hydrogen fuelling stations is available in ISO 19880-1.

5.4 Hydrogen quality control

The means of assuring that the hydrogen quality meets the specification in 5.1 shall be based upon ISO 19880-8.

6 Hydrogen and hydrogen-based fuels, quality requirements for PEM fuel cell stationary applications

6.1 Fuel quality specification

The quality of hydrogen and hydrogen-based fuels, supplied to stationary PEM fuel cell appliances, shall meet the requirements of Table 3 at the boundary point set between the hydrogen fuel supply equipment and the PEM fuel cell power system.

NOTE 1 Annex A provides guidance for the selection of the boundary point.

NOTE 2 Annex B provides the rationale for the selection of the impurities specified in Table 3.

Type I, grade E hydrogen and hydrogen-based fuels, for PEM fuel cell applications for stationary appliances, specify the following subcategories in order to meet the needs of different stationary applications, depending on the requirements specified by the manufacturer:

- Type I, grade E, category 1 (hydrogen-based fuel; high efficiency/low power applications).
- Type I, grade E, category 2 (hydrogen-based fuel; high power applications).
- Type I, grade E, category 3 (gaseous hydrogen; high power/high efficiency applications).

Table 3 — Fuel quality specification for PEM fuel cell stationary applications

Constituents[a] **(assay)**	**Type I, grade E**		
	Category 1	**Category 2**	**Category 3**
Hydrogen fuel index[b] (minimum mole fraction)	50 %	50 %	99,9 %
Total non-hydrogen gases (maximum mole fraction)	50 %	50 %	0,1 %
Water (H_2O)[c]	Non-condensing at any ambient conditions	Non-condensing at any ambient conditions	Non-condensing at any ambient conditions
Maximum concentration of individual contaminants[d]			
Total hydrocarbons except methane[e] (C_1 equivalent)	10 µmol/mol	2 µmol/mol	2 µmol/mol
Methane (CH_4)	5 %	1 %	100 µmol/mol
Oxygen (O_2)	200 µmol/mol	200 µmol/mol	50 µmol/mol
Sum of nitrogen (N_2), argon (Ar) and helium (He) (mole fraction)	50 %	50 %	0,1 %

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Each site shall be evaluated to determine the appropriate maximum water content based on the lowest expected ambient temperature and the highest expected storage pressure.

[d] The maximum concentration of impurities against the total gas content shall be determined on a dry basis.

[e] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmolC/mol).

[f] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[g] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[h] Halogenated compounds includes, for example, hydrogen chloride (HCl) and organic chlorides (R-Cl). Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

Table 3 *(continued)*

Constituents[a] (assay)	Type I, grade E		
	Category 1	**Category 2**	**Category 3**
Carbon dioxide (CO_2)	Included in total non-hydrogen gases	Included in total non-hydrogen gases	2 µmol/mol
Carbon monoxide (CO)	10 µmol/mol	10 µmol/mol	0,2 µmol/mol[f]
Total sulphur compounds[g] (S1 equivalent)	0,004 µmol/mol	0,004 µmol/mol	0,004 µmol/mol
Formaldehyde (HCHO)	3,0 µmol/mol	0,2 µmol/mol	0,2 µmol/mol[f]
Formic acid (HCOOH)	10 µmol/mol	0,2 µmol/mol	0,2 µmol/mol[f]
Ammonia (NH_3)	0,1 µmol/mol	0,1 µmol/mol	0,1 µmol/mol
Halogenated compounds[h] (halogen ion equivalent)	0,05 µmol/mol	0,05 µmol/mol	0,05 µmol/mol
Maximum particulate concentration	1 mg/kg	1 mg/kg	1 mg/kg
Maximum particle diameter	75 µm	75 µm	75 µm

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Each site shall be evaluated to determine the appropriate maximum water content based on the lowest expected ambient temperature and the highest expected storage pressure.

[d] The maximum concentration of impurities against the total gas content shall be determined on a dry basis.

[e] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmolC/mol).

[f] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[g] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[h] Halogenated compounds includes, for example, hydrogen chloride (HCl) and organic chlorides (R-Cl). Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

6.2 Quality verification

6.2.1 General requirements

Quality verification requirements shall be determined at the boundary point using the sampling methods specified in 6.3.

The selection of relevant fuel contaminants for analysis as specified in Table 3 should be carried out based on the hydrogen production method.

All analyses conducted under this document shall be undertaken using gaseous calibration standards (or other calibration devices) that are traceable to the International System of Units (SI) via national standards, where such standards are available.

NOTE ISO 21087 provides guidance for analytical methods.

6.2.2 Analytical requirements of the qualification tests

The frequency of testing and analytical requirements for the qualification tests shall be determined based on the agreement between the supplier and the customer. Consideration shall be given to the consistency of hydrogen supply in determining the test frequency and constituents to be tested.

NOTE Annex C provides a recommended practice of the quality assurance for steam methane reforming (SMR) hydrogen production processes using pressure swing adsorption (PSA) purification.

6.2.3 Report results

The detection limits and the determination limits for analytical methods and instruments used shall be reported along with the results of each test and the date the sample was taken.

6.3 Sampling

6.3.1 Sample size

Where possible, the quantity of hydrogen in a single sample container should be sufficient to perform the analyses for the hydrogen fuel quality specification. If a single sample does not contain a sufficient quantity of hydrogen to perform all of the analyses required to assess the quality level, additional samples from the same lot shall be taken under similar conditions. A large sample or sample with a greater pressure, where applicable, may be required if multiple tests are to be conducted.

6.3.2 Selection of the sampling point

A boundary point shall be established so that gaseous samples are representative of the hydrogen supplies to the PEM fuel cell power systems.

NOTE Annex A provides guidance to assist in the identification of the party responsible for the quality of hydrogen at the boundary point and also the selection of the boundary point.

6.3.3 Sampling procedure

Gaseous hydrogen samples shall be representative of the hydrogen supply, withdrawn from the boundary point through a suitable connection into an appropriately sized sample container. No contamination of the hydrogen fuel shall be introduced between the boundary point and the sample container (a suitable purge valve may be used).

The residual gases inside the sample container shall be evacuated to ensure that the sampled hydrogen is not contaminated. If evacuation is not possible, the sample container shall be cleaned using repeated purge cycles.

Sampled gases are flammable. Measures shall be taken to avoid hazardous situations. Guidance is given in ISO/TR 15916.

6.3.4 Particulates in gaseous hydrogen

Particulates in hydrogen shall be sampled from the boundary point, using a filter, if practical, under the same conditions (pressure and flow rate) as employed in the actual hydrogen supplying condition. Appropriate measures shall be taken for the sample gas not to be contaminated by particulates coming from the connection device and/or the ambient air.

7 Hydrogen quality requirements for applications other than PEM fuel cell road vehicle and stationary applications

7.1 Fuel quality specification

The quality of hydrogen supplied to the example specifications for applications other than PEM fuel cell road vehicles and stationary applications shall meet the requirements of Table 4. A blank indicates no maximum limiting characteristic. The absence of a maximum limiting characteristic in a listed quality level does not imply that the component is or is not present, but merely indicates that there is no limitation regarding this component for compliance with this document.

NOTE Other specifications can be equally suitable for these applications.

Table 4 — Fuel quality specification for applications other than PEM fuel cell road vehicle and stationary applications

Constituents	**Type I**			**Type II**	**Type III**
(assay)	**Grade A**	**Grade B**	**Grade C**	**Grade C**	
Hydrogen fuel index[a] (minimum mole fraction, %)	98,0 %	99,90 %	99,995 %	99,995 %	99,995 %
Para-hydrogen (minimum mole fraction, %)	NS	NS	NS	95,0 %	95,0 %
Impurities (maximum content)					
Total gases	20 000 µmol/mol	1 000 µmol/mol	50 µmol/mol	50 µmol/mol	
Water (H_2O) (mole fraction, %)	Non-condensing at all ambient conditions[b]	Non-condensing at all ambient conditions	[c]	[c]	
Total hydrocarbon	100 µmol/mol	Non-condensing at all ambient conditions	[c]	[c]	
Oxygen (O_2)	[b]	100 µmol/mol	[d]	[d]	
Argon (Ar)	[b]		[d]	[d]	
Nitrogen (N_2),	[b]	400 µmol/mol	[c]	[c]	
Helium (He)			39 µmol/mol	39 µmol/mol	
Carbon dioxide (CO_2)			[e]	[e]	
Carbon monoxide (CO)	1 µmol/mol		[e]	[e]	
Mercury (Hg)		0,004 µmol/mol			
Sulfur (S)	2,0 µmol/mol	10 µmol/mol			
Permanent particulates	[g]	[f]	[f]	[f]	
Density					[f]

Key

NS: Not specified

[a] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" expressed in mole percent, from 100 mole percent.

[b] Combined water, oxygen, nitrogen and argon: maximum mole fraction of 1,9 % (19 000 µmol/mol).

[c] Combined nitrogen, water and hydrocarbon: maximum 9 µmol/mol.

[d] Combined oxygen and argon: maximum 1 µmol/mol.

[e] Total CO_2 and CO: maximum 1 µmol/mol.

[f] To be agreed between the supplier and the customer.

[g] The hydrogen shall not contain dust, sand, dirt, gums, oils or other substances in an amount sufficient to damage the fuelling station equipment or the vehicle (engine) being fuelled.

7.2 Quality verification

7.2.1 General requirements

The supplier shall assure, by standard practice, the verification of the quality level of hydrogen. The sampling and control procedures are described in 7.3.

NOTE ISO 21087 can be used as guidance for validation protocol for analytical methods for the contaminants in Table 4.

7.2.2 Production qualification tests

Production qualification tests are a single analysis or a series of analyses that shall be performed on the product to assure the reliability of the production facility to supply hydrogen of the required quality level. This production qualification may be achieved by verifying the analytical records of product from the supplier, or, if required, by performing analyses of representative samples of the product from the facility at appropriate intervals as agreed between the supplier and the customer. Production qualification tests may be performed by the supplier or by a laboratory agreed upon between the supplier and the customer.

7.3 Sampling

7.3.1 Sample size

The quantity of hydrogen in a single sample container shall be sufficient to perform the analyses for the fuel quality specifications. If a single sample does not contain a sufficient quantity of hydrogen to perform all of the analyses required to assess the quality level, additional samples from the same lot shall be taken under similar conditions.

7.3.2 Gaseous samples

Gaseous samples shall be representative of the hydrogen supply. Samples shall be obtained using one of the following procedures:

a) Fill the sample container and delivery containers at the same time, on the same manifold and in the same manner.

b) Withdraw a sample from the supply container through a suitable connection into the sample container.

   For safety reasons, the sample container and sampling system shall have a rated service pressure at least equal to the pressure in the supply container.

c) Connect the container being sampled directly to the analytical equipment using a suitable pressure regulator to prevent over-pressurizing this equipment.

d) Select a representative container from the containers filled in the lot.

7.3.3 Liquid samples (vaporized)

Vaporized liquid samples shall be representative of the liquid hydrogen supply. Samples shall be obtained using one of the following procedures:

a) by vaporizing, in the sampling line, liquid hydrogen from the supply container;

b) by flowing liquid hydrogen from the supply container into or through a suitable container in which a representative sample is collected and then vaporized.

Annex A
(informative)

Guidance on the selection of the boundary point for PEM fuel cell stationary applications

A.1 Purpose

The following guidance is provided to assist in the identification of the boundary point and who is responsible for the quality of hydrogen at the boundary point.

A.2 Hydrogen production guidance

Hydrogen, and hydrogen-based fuel, may be produced in a number of ways, including reformation of fossil fuels or other hydrocarbons, the electrolysis of pure water or alkaline water, and numerous biological methods. Hydrogen, and hydrogen-based fuels, can be generated on-site, generally in relatively small quantities, or in a larger scale production system off-site, then transported under pressure or as a liquid to the point of use.

A.3 Identification of the party responsible for hydrogen quality at the sampling point

It is recognized that provision of hydrogen to a fuel cell power system may involve numerous parties.

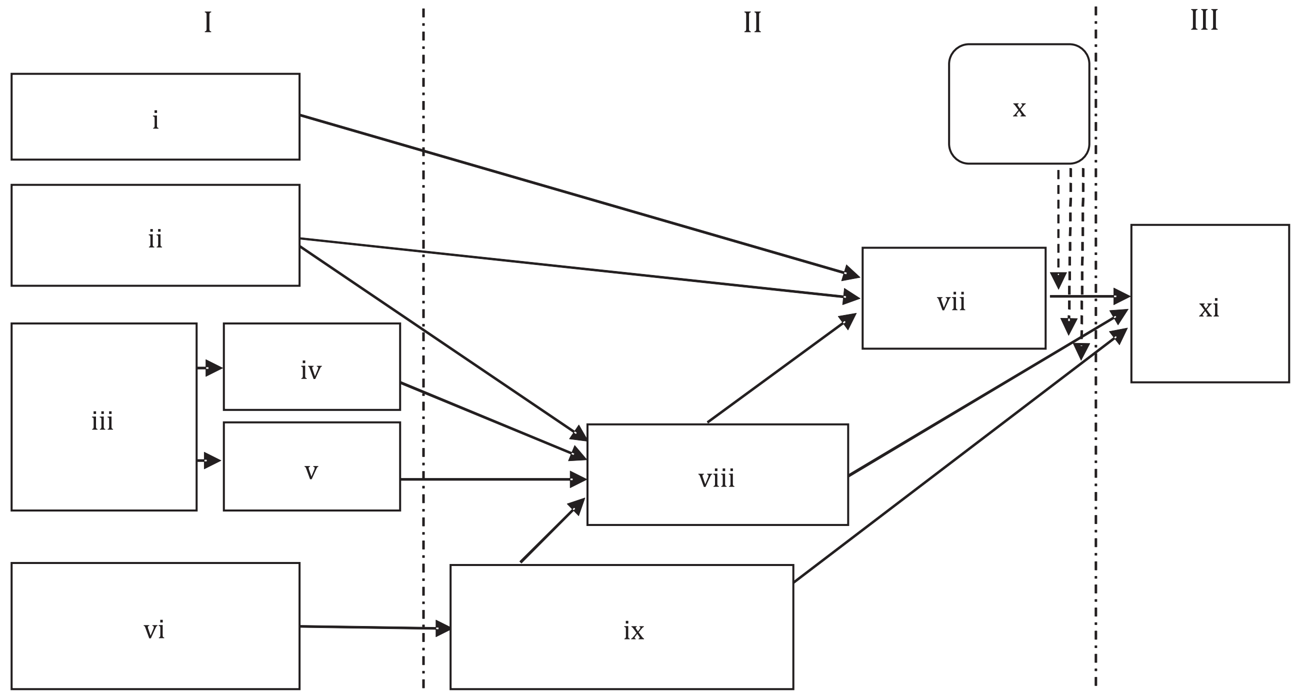
The following text and figure provide examples for information purposes, but are not intended to be comprehensive. Hydrogen delivery systems that incorporate different equipment or hydrogen feedstock should use these examples as a basis for determining the responsibility for the quality of hydrogen at the boundary point and, if appropriate, additional sampling points.

The following are examples of parties involved in and responsible for the supply of hydrogen:

- gaseous hydrogen supplier (for example, cylinders, bundles or tube trailers);
- liquid hydrogen supplier;
- hydrogen via pipeline distributor;
- reformer manufacturer;
- electrolyser manufacturer.

Depending on the form of the hydrogen supply, there may be a requirement for system integrators to provide equipment between the source of the hydrogen and the inlet to the fuel cell power system. Such equipment may comprise, as applicable, the following, shown in Figure A.1:

- pressure regulators;
- liquid hydrogen storage, cryogenic pumps and vaporizers;
- gaseous hydrogen buffer storage;
- additional manifolds from hydrogen source to fuel cell power system inlet.



Key

I	hydrogen supply	II	system integration	III	fuel cell power system
i	delivery by pipeline	ii	delivery by cylinder or tube trailer		
iii	utility supply (natural gas, electricity, water, etc.)	iv	fuel processing system		
v	electrolyser	vi	delivery by truck (liquid hydrogen)	vii	pressure regulator
viii	gaseous hydrogen buffer	ix	liquid hydrogen storage, cryogenics pump, vaporizer		
x	boundary point (for sampling)	xi	PEM fuel cell power system		

Figure A.1 — Examples showing the supply of hydrogen to a fuel cell power system and position of the boundary point

It should be recognized that the system integrator is responsible for the quality of hydrogen at the boundary point, immediately prior to the inlet of the fuel cell power system. If the system integrator and fuel cell power system operator are the same party, one or more appropriate alternative sampling points for meeting hydrogen quality characteristics should be determined by an agreement between the hydrogen supplier and the customer.

In some cases, the system integrator may also be the hydrogen supplier, in which case the responsibility for the hydrogen quality characteristics at the boundary point is that of the hydrogen supplier unless otherwise specified by an agreement between the hydrogen supplier and the customer.

Where the system integrator and hydrogen supplier are different parties, the responsibility for the hydrogen quality characteristics at the boundary point is that of the system integrator. In such cases, the analytical requirements (periodicity, impurities and appropriate interface test point) for the hydrogen supply should be determined by an agreement between the hydrogen supplier, the system integrator and the customer.

It may also be the case that the hydrogen supplier provides some aspects of on-site system integration but does not directly interface with the fuel cell power system. In such cases, the hydrogen supplier is responsible for meeting the hydrogen quality characteristics at the supplier interface to the additional equipment that connects to the fuel cell power system, while the integrator interfacing with the fuel cell power system is responsible for the analytical requirements of the hydrogen quality at the boundary point. The analytical requirements (periodicity, impurities) at any additional sampling points appropriate to the system should be specified by an agreement between the system integrator and the hydrogen supplier.

Where system maintenance is to be carried out by an additional party, the requirements for hydrogen quality assurance following the completion of such maintenance should be determined by an agreement between the system integrator, the party responsible for maintenance and the fuel cell operator.

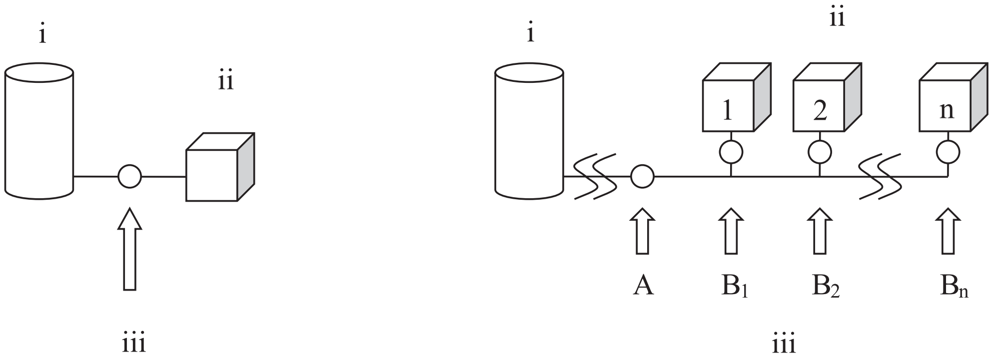
A.4 Selection of the sampling point

In the case of a single fuel cell power system, as shown in Figure A.2 a), the boundary point should be as close as practical to the fuel inlet to the fuel cell power system.

In the case of multiple fuel cell power systems in parallel, as shown in Figure A.2 b), the location of the boundary point should be determined by an agreement between the system integrator and the fuel cell operator.

Examples for the location of the sampling point may include:

- Boundary point A - the supply for fuel cell power systems 1 to n.
- A single boundary point between B_1 and B_n, representing the worst case.
- All boundary points B_1 through B_n.



a) Single fuel cell power system. **b) Multiple fuel cell power systems in parallel.**

Key

i	hydrogen and hydrogen-based fuel supply equipment
ii	PEM fuel cell power system(s)
iii	boundary point(s)

Figure A.2 — Positioning of sampling point

Annex B
(informative)

Rationale for the selection of hydrogen impurities to be measured for PEM fuel cell stationary applications

B.1 Water content

Water (H_2O) generally does not affect the function of a fuel cell; however, it provides a transport mechanism for water-soluble contaminants such as K+ and Na+ when present as an aerosol. Both K+ and Na+ are recommended not to exceed 0,05 µmol/mol for category 3. In addition, water can pose a concern under sub-zero ambient conditions and affect valves. Thus, water must remain gaseous throughout the encountered ambient temperature conditions.

B.2 Total hydrocarbon content

Different hydrocarbons have different effects on fuel cell performance. Generally aromatic hydrocarbons adsorb more strongly on the catalyst surface than alkanes, inhibiting access to hydrogen. Methane (CH_4) is considered an inert gas since its effect on fuel cell performance is to dilute the hydrogen fuel stream.

B.3 Oxygen content

Oxygen (O_2) in low concentrations does not adversely affect the function of the fuel cell power system; but high concentration oxygen causes degradation of the fuel cell.

B.4 Helium, nitrogen and argon contents

Inert constituents, such as helium (He), nitrogen (N_2) and argon (Ar) do not adversely affect the function of fuel cell components or a fuel cell power system. However, they dilute the hydrogen gas.

B.5 Carbon dioxide content

Carbon dioxide (CO_2) does not typically affect the function of fuel cells. It dilutes the hydrogen fuel thereby affecting the efficiency of the fuel cell power system. Furthermore, concentrations of CO_2 higher than 25 % in mole fraction can be catalytically converted via a reverse water gas shift reaction into CO, which in consequence poisons the catalyst. However, under normal operating conditions, such high levels of CO_2 are highly unlikely to be present in the anode.

B.6 Carbon monoxide content

Carbon monoxide (CO) is a severe catalyst poison that adversely affects fuel cell performance and thus needs to be kept at very low levels in hydrogen fuel. While the impact on performance can be reversed by changing operating conditions and/or gas composition, these measures may not be practical. In reformate applications (categories 1 and 2), the impact of the inherently higher CO levels is mitigated through material selection, and/or system design and operation, nonetheless the long term effect of CO on fuel cell durability is a concern, specifically for low anode catalyst loadings.

B.7 Total sulphur concentration

Sulphur-containing compounds are catalyst poisons that at even very low levels can cause some irreversible effects on fuel cell performance. The minimum specific sulphur compounds that need to be included in the testing are: hydrogen sulphide (H_2S), carbonyl sulphide (COS), carbon disulphide (CS_2), mercaptans (e.g. methyl mercaptan), which may be found in hydrogen reformed from natural gas. The total sulphur concentration should be monitored. Lower catalyst loadings are particularly susceptible to catalyst poisoning contaminants.

B.8 Formaldehyde and formic acid contents

Formaldehyde (HCHO) and formic acid (HCOOH) have a similar effect on fuel cell performance as CO and are thus considered as contaminants which cause reversible effects. The effect of HCHO and HCOOH on fuel cell performance can be more severe than that of CO due to slower recovery kinetics and their specifications are lower than that for CO. Lower catalyst loadings are particularly susceptible to catalyst poisoning contaminants.

B.9 Ammonia content

Ammonia (NH_3) causes some irreversible effects on fuel cell performance by contaminating the proton exchange membrane/ionomer and reacting with protons in the membrane/ionomer to form NH_4^+ ions. Test data for ammonia tolerance should include ion exchange capacities of membrane and/or electrodes. Lower catalyst loadings imply lower ion exchange capacities within the electrode.

B.10 Total halogenated compounds contents

Halogenated compounds cause irreversible effects on performance. Potential sources include chlor-alkali production processes and refrigerants used in processing and cleaning agents.

B.11 Particulates

A maximum particulate concentration and size are specified to ensure that filters are not clogged and/or particulates do not enter the PEM fuel power system and affect the operation of valves and fuel cell stacks. Potassium and sodium ions present in aerosols cause irreversible effects on performance by contaminating the proton exchange membrane/ionomer. Iron-containing particulates, even at very low concentrations, cause severe membrane/ionomer degradation.

Annex C
(informative)

Pressure swing adsorption and applicability of CO as an indicator for PEM fuel cell stationary applications

C.1 Indicator: major impurities from different H_2 production and purification processes

For SMR-PSA production and purification, CO can serve as an indicator for the presence of other impurities listed in Table 3 because it has the highest probability of presence in a fuel produced by the given process. Confirmation that CO content is less than its specified limit indicates that other impurities, except inert impurities, are present at less than their specified limits.

The maximum content of inert impurities in the product can be estimated by using the maximum content of inert impurities in the feedstock specified by the supplier and the flow increase in the SMR system and the flow decrease in the PSA system. The flow increase in the SMR system and the flow decrease in the PSA system can be calculated from the feedstock composition, steam to carbon ratio and the hydrogen conversion rate.

C.2 In-line monitoring of the indicator

In-line monitoring of CO is strongly recommended to show that its content in the hydrogen fuel is less than the specification on a real-time basis, which indicates that other contaminants are less than their specifications on a real-time basis. For this purpose, commercially available infrared CO analysers can be used. In the case of an SMR-PSA system, the analyser should be placed just after the SMR-PSA system to avoid contamination of the equipment downstream.

C.3 Batch analysis

For back-up of in-line monitoring of CO content, batch sampling of product hydrogen and laboratory analyses of all impurities constituents as listed in Table 3 are also recommended. The batch sample should be taken at the boundary point. The frequency of sampling and analysis is determined by the hydrogen supplier. The analytical methods as described in 6.2 and 6.3 should be applied.

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New Zealand Standard

Transportable gas storage devices − Hydrogen absorbed in reversible metal hydride

Contents

Preface
[ISO] standard

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

The standard specifies the requirements applicable to the material, design, construction, and testing of transportable hydrogen gas storage systems, referred to as metal hydride (MH) assemblies, which utilise shells not exceeding 150 litres' internal volume and having a maximum developed pressure (MDP) not exceeding 25 MPa.

This document is applicable to refillable storage MH assemblies where hydrogen is the only transferred medium. It is not applicable to storage MH assemblies intended to be used as fixed fuel-storage aboard hydrogen-fuelled vehicles.

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INTERNATIONAL STANDARD

ISO 16111

Second edition
2018-08

Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride

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

Reference number
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by ISO/TC 197, *Hydrogen technologies.*

This second edition cancels and replaces the first edition (ISO 16111:2008), which has been technically revised.

The following clauses have been modified with respect to the previous edition: 2; 3.4; 3.5; 3.9; 3.10; 3.11; 3.12; 3.13; 3.14; 3.15; 3.16; 3.17; 3.18; 3.19; 3.20; 3.21; 3.22; 4.1; 4.3; 5.2.1; 5.3; 5.5; 5.8; 6.2; 6.3; 7.2; 8.1 and Annex D.

The main changes compared to the previous edition concern the following:

- service temperature conditions have been described in further detail (4.3.2);
- shell design has been extended to ISO 11119-3 standard reference (5.3);
- drop test conditions have been modified (6.2.4);
- acceptance criteria have been modified for leak testing (6.2.5);
- hydrogen cycling conditions have been modified (6.2.6);
- new warning labelling has been proposed (7.2);
- information in safety data sheets has been updated (8.1).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

As the utilization of gaseous hydrogen evolves from the chemical industry into various emerging applications, such as fuel for fuel cells and internal combustion engines and other specialty hydrogen 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 the hydrogen later released and used under specific thermodynamic conditions. This document describes the service conditions, design criteria, type tests, batch tests and routine tests for transportable hydride-based hydrogen storage systems, referred to as “metal hydride assemblies” (MH assemblies). Types of MH assemblies may serve as: fuel cell cartridges; hydrogen fuel storage containers; high-purity hydrogen supplies as well as other uses.

Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride

1 Scope

This document defines the requirements applicable to the material, design, construction, and testing of transportable hydrogen gas storage systems, referred to as “metal hydride assemblies” (MH assemblies) which utilize shells not exceeding 150 l internal volume and having a maximum developed pressure (MDP) not exceeding 25 MPa.

This document is applicable to refillable storage MH assemblies where hydrogen is the only transferred media. It is not applicable to storage MH assemblies intended to be used as fixed fuel-storage onboard hydrogen fuelled vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 9809-2, *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 10297:2014, *Gas cylinders — Cylinder valves — Specification and type testing*

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

ISO 11114-2, *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 steels resistant to hydrogen embrittlement*

ISO 11119-1, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 1: Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l*

ISO 11119-2:2012, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners*

ISO 11119-3, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners*

ISO 14246, *Gas cylinders — Cylinder valves — Manufacturing tests and examinations*

ISO 14687 (all parts), *Hydrogen fuel — Product specification*

ISO 16528-1, *Boilers and pressure vessels — Part 1: Performance requirements*

UN Recommendations on the Transport of Dangerous Goods: Model Regulations

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
absorbed, adj.
taken and held through the formation of chemical bonds within the bulk of the material

3.2
burst pressure
highest pressure reached in an MH assembly during a burst test

3.3
design stress limit
total stress loading allowed on the shell wall

Note 1 to entry: In MH assemblies, the shell design takes into account the gas pressure plus other stresses, such as pressure exerted by expansion of the hydrogen absorbing alloy.

3.4
fuel cartridge
MH assembly, which stores hydrogen for use as a fuel in a fuel cell through a valve(s) that controls the discharge of fuel into the fuel cell

3.5
full flow capacity pressure
gas pressure at which the pressure relief device is fully open to have the maximum gas flow

3.6
hydrogen absorbing alloy
material capable of reacting with hydrogen gas to form a reversible metal hydride

3.7
internal component
structure, matrix, material or device contained within the shell (excluding hydrogen gas, hydrogen absorbing alloy and metal hydride)

Note 1 to entry: Internal components may be used for purposes such as heat transfer, preventing movement of the hydrogen absorbing alloy/metal hydride and/or to prevent excessive stress on the shell walls due to hydride expansion.

3.8
internal volume
water capacity of the shell

3.9
maximum developed pressure
MDP

highest gas gauge pressure developed internally to an MH assembly at rated capacity and equilibrium under normal service conditions or normal operating conditions, whichever is greater

Note 1 to entry: The MDP term was specifically selected for MH assemblies to avoid confusion with the maximum allowable working pressure (MAWP) and the service pressure used in other ISO International Standards.

3.10
metal hydride
solid material formed by reaction between hydrogen and hydrogen absorbing alloy

3.11
metal hydride assembly
MH assembly

single complete hydrogen storage system, including shell, metal hydride, pressure relief device (PRD), shut-off valve, other appurtenances and internal components

Note 1 to entry: The MH assembly extends only to, and including, the first shut-off valve.

Note 2 to entry: A fuel cell cartridge is a type of MH assembly.

3.12
normal operating conditions
range of pressures, MH assembly external shell temperatures, hydrogen flow rates, hydrogen quality, etc., specified for all use and filling operations

3.13
normal service conditions
range of pressures and environmental temperatures, specified for transportation and storage conditions

3.14
pressure relief device
PRD

device intended to prevent the rupture of an MH assembly in the event of overpressure or exposure to fire

Note 1 to entry: A pressure relief device may be “pressure-activated”, set to activate at a certain pressure. Alternatively, 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”.

3.15
pressure relief valve
PRV

reseatable pressure relief device (PRD)

3.16
rated capacity
maximum quantity of hydrogen deliverable under specified conditions

3.17
rated charging pressure
RCP

maximum pressure to be applied to the MH assembly for refilling

Note 1 to entry: The RCP is not necessarily equal to the equilibrium plateau pressure of the hydrogen absorbing alloy.

3.18
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 1 to entry: 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.

3.19
rupture
structural failure of a shell resulting in the sudden release of stored energy

3.20
shell
enclosure of any shape (cylindrical, prismatic, cubic, etc.) designed to contain the hydrogen gas, metal hydride and other internal components of the MH assembly

Note 1 to entry: A shell may be a gas cylinder, a pressure vessel or other type of container.

3.21
stress level at MDP
sum of all the stresses on the shell wall caused by the metal hydride at rated capacity, hydrogen gas at MDP and any other applicable mechanical loadings

3.22
test pressure
required pressure applied during a pressure test for qualification

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. In no case shall the MDP exceed 0,8 times the test pressure of the shell. The MDP shall not exceed 25 MPa.

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 MH assembly, and other applicable mechanical loadings.

4.2 Rated capacity

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

4.3 Temperature ranges

4.3.1 Operating temperature range

The minimum and maximum MH assembly temperature for normal operating conditions shall be specified by the manufacturer.

4.3.2 Service temperature range

The minimum and maximum ambient shell temperatures for normal service conditions shall be a minimum of −40 °C and a maximum of +65 °C. If the maximum and minimum shell temperatures are to be different from those specified, they shall be identified by the manufacturer.

4.4 Environmental conditions

The MH assemblies 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 MH assembly was designed.

4.5 Service life

The service life for the MH assemblies 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 according to 5.3.

4.6 Hydrogen quality

The minimum quality of the hydrogen gas that shall be used to fill an MH assembly shall be specified by the manufacturer according to ISO 14687 (all parts) or as appropriate.

If the quality of the hydrogen gas is considered a critical issue to avoid performance degradation of the MH assembly, the manufacturer may consider including the information on the product label.

4.7 Special service conditions

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

5 Design considerations

5.1 General

The MH assembly shall be designed and constructed to prevent leakage of free hydrogen gas or metal hydride particles under normal service and operating conditions.

5.2 Material selection

5.2.1 General

The MH assembly components shall be made of materials that are suitable for the range of conditions expected over the life of the MH assembly. 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 or operating conditions to maintain operational and pressure containment integrity.

Hydrogen absorbing alloys and/or metal hydride materials that are classified as Type I explosive materials according to the UN Recommendations on the Transport of Dangerous Goods shall not be used in an MH assembly.

5.2.2 External surfaces

The MH assembly shell, shut-off valve, PRDs and other components 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 applicable test methods specified in Annex B. Any coatings applied to MH assemblies 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 MH assembly.

5.2.3 Compatibility

The compatibility of MH assembly materials with process fluids and solids, specifically embrittlement due to the exposure to hydrogen, shall be considered. Guidance on compatibility of materials with gases is given in ISO 11114-1 and ISO 11114-2. Materials necessary for the pressure containment and structural integrity of the MH assembly and its internal and external components shall be resistant to hydrogen embrittlement, hydrogen attack and reactivity with contained materials and maintain their integrity for the service life of the MH assembly. 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.

Consideration shall be given to all of the chemical species that may be present during the charged, partially charged and discharged states and their potential reactivity with the MH assembly material. The MH assembly materials shall be selected so as the combination does not endanger the MH assembly 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.

5.2.4 Temperature

The MH assembly materials shall be suitable for the service and operating temperature range specified in 4.3.1 and 4.3.2.

5.3 Shell design

5.3.1 Shells with internal volume greater than 120 ml

The MH assembly shell shall be designed and tested according to ISO 7866, ISO 9809-1, ISO 9809-3, ISO 11119-1, ISO 11119-2, ISO 11119-3 or for design or shape shell not covered by the previous standards the manufacturer shall prove their performance in accordance to ISO 16528-1. Shells designed and tested in accordance with ISO 9809-1 shall have a tensile strength less than 950 MPa. Shells designed and tested in accordance with ISO 11119-1 or ISO 11119-2 that use seamless steel liners conforming to ISO 9809-2 or to ISO 9809-1 shall have a tensile strength less than 950 MPa. Shells designed with proof of performance according to ISO 16528-1 are considered as pressure vessels.

The shell shall not exceed 150 l internal volume, and the MDP shall not exceed 25 MPa. The maximum combined stresses for the loads described in 5.4 as well as the operating and service temperature ranges for the MH assembly shall not exceed the limits prescribed by the standard to which the shell is designed.

NOTE An equivalent gas pressure calculated to be equal to the stress level at MDP can be used as the design hydraulic test pressure for determining minimum shell wall thickness.

5.3.2 Shells with internal volume of 120 ml or less

For MH assemblies with an internal volume of 120 ml or less, the shell design shall be deemed to be appropriate if the shell meets 5.3.1 or the MH assembly meets the following design and test criteria:

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

b) the MH assembly design shall withstand as required by 6.2.3, without leaking or bursting, a minimum shell burst pressure of 2 times the pressure in the MH assembly at 55 °C when filled to rated capacity, or 1,6 times the pressure in the MH assembly at the maximum service temperature when filled to rated capacity, or 200 kPa more than the MDP of the assembly at 55 °C when filled to rated capacity, whichever is greater.

5.4 Design strength

The shell design shall take into account the stress level at 1,25 times MDP. Consideration of components contributing to the stress level at MDP shall include but not be limited to:

- 1,25 × MDP;
- thermal stress, including dissimilar rates of thermal expansion and contraction;
- weight of internals in any possible MH assembly 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 MH assembly design shall be subjected to the hydrogen cycling and strain measurement test described in 6.2.6.

NOTE The process of introducing and subsequently removing hydrogen in the hydrogen absorbing alloy typically 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 can have significantly decreased. Stresses on the MH assembly walls can 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 MH assembly. The magnitude of the expansion/contraction phenomena varies greatly as a function of the hydrogen absorbing alloy used.

5.5 Overpressure and fire protection

5.5.1 General

The MH assembly shall be protected with one or more PRDs of the non-reclosing type, such as thermally activated PRD, rupture disks and diaphragms, or of the re-sealable type, such as spring-loaded PRVs. The MH assembly and any added component (e.g. insulation or protective material) shall collectively pass the fire test specified in 6.2.2. The PRD shall conform to the requirements of 5.5.2 and 5.5.3 and the additional requirements of the competent authority of country of use, as applicable.

For MH assemblies with an internal volume of 120 ml or less, other means may be used to protect from overpressurization, such as venting through a feature integral to the shell. MH assemblies that use an alternative means of relieving pressure shall meet the acceptance criteria of the fire test specified in 6.2.2.

Re-sealable PRV is not recommended for MH assembly having composite or aluminium shell. For these MH assemblies the manufacturer shall use other type of overpressure and fire protection.

5.5.2 PRD activation pressure

The pressure of actuation of pressure-activated PRDs shall be specified by the manufacturer and shall be greater than the MDP but less than 1,25 times the MDP. In no case shall the pressure of actuation of a pressure-activated PRD exceed the test pressure of the shell. For PRVs, the full flow capacity pressure shall also be specified, and shall not exceed the test pressure of the shell.

5.5.3 PRD activation temperature

The temperature at which any thermally activated PRD is set to activate shall be specified by the manufacturer and correspond to an equilibrium pressure inside the MH assembly of less than 1,25 times the MDP. In no case shall the temperature of actuation of a temperature-activated PRD result in an equilibrium pressure inside the MH assembly that exceeds the test pressure of the shell. The PRD shall have a pressure rating greater than the MDP at all temperatures less than or equal to 10 °C above the maximum service temperature or operating temperature (whichever is higher). In no case shall the PRD activate at a temperature lower than the maximum service or operating temperature.

Due to the MDP definition, an equilibrium pressure less than 1,25 times the MDP is in accordance with 4.1.1 and 5.4, which respectively refer to the MDP assessment and the shell design. As an immediate consequence, the pressure inside the MH assembly cannot exceed the test pressure of the shell at the temperature of actuation**.**

5.6 Loading of hydrogen absorbing alloy

Procedures and verification testing shall be put in place to ensure the consistent loading of the hydrogen absorbing alloy/metal hydride in the MH assembly.

5.7 Shut-off valves

5.7.1 General

The MH assembly shall incorporate a shut-off valve that shall be capable of being closed when the MH assembly is disconnected from the refill or gas-consuming equipment. The shut-off valve may be manually actuated, such as by a handwheel, or automatically actuated.

All MH assemblies shall provide a means of shut-off valve protection that complies with 5.7.4 or 5.7.5.

The shut-off valve selection shall include verification that the shut-off valve seal is maintained with vacuum conditions within the MH assembly.

NOTE Due to the temperature/pressure characteristics of metal hydrides, the development of sub-ambient pressures is possible within MH assemblies.

5.7.2 MH assemblies with internal volume greater than 120 ml

Shut-off valves shall comply with ISO 10297, or equivalent, with the following adjustment:

a) 3 times MDP shall be used as the resistance pressure for the valve.

b) Valve test pressure, p_{vt}, shall be equal to 1,5 times the MDP.

c) Gas pressure for endurance test shall be equal to 0,5 times the MDP.

In addition, the shut-off valve shall meet all requirements and tests prescribed in this document.

Alternatively, if the shut-off valve cannot demonstrate full compliance to ISO 10297 or equivalent, the shut-off valve construction and performance shall meet all the requirements and tests prescribed in this document as well as the following requirements:

- the material requirements of ISO 10297:2014, 4.3;
- the test requirements of ISO 10297:2014, 6.1 to 6.8, as they apply to the tests prescribed below with the exception the valve test pressure, p_{vt}, shall be equal to 1,5 times the MDP;
- the hydraulic pressure test of ISO 10297:2014, 6.9, with the exception that 3 times the MDP shall be used as the test pressure;
- the leak tightness test of ISO 10297:2014, 6.11, where p_{vt} shall be equal to 1,5 times the MDP;
- the endurance test of ISO 10297:2014, 6.12, using a gas pressure equal to 0,5 times the MDP. When the shut-off valve does not incorporate a handwheel, the forces and torques used in the endurance test shall be representative of those used in service to open and close the valve member. Prior to and following the endurance test, the shut-off valve shall be tested for leakage from an internal and external leakage perspective at a test pressure of 1,5 times MDP at minimum and maximum service temperature. Leakage rates less than or equal to 6 standard cm^3/h (standard conditions of 0 °C and 101,325 kPa absolute) shall be acceptable.

The minimum rated pressure of the shut-off valve shall be at least equal to 1,5 times MDP.

In addition, the shut-off valve manufacturer shall demonstrate that the shut-off valve is subjected to the requirements of ISO 14246.

5.7.3 MH assemblies with internal volume of 120 ml or less

For MH assemblies with an internal volume of 120 ml or less, the shut-off valve construction and performance shall meet all requirements and tests prescribed in this document as well as the following requirements:

- the material requirements of ISO 10297:2014, 4.3;
- the test requirements of ISO 10297:2014, 6.1 to 6.8, as they apply to the tests prescribed below with the exception that the valve test pressure, p_{vt}, shall be equal to 1,5 times the MDP;
- the hydraulic pressure test of ISO 10297:2014, 6.9, with the exception that the test pressure shall be in accordance with 5.3.2 b) and the test may be performed pneumatically;
- the leak tightness test of ISO 10297:2014, 6.11, where p_{vt} shall be equal to 1,5 times the MDP. Valve closure may be determined using torque, compression or other suitable means and the test gas shall be helium;
- the endurance test of ISO 10297:2014, 6.12, using a gas pressure equal to 0,5 times the MDP and minimum number of 100 cycles. When the shut-off valve does not incorporate a handwheel, the forces and torques used in the endurance test shall be representative of those used in service to open and close the valve member. Prior to and following the endurance test, a shut-off valve shall be tested for leakage from an internal and external leakage perspective at a test pressure of 1,5 times MDP at minimum and maximum service temperature. Leakage rates less than or equal to 3 standard cm^3/h (standard conditions of 0 °C and 101,325 kPa absolute) shall be acceptable.

The minimum rated pressure of the shut-off valve shall be at least equal to the MDP.

In addition, the shut-off valve manufacturer shall demonstrate that the shut-off valve is subjected to the requirements of ISO 14246.

5.7.4 Integral shut-off valve protection

An MH assembly design that uses an integral method of shut-off valve protection that is not meant to be removed for MH assembly operation, such as the use of a shroud, collar or recessing the valve in the MH assembly, shall meet the requirements of the drop test in 6.2.4.

5.7.5 Removable shut-off valve protection

MH assembly designs that use a removable means of shut-off valve protection that is meant to be removed for MH assembly operation, such as a cover, cap or guard, shall meet the requirements of the drop test in 6.2.4 with the protective means in place and meet the requirements of the shut-off valve impact test in 6.2.7 without the protective means in place.

Removable means of shut-off valve protection, having passed the drop test in 6.2.4, shall be acceptable for use only with filled MH assemblies at a mass equal to or less than the mass tested and with MH assemblies with shut-off valves of dimensions not exceeding those of the tested shut-off valve.

5.8 Actively cooled MH assemblies

MH assemblies that employ an active cooling system to control and/or affect system temperature shall be designed to ensure that there will be no inadvertent leakage of fluid between the MH assembly and the cooling system. The cooling system shall be employed when performing the hydrogen cycling and strain measurement test in 6.2.6.

Some coolants can react with hydrides. If such coolant is used it shall be properly addressed in the risk assessment.

5.9 Particulate containment

Particulate matter shall not impede the functioning of the valves or PRDs. A means of particulate matter containment may be used to achieve this purpose. The MH assemblies shall meet the requirements of the fire test of 6.2.2 and the hydrogen cycling and strain measurement test of 6.2.6.

6 Inspection and testing

6.1 General

In order to ensure that the MH assemblies are in compliance with this document, they shall be subject to inspection and testing in accordance with this clause.

6.2 Type/qualification tests

6.2.1 General

The following type tests shall be performed to qualify an MH assembly design. The MH assemblies used for the type tests shall be representative of production MH assemblies. The data for all type tests shall be acquired using calibrated instruments.

Any change in shell design, hydrogen absorbing alloy, manufacturing process or loading procedure of hydrogen absorbing alloy shall require repeating the fire test of 6.2.2, the drop test of 6.2.4 and the hydrogen cycling and strain measurement test of 6.2.6, and, if applicable, the thermal cycling test of 6.2.8.

Compliance to this document shall be recorded for each MH assembly design on a type approval certificate. An example of a suitably worded certificate is given in Annex C.

6.2.2 Fire test

6.2.2.1 General

The fire test shall be performed on all new MH assembly designs to demonstrate that the fire protection system, such as PRD and/or integral thermal insulation, will prevent the rupture of the MH assembly under the specified fire conditions. The bonfire test conditions should be in agreement with the one proposed in the reference standard used for the shell design in 5.3.

Any significant change to the design as defined in the standard (see 5.3) to which the shell is designed (including, but not limited to, changes in diameter, length, shell material type and minimum design thickness) and any change to the type, number or flow capacity of the PRD, means of solid particulate containment or in the hydrogen absorbing alloy shall necessitate repeating the fire test.

As an exception, a manufacturer may use data and engineering calculations, based on previous fire test results on existing designs, in cases involving design changes that would reduce the risk of shell failure in the fire test (e.g. reduction in shell length, or increase in PRD flow capacity), to show that a new design does not require repeating the fire test.

Precautions should be taken to ensure safety of personnel and property during the fire test in the event that an MH assembly rupture occurs.

6.2.2.2 Sample preparation

The MH assembly shall be filled to rated capacity with hydrogen.

6.2.2.3 Data monitoring and recording

The temperature and pressure of the MH assembly shall be monitored remotely and recorded at intervals not more than 15 s. A valve shall be installed to allow venting of the MH assembly in the event of a malfunction of the test equipment or system.

In addition to the temperature and pressure readings, the following information shall also be recorded for each test:

- MH assembly manufacturer;
- MH assembly part or model number;
- unique identifier;
- PRD-type and rating;
- PRD location and orientation;
- date of test;
- MH assembly RCP;
- number of charge/discharge cycles that the MH assembly has undergone;
- MH assembly orientation (vertical, horizontal or inverted);
- ambient temperature;
- estimated wind condition/direction;
- names of witnesses;
- time of activation of PRD; and
- elapsed time to completion of the test.

For MH assembly designs that contain small quantities of hydrogen that preclude accurate monitoring of pressure during the fire test, a statement of justification for not monitoring the pressure during the fire test shall be provided, along with a description of the means for determining activation of the PRD.

6.2.2.4 Test set-up, fire source and test method

The fire tests shall be conducted on at least three MH assemblies in each orientation of intended use and/or transportation. For MH assembly designs for which the orientation of use and transportation are not specified, at least three MH assemblies shall be fire tested in each of the vertical and horizontal orientation and any other orientation due to asymmetry of the MH assembly design, if applicable. The tests shall include at least one test with the PRD oriented towards the fire source and at least one test with the PRD oriented 180° away from the fire source.

The MH assemblies, over their entire width, shall be subjected to a fire source of a maximum length of 1,65 m. For MH assemblies less than 1,65 m in length, the fire source shall totally engulf the MH assembly. MH assemblies longer than 1,65 m or equipped with multiple PRDs with a spacing greater than 1,65 m, shall be subjected to a partial engulfment fire test in the horizontal orientation. If an MH assembly is longer than 1,65 m and is fitted with a PRD at one end, the opposite end of the MH assembly shall be subjected to the fire source. If the MH assembly is fitted with PRDs at both ends, or at more than one location along the length of the MH assembly, the fire source shall be centred midway between the PRDs that are separated by the greatest horizontal distance.

For MH assemblies less than or equal to 0,30 m in length, a temperature-indicating device shall be installed within 0,05 m of, but not in contact with, the MH assembly surface near each end. For MH assemblies greater than 0,30 m in length, a temperature-indicating device shall be installed at each end and one at the midpoint. Temperature-indicating devices may be inserted into small metallic blocks (less than 0,025 m per side).

MH assemblies shall be subjected to a direct flame impingement test. Sufficient fuel shall be supplied to ensure a burn time of at least 20 min. The MH assembly shall be placed in the test orientation with the MH assembly at least 0,1 m above the fuel or at a greater height to ensure total flame engulfment. The fire shall produce a flame that totally engulfs the MH assembly. Shielding shall be used to prevent direct flame impingement on the shut-off valve, fittings, and/or PRD(s). The shielding shall not be in direct contact with the specified fire protection system.

Any fuel may be used for the fire source, provided it supplies uniform heat sufficient to maintain the specified test conditions for a minimum of 20 min. The fire test should be carried out in a properly ventilated facility or in open ground for safety. The selection of a fuel should take into consideration air pollution concerns. The arrangement of the fire shall be recorded in detail to ensure that the rate of heat input to the MH assembly is reproducible.

MH assemblies that have been subjected to the cycling and strain measurement test of 6.2.6 may be used in this test.

6.2.2.5 Acceptance criteria

Any failure or inconsistency of the fire source during a test shall invalidate the result, and a re-test shall be carried out. Any venting through, or rupture of, the shell, valve, fitting or tubing during the test that is not part of the intended protection system, shall invalidate the result and a re-test shall be carried out.

The MH assembly design shall be deemed to have passed the fire test if, for all valid tests, there is no generation of projectiles and one of the following criteria is met:

— the PRD or other venting method of all MH assemblies subjected to the fire test vent each MH assembly to zero gauge pressure without rupture of the MH assembly; or

— all MH assemblies subjected to the fire test withstand the fire for a minimum of 20 min without rupture.

6.2.3 Initial burst tests for MH assemblies with an internal volume of 120 ml or less

At least three MH assemblies shall be subjected to an initial burst test to demonstrate compliance to 5.3.2 b). Either a hydrostatic or a pneumatic burst test shall be performed; however, all tests shall be performed in the same manner. All bursts shall occur in the same manner for all tests performed. The rate of pressurisation shall be less than 345 kPa/sec.

Adequate precautions should be taken to ensure safety of equipment and personnel. In particular, during a pneumatic burst testing, personnel should be aware of the potential for releases of large amounts of stored energy and potentially hazardous materials as a result of the burst.

6.2.4 Drop or impact test

6.2.4.1 General requirements

6.2.4.1.1 MH assembly with mass of 25 kg or less

All MH assembly with mass lower than 25 kg designs shall meet the requirements of the drop test. Any significant change to the design as defined in the standard (see 5.3) to which the shell is designed (including, but not limited to, changes in diameter, length, shell material type and minimum design thickness) and any change in shut-off valve, means of solid particulate containment or loaded mass of the hydrogen absorbing alloy shall necessitate repeating the drop test.

The surface onto which the MH assemblies are dropped shall be a smooth, horizontal, concrete or steel surface. The container shall be allowed to bounce on the concrete or steel surface after the initial impact. No attempt shall be made to prevent this secondary impact. A guide rail for posture maintenance may be used, provided that it does not reduce the free-fall velocity.

6.2.4.1.2 MH assembly with mass greater than 25 kg

All MH assembly with mass higher than 25 kg designs shall meet the requirement of the blunt impact test. Any significant change to the design as defined in the standard (see 5.3) to which the shell is designed (including, but not limited to, changes in diameter, length, shell material type and minimum design thickness) and any change in shut-off valve, means of solid particulate containment or loaded mass of the hydrogen absorbing alloy shall necessitate repeating blunt test.

6.2.4.2 Sample preparation MH assembly with mass of 25 kg or less

The MH assemblies used for these tests shall include their integral or removable shut-off valve protection (see 5.7.4 and 5.7.5). The MH assemblies shall have an equivalent weight (±2 %), packing density and internal structure as production MH assemblies. Ballast material may be used in place of the hydrogen absorbing alloy. The MH assemblies shall not be pressurized.

6.2.4.3 Drop test procedure

MH assemblies shall be drop tested in accordance with the following conditions. One MH assembly may be used for all drop tests performed in a) to c). The drop tests shall be carried out at room temperature $\left(20^{+10}_{-5}\right)$ °C.

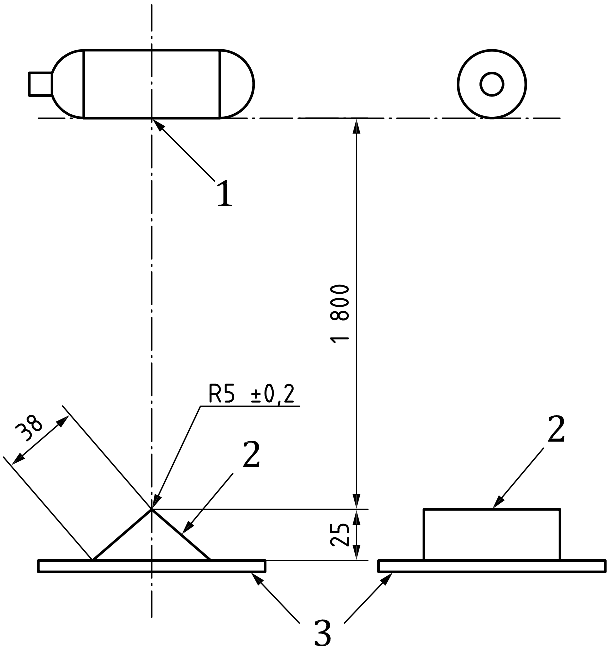
a) One MH assembly shall be dropped vertically on the end containing the shut-off valve assembly. One MH assembly shall be dropped vertically on the end opposite the shut-off valve assembly. In both cases, the MH assembly shall be dropped from a height of not less than 1,8 m measured from the lower end of the MH assembly.

b) One MH assembly shall be dropped at a 45° angle on the end containing the shut-off valve assembly from a height such that the centre of gravity is at a minimum height of 1,8 m. If the lower end of the MH assembly is at a height of less than 0,6 m, the drop angle shall be changed to maintain the lower end of the MH assembly and the centre of gravity at a minimum height of 0,6 m and 1,8 m respectively. When the shut-off valve, PRD and other components are set on both ends of the MH assembly, the MH assembly shall be dropped at a 45° angle on its weakest end.

c) One MH assembly shall be dropped horizontally from a height of 1,8 m onto a steel apex as shown in Figure 1. The MH assembly shall be placed such that its centre of gravity is aligned with the rounded edge of the steel apex as shown in Figure 1. In order to prevent movement of the steel apex by the collision of the MH assembly, the steel apex shall be fixed to the concrete pad or flooring. The MH assembly shall strike the steel apex before striking the concrete pad or flooring.

d) For shells of composite design (such as shells designed according to ISO 11119-1, ISO 11119-2 or ISO 11119-3) at least one additional MH assembly shall be dropped according to a) and b).

Dimensions in millimetres



Key

1 centre of gravity

2 steel apex

3 smooth, horizontal concrete pad or flooring

Figure 1 — MH assembly drop test onto an apex

6.2.4.4 Acceptance criteria for MH assembly with mass of 25 kg or less

6.2.4.4.1 General

The shut-off valve shall remain operational (i.e. capable of being opened and closed) after all drop tests.

All MH assemblies that have undergone the drop tests shall be visually inspected and all apparent damage recorded. All MH assemblies shall be subjected to the leak test of 6.2.5 at a temperature of $\left(20^{+10}_{-5}\right)$ °C and MDP and meet the acceptance criteria.

MH assemblies dropped in accordance to 6.2.4.3 d), shall additionally be subjected to the ambient cycle test of ISO 11119-2:2012, 8.5.5, and withstand 3 000 pressurization cycles at five-sixths of the MDP without failure by burst or leakage.

After successful completion of the leak test and, if applicable, the ambient cycle test specified above, all MH assemblies shall be pressurized to destruction as per 6.2.4.4.2 or 6.2.4.4.3 and meet the acceptance criteria.

6.2.4.4.2 MH assemblies with internal volume greater than 120 ml

The MH assemblies shall be pressurized to destruction using a hydrostatic burst test. The recorded burst pressures shall exceed 85 % of the minimum shell burst pressure specified by the standard to which the shell was designed. All bursts shall occur in a manner consistent with the standard to which the shell was designed and in the same manner for all tests performed.

6.2.4.4.3 MH assemblies with internal volume of 120 ml or less

The MH assemblies shall be pressurized to destruction using a hydrostatic or a pneumatic burst test. The recorded burst pressures shall exceed 85 % of the minimum shell burst pressure specified in 5.3.2. All bursts shall occur in a manner consistent with the initial burst test of 6.2.3 and in the same manner for all tests performed.

Adequate precautions should be taken to ensure safety of equipment and personnel. In particular, during a pneumatic burst testing, personnel should be aware of the potential for releases of large amounts of stored energy and potentially hazardous materials as a result of the burst.

6.2.4.5 Blunt impact test for MH assembly with mass greater than 25 kg

The shells of MH assemblies designed and tested according to ISO 7866, ISO 9809-1, ISO 9809-3, ISO 11119-1, ISO 11119-2, ISO 11119-3 having mass higher that 25 kg shall be subjected to blunt impact testing in accordance with 6.2.4.6.

The shells of MH assemblies designed with proof of performance in accordance to IS0 16528 shall be tested in accordance to the procedure of Type 1 and Type 2 shells following procedure described in 6.2.4.6 the blunt impact test must be performed at the lowest shell thickness location.

6.2.4.6 Blunt impact test procedure

For MH assemblies using Type 1 and Type 2 shells, one empty shell shall be subjected to two impacts: The blunt impact test must be performed at the lowest shell thickness location:

a) at the MH assembly sidewall midway between the ends;

b) at the termination of the overwrap near the domes for Type 2.

For MH assemblies using Type 3 and Type 4 shells, one empty shell shall be subjected to two impacts in each of the following positions:

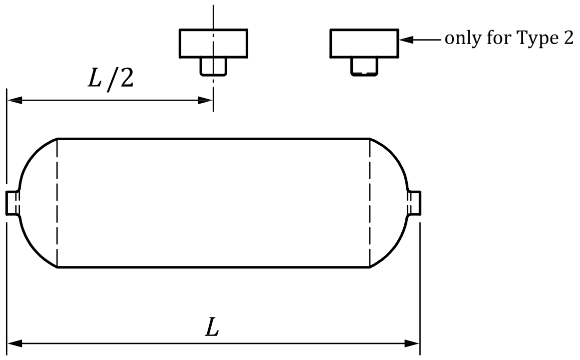
a) at the MH assembly sidewall midway between the ends;

b) at an angle of 45° to strike the shoulder of the tube (mid arc length at the dome).

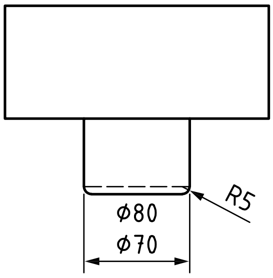
The impact can be conducted by dropping a suitable weight or by a pendulum impact.

The MH assembly shall be secured to ensure it does not move during the impact. The impactor shall be made from a steel bar and have a diameter of between 70 mm and 80 mm and strike the tube with an energy of 1 200 joules.

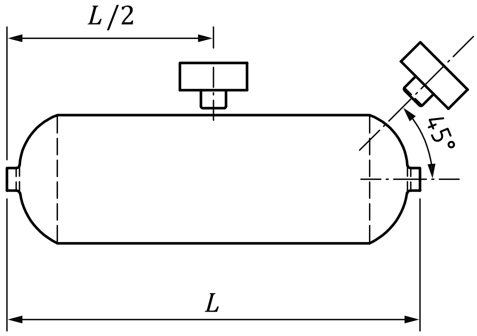
Parameters to monitor and record is the visual appearance after each impact. Record position and dimensions of impact damage.



a) Type 1 & Type 2 tubes



b) Example of impactor



c) Type 3 & Type 4 tubes

Figure 2 — Blunt impact test procedure

6.2.4.7 Acceptance criteria for MH assemblies with mass greater than 25 kg

The shell shall withstand N/4 pressurisation cycles at MDP without failure by burst or leakage. The test shall continue for a further N cycles, or until the shell fails by leakage, whichever is the sooner. In either case the MH assembly shall be deemed to have passed the test. However if failure during this second part of the test is by burst, then the MH assembly shall have failed the test. N is the number of cycles required in the shell standards for example 12 000 cycles for ISO 7866.

The parameter recorded during these tests are:

a) temperature of the MH assembly;

b) number of cycles achieving upper cyclic pressure;

c) minimum and maximum cyclic pressures;

d) cycle frequency;

e) test medium used;

f) mode of failure, if appropriate.

6.2.5 Leak test

6.2.5.1 Test procedure

The MH assembly shall be charged with hydrogen, helium, or a blend of the two, and monitored for leaks at the conditions indicated in Table 1.

Table 1 — Temperature/pressure conditions for leak test

Temperature	Pressure
Minimum service temperature	RCP
$\left(20_{-5}^{+10}\right)$ °C	RCP
Highest temperature between maximum service temperature or maximum operating temperature	MDP

Before placing the MH assembly in an enclosed area to perform the leak test of either 6.2.5.2.1 or 6.2.5.2.2, it is recommended to test for the presence of major leaks using a soap bubble solution, or by other adequate means, on all possible leak locations.

6.2.5.2 Acceptance criteria

6.2.5.2.1 MH assemblies with internal volume greater than 120 ml

The total hydrogen leak rate shall be less than K standard cm^3/h (standard conditions of 0 °C and 101,325 kPa absolute). If hydrogen gas is not used, the leak rate shall be converted into an equivalent hydrogen leak rate.

The value of K is defined by the following equation: K should be the greater value of 6 or 0,1 times the internal volume of the shell (in litres/150).

6.2.5.2.2 MH assemblies with internal volume of 120 ml or less

The total hydrogen leak rate shall be less than 3 standard cm^3/h (standard conditions of 0 °C and 101,325 kPa absolute). If hydrogen gas is not used, the leak rate shall be converted into an equivalent hydrogen leak rate.

6.2.6 Hydrogen cycling and strain measurement test

6.2.6.1 General

The hydrogen cycling and strain measurement test shall be performed on all new MH assembly designs to demonstrate that the design stress limits of the shell are not exceeded during use. Any significant change to the design as defined in the standard (see 5.3) to which the shell is designed (including, but not limited to, changes in diameter, length, shell material type and minimum design thickness) and means of solid particulate containment or formulation of or loaded mass of the hydrogen absorbing alloy shall necessitate repeating the hydrogen cycling and strain measurement test. MH assemblies that employ an active cooling system to control and/or affect system temperature shall be subjected to the test with the cooling system in place.

Precautions should be taken to ensure safety of personnel and property during testing in the event that an MH assembly failure or hydrogen release occurs.

6.2.6.2 Test set-up

Each MH assembly shall be adequately instrumented with strain gauges to determine the maximum local strain that the shell experiences during cycling. With MH assemblies, the strain may not be uniform throughout the MH assembly. The number and location of the strain gauges required to measure the highest strain experienced by the shell may be determined from engineering models based on knowledge of the design, including stress distribution and analysis information provided by the shell manufacturer, the internal configuration and geometry, hydrogen absorbing alloy distribution, etc. If engineering models cannot accurately determine the points of expected highest strain, the number and locations of required strain gauges shall be empirically determined by extensively instrumenting at least two MH assemblies with strain gauges and performing the test. Based on the results, further testing may be performed using fewer strain gauges that are strategically placed to measure the highest strain levels experienced by the shell.

As a minimum, the hoop strain shall be monitored on cylindrical and dome sections of MH assemblies, bending strain shall be monitored on flat sections of MH assemblies and for strain concentration points (such as corners and edges), the strain in areas around the concentration point shall be monitored, and a concentration factor shall be used to estimate the strain at the concentration point.

The strain gauges shall be protected from damage during extended testing and exposure to the cycling environment, for example by the use of a chemically-resistant epoxy. Periodically during and, at least, at the start and end of cycling, the strain gauges shall be calibrated to ensure proper functioning. If any strain gauge is found to not be properly functioning, it shall be replaced.

The strain at the design stress limit shall be determined either by engineering calculations based on the shell design and material properties, or empirically by internally applying either a pneumatic or hydrostatic pressure up to a pressure equivalent to the shell design stress limit and measuring the strain. For any MH assembly where the strain gauges are applied to an outer layer and not directly to the shell or liner in contact with the metal hydride and hydrogen gas (such as shells of type II and III fibre-wrapped composite cylinder design) or for any shell that has been intentionally subjected to plastic deformation (i.e. autofrettage), the strain at the design stress limit for each gauge shall be determined empirically prior to cycling the MH assemblies with hydrogen.

6.2.6.3 Test method

For MH assemblies designed to be transported and used in a single orientation, at least five MH assemblies shall be tested in that orientation, four shall be tested with the procedure including vibrational sequence described below and one shall be tested only with hydrogen cycling without vibration. For MH assembly designs that do not preclude use in more than one orientation, at least three MH assemblies shall be tested in two orientations perpendicular to each other, with the MH assembly axis horizontal and vertical. Two of each set of three shall be tested with the procedure including vibrational sequence and one shall be tested only with hydrogen cycling without vibration. The MH assemblies shall be hydrogen charge cycled from not more than 5 % of rated capacity to not less than 95 % of rated capacity. The RCP shall be used for charging and the temperatures shall be held within the operating temperature range. The cycling shall be continued for at least 106 cycles and until the acceptable results defined in 6.2.6.4 are met. If the measured strain on consecutive cycles exceeds the design stress limit or plastic deformation of the shell material occurs, the testing shall be discontinued.

As a minimum, a measurement from each strain gauge shall be recorded on every cycle while at the maximum charge condition.

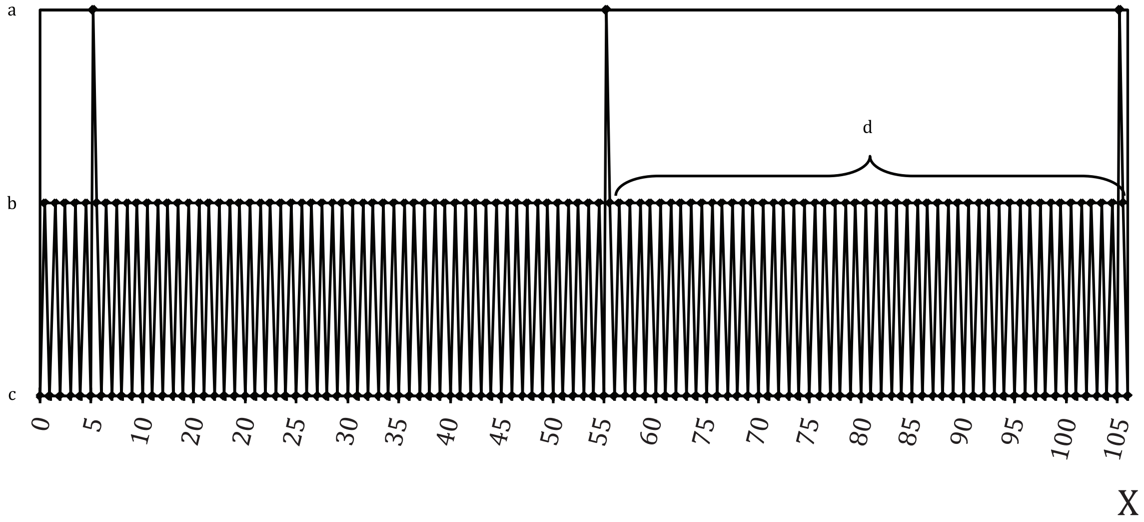
After the fifth complete cycle and then at intervals of not more than 50 cycles, with the MH assemblies charged to not more than 5 % of their rated capacity, depending on the orientation of use several MH assemblies shall be subjected to the following vibration sequence while in the orientation for cycling:

— A sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min. This cycle shall be repeated 12 times for a total of 3 h for each MH assembly. The logarithmic frequency sweep shall be as follows: from 7 Hz a peak acceleration of 1 g_n shall be maintained until 18 Hz is reached. The amplitude shall then be maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately at 50 Hz). A peak acceleration of 8 g_n shall then be maintained until the frequency is increased to 200 Hz.

For MH assemblies with a mass greater than 100 kg, the following vibration sequence may be used as an alternative to the above sequence.

— Simple harmonic motion with a vertical amplitude of 0,8 mm with a 1,6 mm maximum total excursion. The frequency shall be varied at a rate of 1 Hz/min between the limits of 10 Hz to 55 Hz. The entire range of frequencies and return shall be traversed in (95 ± 5) min.

Figure 3 shows the minimum cycling requirements.



Key

X cycle number

a Vibrate.

b Charge.

c Discharge.

d Last 50 consecutive cycles.

Figure 3 — Graphical depiction of minimum cycle requirements

Depending on the orientation of use of MH assemblies, one or two MH assemblies shall be subjected only to the charge and discharge of hydrogen.

6.2.6.4 Acceptance criteria

For each strain gauge in a period of 50 consecutive cycles, either the maximum measured strain shall not be greater than 50 % of the strain at the design stress limit, or, there is no trend of increasing strain. The MH assembly shall be considered to have failed the test and a redesign shall be required if, for any strain gauge, the strain for consecutive cycles exceeds the strain for the shell at the design stress limit or if the shell experiences plastic deformation.

To determine that there is no trend of increase in strain, the data for each strain gauge with a maximum strain greater than 50 % of the strain at the design stress limit shall be analysed by the least squares linear regression method, according to Formula (1):

$$a = \frac{\left(\sum_{i=j}^{j+N} y_i x_i\right) - N\,\bar{y}\,\bar{x}}{\left(\sum_{i=j}^{j+N} x_i^2\right) - N\,\bar{x}^{\,2}} \qquad (1)$$

where

a	is the coefficient indicating the slope of the measured strain data;
x	is the cycle number;
$\bar{x}=\frac{1}{N}\sum_{i=j}^{j+N} x_i$	(average cycle number);
N	shall be 50, the number of consecutive cycles analysed;
y	the measured strain; and
$\bar{y}=\frac{1}{N}\sum_{i=j}^{j+N} y_i$	(average strain).

The MH assembly shall be cycled until, for a period of 50 consecutive cycles, the coefficient a is less than or equal to zero for all strain gauges that have a strain reading greater than 50 % of the strain at the design stress limit. The 50 cycles analysed shall be the final 50 consecutive cycles performed. This criterion shall be met by all strain gauges on an MH assembly for the same period of consecutive cycles.

Additionally, after completion of the cycling and strain measurement test, all MH assemblies shall be pressurized, and with a blank-off on the outlet, the valve shall be cycled between the open and closed positions a minimum of two times. With the blank-off removed from the outlet, all MH assemblies shall meet the acceptance criteria of the leak test of 6.2.5. At least two MH assembly from each orientation tested shall be subjected to the fire test of 6.2.2 and meet the acceptance criteria. One of the MH assembly shall tested with vibrational sequence and one without.

Further, for MH assemblies with an internal volume of 120 ml or less, after completion of the leak testing, at least one MH assembly from each orientation, tested with vibrational sequence, shall be pressurized to destruction. The burst test may be either a hydrostatic or a pneumatic burst test. The recorded burst pressures shall exceed the minimum shell burst pressure specified in 5.3.2. All bursts shall occur in a manner consistent with the initial burst specified in 6.2.3 and in the same manner for all tests performed.

Adequate precautions should be taken to ensure safety of equipment and personnel. In particular, during pneumatic burst testing, personnel should be aware of the potential for releases of large amounts of stored energy and potentially hazardous materials as a result of the burst.

For MH assemblies that employ an active cooling system to control and/or affect system temperature, any inadvertent leakage between the MH assembly and cooling fluid shall be considered a failure to meet the acceptance criteria of this test.

6.2.7 Shut-off valve impact test

6.2.7.1 General

As indicated in 5.7.5, MH assembly designs that employ a removable means of valve protection shall be subjected to the following shut-off valve impact test.

6.2.7.2 Sample preparation

Three MH assemblies shall be subjected to this shut-off valve impact test. For the purpose of this test, ballast may be used in place of the hydrogen absorbing alloy or the shell may be left empty. The MH assemblies shall not be pressurized with gas during the test. The removable shut-off valve protection shall be removed for this test.

6.2.7.3 Test procedure

A hardened steel ball or an impact object tipped with a hardened steel ball shall be used for this test. The hardened steel ball shall have a Brinell hardness of 248 ± 3 and its diameter shall be allowed to vary with respect to the size of the shut-off valve to allow it to strike the side of the valve 90° to the longitudinal axis of the valve and co-incident with a plane passing through the same axis.

The hardened steel ball, or the impact object tipped with a hardened steel ball, as well as the MH assembly, shall be conditioned for at least 4 h at −40 °C. Within 5 min after conditioning, the MH assembly shall be rigidly anchored and the shut-off valve shall be subjected to the following two impacts. The first impact shall strike the side of the shut-off valve 90° to the longitudinal axis of the valve and co-incident with a plane passing through the same axis. The points of impact on the shut-off valve shall not be obstructed by features such as outlet connecting threads, pressure relief devices, handwheel, etc. The hardened steel ball or the impact with a hardened steel ball object shall have sufficient mass and velocity to impart the minimum energy specified in Table 2. After the first impact, the MH assembly shall be rotated 180° and a second side impact test shall be conducted on the other side of the shut-off valve.

Table 2 — Ball impact requirements for valves

MH assembly type (V = internal volume in litres)	**Minimum energy (E)**[a] joules
$V < 0{,}35$	1,02
$0{,}35 < V < 10$	6,80
$10 < V < 25$	13,50
$25 < V < 100$	27,10
$100 < V$	162,70

[a] For example, for a free falling impact object tipped with a hardened steel ball,

$$E = mg_c h$$

where

E is energy, expressed in joules (J);

m is mass of the impact object tipped with a hardened steel ball, expressed in kilograms (kg);

g_c is the acceleration due to gravity (9,8 m/s^2);

h is the vertical drop height, expressed in metres (m).

6.2.7.4 Acceptance criteria

Following the two impact tests, each shut-off valve and MH assembly shall be visually inspected for damage and subjected to the leak test of 6.2.5 at $\left(20^{+10}_{-5}\right)$°C and MDP and meet the requirements therein.

The shut-off valve connection (inlet threads) shall remain intact without cracking and the shut-off valve shall be operative. A break of the handwheel shall not be considered as a failure to meet the test requirements as long as the shut-off valve is still capable of being opened and closed.

If the requirements of the leak test are not met or the shut-off valve does not remain operational after the tests, the test shall be repeated on three MH assemblies fitted with their removable shut-off valve protection. If the three MH assemblies meet the acceptance criteria, the design shall be considered as acceptable, provided each MH assembly is marked in accordance with 7.2.3.

6.2.8 Thermal cycling test

6.2.8.1 General

The thermal cycling test shall be performed on MH assemblies with an internal volume of 120 ml or less only.

NOTE This test is performed to address potential concerns regarding not having performed a pressure cycling test similar to that prescribed in the ISO cylinder standards. This test is intended to thermally cycle a complete MH assembly over its service temperature range.

6.2.8.2 Test set-up

For MH assemblies designed to be transported and used in a single orientation, at least five MH assemblies shall be tested in that orientation. For MH assembly designs that do not preclude use in more than one orientation, at least three MH assemblies shall be tested in two orientations perpendicular to each other, with the MH assembly axis horizontal and vertical.

The MH assembly shall be filled to rated capacity with hydrogen. The MH assembly shall be placed in a temperature-controlled test chamber capable of cycling from minimum service temperature to maximum service temperature and vice versa over a period of 2 h.

6.2.8.3 Test procedure

The MH assemblies shall be subjected to the following thermal cycles (see Figure 4).

a) Place the MH assembly in the temperature-controlled test chamber and increase the chamber temperature from $\left(20_{-5}^{+10}\right)$ °C to the maximum service temperature with a tolerance of ±5 °C in 1 h ± 5 min.

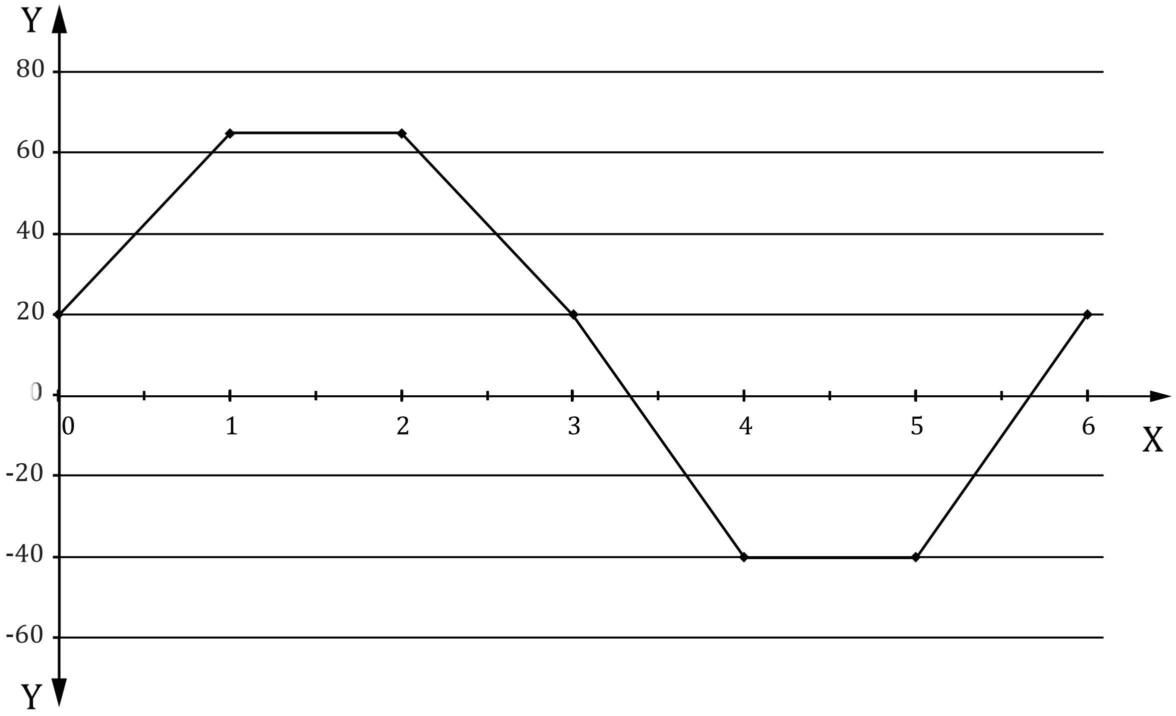
b) Keep the MH assembly at the maximum service temperature with a tolerance of ±5 °C for a minimum of 1 h.

c) Decrease the chamber temperature to $\left(20_{-5}^{+10}\right)$ °C in 1 h ± 5 min, then decrease the chamber temperature to the minimum service temperature with a tolerance of ± 5 °C in 1 h ± 5 min.

d) Hold the chamber temperature at the minimum service temperature with a tolerance of ±5 °C for a minimum of 1 h.

e) Increase the chamber temperature to $\left(20_{-5}^{+10}\right)$ °C in 1 h ± 5 min.

f) Repeat steps a) to e) 50 times.



Key

X	time (h)
Y	temperature (°C)

Figure 4 — Temperature cycling test example cycle

6.2.8.4 Acceptance criteria

Each MH assembly shall be subjected to, and meet the acceptance criteria of, the leak test of 6.2.5 following the thermal cycling test.

After completion of the leak testing, at least one MH assembly from each orientation tested shall be pressurized to destruction. The burst test may be either a hydrostatic or a pneumatic burst test. The recorded burst pressures shall exceed the minimum shell burst pressure specified in 5.3.2. All bursts shall occur in a manner consistent with the initial burst test specified in 6.2.3 and in the same manner for all tests performed.

Adequate precautions should be taken to ensure safety of equipment and personnel. In particular, during pneumatic burst testing, personnel should be aware of the potential for releases of large amounts of stored energy and potentially hazardous materials as a result of the burst.

6.2.9 Type test reports

The type test reports verifying compliance with the requirements of this document shall be made available to users upon request.

6.3 Batch tests

6.3.1 General requirements

Batch testing shall be conducted at specified intervals during manufacturing to ensure consistency of the manufactured MH assemblies with the prototype design.

The size of a batch shall be determined by the manufacturer with consideration to the volume of MH assembly and the material of construction. Two type of batch size can be considered:

a) The hydride–batch size consists of one lot of hydrogen absorbing alloy or as approved by the competent authority.

b) The shell-batch size consists of the batch size of the shell as defined in the shell standard, or as approved by the competent authority.

All batch tests of the MH assembly shall be carried out on finished MH assemblies.

6.3.2 Burst test for shell-batch

At least one shell from each batch shall be pressurized to destruction.

For MH assemblies with internal volume greater than 120 ml, the burst tests methods and acceptance criteria shall meet the requirements of the standard (see 5.3.1) to which the shell is designed.

For MH assemblies with an internal volume of 120 ml or less, the burst tests shall be performed in accordance with 6.2.3. All bursts shall occur in a manner consistent with the initial bursts tests specified in 6.2.3 and in the same manner for all tests performed.

Adequate precautions should be taken to ensure safety of equipment and personnel. In particular, during pneumatic burst testing, personnel should be aware of the potential for releases of large amounts of stored energy and potentially hazardous materials as a result of the burst.

6.3.3 MDP Test for hydride-batch

At least one MH assembly from each hydride-batch shall be tested to verify the MDP according to 4.1.1. In no case the MDP of each batch shall exceed 0,80 times the test pressure of the shell or 25 MPa.

6.4 Routine tests and inspections

6.4.1 Routine tests

The manufacturer shall perform routine tests and inspection on each MH assembly and maintain records for not less than 20 years or 1,5 times the service life of the MH assembly, whichever is longer.

As part of the routine tests, each completed MH assembly shall be subjected to the leak test of 6.2.5 at $\left(20^{+10}_{-5}\right)$ °C and RCP and meet the acceptance criteria.

For all shells used in the manufacturing of MH assemblies, the MH assembly manufacturer shall obtain and maintain the documentation verifying that the shell was manufactured, tested and qualified in accordance to the shell standard. The MH assembly manufacturer shall also perform incoming inspection of shells to the degree necessary to ensure that the shells meet the specified requirements.

6.4.2 Certificates of manufacture

A certificate of manufacture shall be prepared for each batch of MH assemblies that meets the requirements of this document in all respects. An example of a suitably worded certificate is given in Annex D.

7 Marking, labelling, and documentation

7.1 Marking

The MH assembly shall have, as a minimum, the following information permanently marked in a clearly visible location:

a) a reference to this document, i.e. ISO 16111;

b) the RCP in bar;

c) the manufacturer's identification;

d) the date of manufacturing (month and year);

e) a manufacturer's serial or unique identification number; and

f) the date of expiry based on the maximum service life (month and year).

In cases where, due to size or area limitations, it is not possible to include all of the above information in a legible format, the use of a traceable code may be used. If a traceable code is used, the MH assembly shall still be permanently marked with the RCP, the manufacturer's serial or unique identification number and the date of expiry as per b), e) and f).

7.2 Labelling

7.2.1 General

The precautionary labelling shall be in accordance with ISO 7225. Labels shall not obscure any permanent shell markings.

In cases where, due to size or area limitations, it is not possible to include all information on the label, the information may be included on the packaging or in the documentation distributed with the product, except for a warning that the “contents are flammable”, which shall always be included on the product label.

NOTE The authority having jurisdiction might require additional labelling such as the appropriate UN identification number and description as defined in the UN Model Regulations on the Transport of Dangerous Goods, part or model number and other cautions and hazard warnings pertinent to the metal hydride MH assembly.

7.2.2 Hazards associated with the solid materials

The manufacturer shall include on the label warnings consistent with the potential hazards of the materials contained within the MH assembly. Consideration should include hazards from reactivity with air, water or other fluids.

7.2.3 Labelling concerning removable valve protection

When required by 6.2.7.4, labelling shall include the following, “WARNING: Valve may be damaged if subjected to impact. KEEP VALVE PROTECTION IN PLACE WHEN NOT CONNECTED FOR USE.”

7.2.4 Temperature warning labelling

The manufacturer shall include on the label a warning: “DO NOT EXPOSE TO TEMPERATURES ABOVE xx °C, OPEN FLAMES OR IGNITION SOURCES.”, where xx shall be no greater than the maximum service or operating temperature whichever is greater.

According to 4.3.2, the minimum and maximum ambient shell temperatures for normal service conditions shall be a minimum of −40 °C and a maximum of +65 °C. If the maximum and minimum shell temperatures are to be different from those specified, they shall be identified by the manufacturer on the label.

8 Documentation accompanying the product

8.1 Safety data sheets

The safety data sheets (SDS) covering both the hydrogen gas and the contained hydrogen absorbing alloy shall be provided for inclusion with all product shipments. The SDS shall include safety and handling requirements to be followed in case of hydrogen leakage and/or breach of the storage system, exposing the hydrogen absorbing alloy and any potential reactivity with substances such as air, water and cooling fluids, if applicable. Particular attention should be provided by the manufacturer about the flammability of metal hydride and shall provide safety recommendation in case of metal hydride fire.

8.2 User's or operating manual

8.2.1 General

A user's or operating manual shall be provided by the manufacturer. The user's or operating manual shall include the minimum service conditions specified in Clause 4, hydrogen quality, initial fill and refill procedures, disposal and recycling information and/or other pertinent limitations on use, including the minimum ventilation for the in-use and storage locations, the minimum periodic testing and inspection procedures, if applicable.

8.2.2 Initial fill and refill procedures

8.2.2.1 Inspection prior to initial filling and refilling

The manufacturer shall specify inspection procedures to be carried out prior to initial filling and prior to refilling of the MH assembly.

Items to be inspected shall include whether the MH assembly is within its service life, labels are legible and secure, components are not damaged or missing in the interface, and that the shell and valve are not damaged, and have not been tampered with or abused.

Criteria shall be provided as to when refilling is allowed or when an MH assembly shall be removed from service.

8.2.2.2 Charging specifications

The manufacturer shall provide the following information, for the initial filling and refilling of the MH assembly:

- safety precautions and potential hazards of which to be aware;
- method for determining when the rated capacity described in 4.2 has been achieved;
- minimum and maximum pressure range (maximum pressure shall not exceed RCP);
- minimum and maximum temperature range;
- other special conditions required for the initial filling and refilling.

8.2.2.3 Equipment

The manufacturer shall specify the requirements for the equipment to be used for initial filling and refilling of MH assemblies to prevent overcharging.

8.2.2.4 Inspections and checks after initial filling and refilling

The manufacturer shall specify an inspection procedure to be carried out after the initial filling and after refilling of the MH assembly. Items to be inspected shall include leakage of hydrogen from the MH assembly and damaged or missing components in the interface (e.g. damaged threads, O-rings or seals).

8.2.2.5 Periodic inspection and testing

The manufacturer shall specify the minimum periodic inspection and testing requirements. These requirements shall be in accordance with the applicable ISO periodic inspection and test standard for the shell (e.g. ISO 6406, ISO 10461 and ISO 11623). In all cases, the periodicity for the periodic inspection and testing shall not exceed 5 years.

Annex A
(informative)

Material compatibility for hydrogen service

A.1 Material compatibility for hydrogen service

The components in which gaseous hydrogen or hydrogen-containing fluids are processed, as well as all parts used to seal or interconnect the same, should be sufficiently resistant to the chemical and physical action of hydrogen at the operating conditions.

A.2 Metals and metallic materials

The users of this document should be aware that engineering materials exposed to hydrogen in their service environment may exhibit an increased susceptibility to hydrogen assisted corrosion via different mechanisms such as hydrogen embrittlement and hydrogen attack.

Hydrogen embrittlement is defined as a process resulting in a decrease of the toughness or ductility of a metal due to the permeation of atomic hydrogen.

Hydrogen embrittlement has been recognized classically as being of two types. The first, known as internal hydrogen embrittlement, occurs when the hydrogen enters the metal matrix through material processing techniques and supersaturates the metal with hydrogen. The second type, environmental hydrogen embrittlement, results from hydrogen being absorbed by solid metals coming from the service environment.

The atomic hydrogen dissolved within a metal interacts with the intrinsic defects of the metal typically increasing crack-propagation susceptibility, and thus degrading such basic properties as ductility and fracture toughness. There are both important material and environmental variables that contribute to hydrogen-assisted fractures in metals. The material microstructure is an important consideration as second phases, which may or may not be present due to compositional and processing variations, may affect the resistance of the metal to fracture. Second phases, such as ferrite stringers in austenitic stainless steels, may also have a specific orientation leading to profound anisotropic response in the materials. In general, metals can also be processed to have a wide range of strengths, and the resistance to hydrogen-assisted fracture is known to decrease as the strength of the alloy is increased.

The environmental variables affecting hydrogen-assisted fracture include the pressure of hydrogen, temperature, chemical environment and strain rate. In general, the susceptibility to hydrogen-assisted fracture increases as hydrogen pressure increases. The effect of temperature, however, is not as systematic. Some metals such as austenitic stainless steels exhibit a local maximum in hydrogen-assisted fracture susceptibility as a function of temperature. Although not well understood, trace gases mixed with hydrogen gas can also affect hydrogen-assisted fractures. Moisture, for example, may be detrimental to aluminium alloys since wet oxidation produces high-fugacity hydrogen, while in some steels moisture is believed to improve the resistance to hydrogen-assisted fracture by producing surface films that serve as kinetic barriers to hydrogen uptake. A so-called inverse strain rate effect is generally observed in the presence of hydrogen; in other words, metals are less susceptible to hydrogen-assisted fracture at high strain rates.

At temperatures close to ambient, this phenomenon can affect metals with body centred cubic crystal lattice structure, for example ferritic steels. In the absence of residual stress or external loading, environmental hydrogen embrittlement is manifested in various forms, such as blistering, internal cracking, hydride formation and reduced ductility. With a tensile stress or stress-intensity factor exceeding a specific threshold, the atomic hydrogen interacts with the metal to induce sub-critical crack growth leading to fracture.

Hydrogen embrittlement can occur during elevated-temperature thermal treatments, and in service during electroplating, contact with maintenance chemicals, corrosion reactions, cathodic protection, and operating in high-pressure or high temperature hydrogen.

Many low-alloyed structural steels may suffer from hydrogen attack at temperatures as low as 200 °C. This is a non-reversible degradation of the steel microstructure caused by a chemical reaction between diffusing hydrogen and the carbide particles in the steel that results in the nucleation, growth and merging of methane bubbles along grain boundaries to form fissures.

Hydride embrittlement occurs in metals such as titanium and zirconium and is the process of forming thermodynamically stable and relatively brittle hydride phases within the structure.

Clad welding and welds between dissimilar materials often involve high alloy materials. During operation at temperatures over 250 °C, hydrogen diffuses in the fusion line between the high-alloy weld and the unalloyed/low alloy base material. During shutdown, the material temperature drops. The reduced solubility and diffusibility of hydrogen breaks the weld by disbonding.

The following are some general recommendations for managing the risk of hydrogen embrittlement.

- Select raw materials with a low susceptibility to hydrogen embrittlement by controlling the chemistry (e.g. use of carbide stabilizers), microstructure (e.g. use of austenitic stainless steels), and mechanical properties (e.g. restriction of hardness, preferably below 225 HV, and minimization of residual stresses through heat treatment). Use test methods specified in ISO 11114-4 to select metallic materials resistant to hydrogen embrittlement. The API Publication 941 shows the limitations of various types of steel as a function of hydrogen pressure and temperature. The susceptibility to hydrogen embrittlement of some commonly used metals is summarized in ISO/TR 15916.
- Clad welds and welds between dissimilar materials used in hydrogen service should be ultrasonically tested at regular intervals and after uncontrolled shutdowns in which the equipment may have cooled rapidly.
- Minimize the level of applied stress and exposure to fatigue situations.
- When plating parts, manage the anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.
- Clean the metals using non-cathodic alkaline solutions, and using inhibited acid solutions.
- Use abrasive cleaners for materials having a hardness of 40 HRC or above.
- Use process control checks, when necessary, to mitigate risk of hydrogen embrittlement during manufacturing.

A.3 Polymers, elastomers and other non-metallic materials

Most polymers can be considered suitable for gaseous hydrogen service. Due account should be given to the fact that hydrogen diffuses through these materials much more easily than through metals. Polytetrafluoroethylene (PTFE) and polychlorotrifluoroethylene (PCTFE) are generally suitable for hydrogen service. Suitability of other materials should be verified. Guidance can be found in ISO 11114-2, ISO/TR 15916 and ANSI/AIAA G-095.

A.4 Other references

Further guidance on hydrogen assisted corrosion and control techniques may be found through the following organizations and their standards:

A.4.1 International Organization for Standardization (www.iso.org)

See Bbibliography [1] to[12].

A.4.2 American Institute of Aeronautics and Astronautics (www.aiaa.org)

See Bibliography [13].

A.4.3 American Petroleum Institute (www.api.org)

See Bibliography [14] and [15].

A.4.4 American Society for Testing and Materials (www.astm.org)

See Bibliography [16] to [30].

A.4.5 American Society of Mechanical Engineers (www.asme.org)

See Bibliography [31] to [33].

A.4.6 American Welding Society (www.aws.org)

See Bibliography [34].

A.4.7 ASM International (www.asminternational.org) and Society of Automotive Engineers (www.sae.org)

See Bibliography [35] to [37].

A.4.8 National Association of Corrosion Engineers (www.nace.org)

See Bibliography [38] and [39].

Annex B
(normative)

Environmental tests

B.1 Exposure to fluids

B.1.1 General

This test is applicable to MH assembly shells comprised of Type II, III and IV fibre-wrapped cylinders.

Two shells shall be tested in a condition representative of installed geometry including coating (if applicable), brackets and gaskets, and pressure fittings using the same sealing configuration (i.e. O-rings) as that used in service.

The two shells are subjected to preconditioning in accordance with B.1.2 and then exposed to a sequence of environments, pressures and temperatures in accordance with Table B.1. Although preconditioning and fluid exposure is performed on the cylindrical section of the shell, all of the shell, including the domed sections, shall be as resistant to the exposure environments as are the exposed areas. As an alternative, a single cylinder approach may be used in which both the immersion test and the other fluid exposure test may be carried out on one cylinder as indicated in Table B.1. In this case, care shall be taken to prevent cross contamination among the fluids.

B.1.2 Preconditioning

B.1.2.1 Preconditioning apparatus

The following types of apparatus shall be used for preconditioning the test shell by pendulum and gravel impact.

The pendulum impact apparatus shall comprise:

a) a steel impact body having the shape of a pyramid with equilateral triangle faces and a square base, the summit and the edges being rounded to a radius of 3 mm;

b) a pendulum, the centre of percussion of which coincides with the centre of gravity of the pyramid; its distance from the axis of rotation of the pendulum being 1 m and the total mass of the pendulum referred to its centre of percussion being 15 kg;

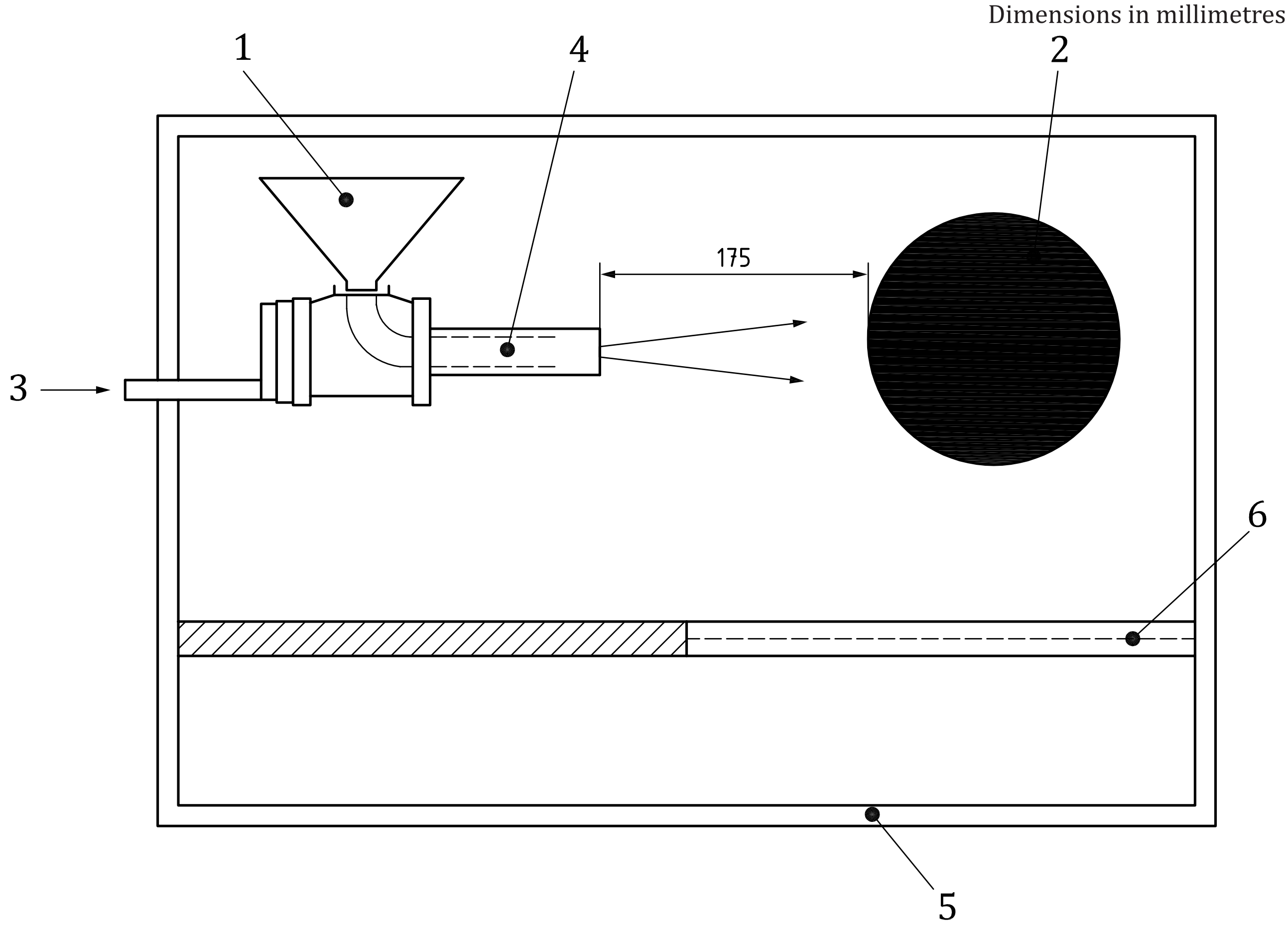
c) a means of determining that the energy of the pendulum at the moment of impact is not less than 30 N·m and is as close to that value as possible;

d) a means of holding the shell in position by the end bosses during impact.

The gravel impact machine shall comprise:

a) an impact machine, constructed according to the design specifications shown in Figure B.1 and capable of being operated in accordance with ASTM D3170 except that the shell may be at ambient temperature during gravel impact;

b) gravel, comprising alluvial road gravel passing through a 16 mm space screen but retained on a 9,5 mm space screen. Each application shall consist of 550 ml of graded gravel (approximately 250 stones to 300 stones).



Key

1	funnel
2	shell under test
3	air inlet
4	50 mm pipe
5	cabinet approximately 500 mm wide
6	sizing screen

Figure B.1 — Gravel impact machine

B.1.2.2 Preconditioning procedure

B.1.2.2.1 Preconditioning for the immersion test

Preconditioning by both pendulum impact and gravel impact shall be carried out on the portion of the shell to be used for the immersion test (see B.1.3.1).

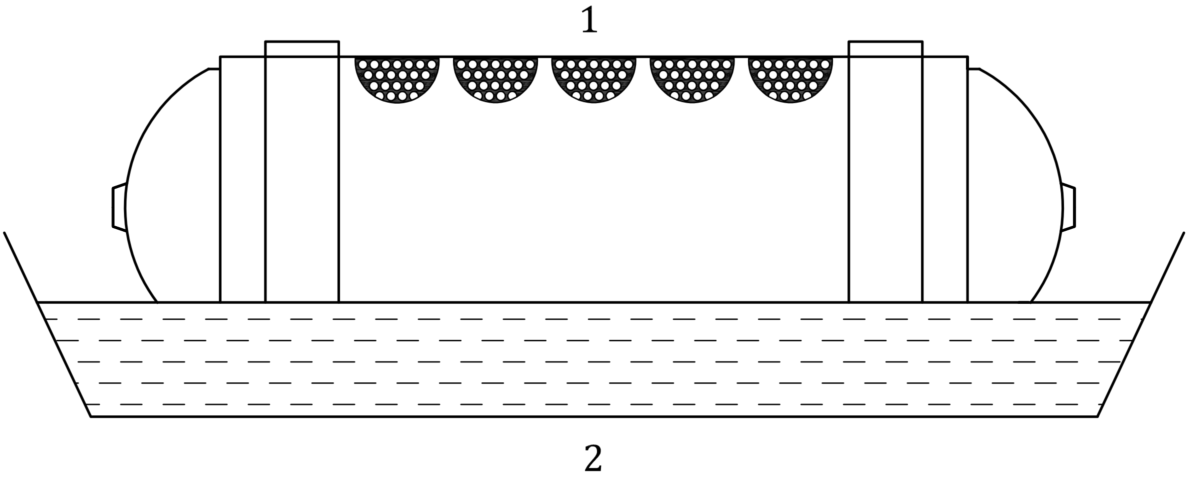
With the shell unpressurized, precondition the central section of the shell that will be submerged, by an impact of the pendulum body at three locations spaced approximately 150 mm apart. Following the pendulum impact, precondition each of the three locations by gravel impact application. Additionally, precondition by a single impact of the pendulum body a location within the submerged portion of each domed section and 50 mm (measured axially) from the tangent.

B.1.2.2.2 Preconditioning for the other fluid exposure test

Preconditioning by gravel impact only shall be carried out on the portion of the shell to be used for the other fluid exposure test (see B.1.3.2).

Divide the upper section of the cylinder used for the other fluid exposure test into five distinct areas of a nominal diameter 100 mm and mark these for preconditioning and fluid exposure (see Figure B.2). Ensure that the areas do not overlap on the shell surface. If the single shell approach is used, also ensure that these areas do not overlap with the section of the shell that will be subjected to the immersion test. While convenient for testing, the areas need not be oriented along a single line.

With the shell unpressurized, precondition each of the five marked areas identified as per the above instructions (see Figure B.2) for the other fluid exposure test by gravel impact application.



Key

1	other fluid exposure area
2	immersion area (lower third)

Figure B.2 — Cylinder orientation and layout of exposure areas

B.1.3 Test conditions

B.1.3.1 Immersion test

At the appropriate stages in the test sequence (see Table B.1), orient the shell horizontally to immerse the lower third of the shell diameter in a simulated acid rain/road salt water solution composed of the following compounds:

- deionized water;
- a mass fraction of (2,5 ± 0,1) % of sodium chloride;
- a mass fraction of (2,5 ± 0,1) % of calcium chloride;
- sulfuric acid in sufficient quantity to achieve a solution pH of 4,0 ± 0,2.

Adjust the solution level and pH prior to each step of the immersion test.

Maintain the temperature of the bath at (21 ± 5) °C. During immersion, hold the unsubmerged section of the shell in ambient air.

B.1.3.2 Other fluid exposure

At the appropriate stages in the test sequence (see Table B.1), expose each marked area to one of five test solutions described below. Use the same test solution for each location throughout the test:

- an aqueous solution with a minimum volume fraction of 19 % of sulfuric acid;
- an aqueous solution with a minimum mass fraction of 25 % sodium hydroxide;
- a volume fraction of 30 % methanol in gasoline;
- an aqueous solution with a minimum mass fraction of 28 % ammonium nitrate;
- an aqueous solution with a minimum volume fraction of 50 % methyl alcohol (i.e. windscreen washer fluid).

During the exposure, orient the test cylinder with the exposure area uppermost. Place a pad of glass wool approximately 0,5 mm thick and 100 mm in diameter on each of the preconditioned areas. Using a pipette, apply 5 ml of the test solution to the glass wool pad. Ensure that the glass wool pad is wetted evenly across its surface and through its thickness. Pressurize the shell and remove the glass wool pad after pressurization for 30 min.

B.1.3.3 Pressure cycle

At the appropriate stage in the test sequence (see Table B.1), subject the shell to hydraulic or pneumatic pressure cycles of between 5 % MDP and MDP for the ambient and high temperature steps, and between 5 % MDP and 60 % MDP for the lower temperature steps. Hold the maximum pressure for a minimum of 60 s and ensure that each full cycle takes no less than 66 s.

B.1.3.4 High and low temperature exposure

At the appropriate stages in the test sequence (see Table B.1), bring the surface of the shell to a high or low temperature in air. The low temperature shall be no higher than −35 °C and the high temperature shall be at minimum the maximum service temperature (65 °C or greater) as measured on the surface of the shell.

B.1.4 Test procedure

Precondition the shells (or shell in the single shell approach) in accordance with B.1.2.

Carry out the sequences of fluid, pressure cycling and temperature exposure as defined in Table B.1. Do not wash or wipe the shell surface between stages;

Table B.1 — Test conditions and sequence

Test steps			**Environment**	**Number of pressure cycles**	**Temperature**
Two shell approach		**Single shell approach**			
Shell no. 1	Shell no. 2	Alternative single shell			
—	1	1	other fluids (30 min)	—	ambient
1	—	2	immersion	500 × service life (years)	ambient
—	2	—	air	250 × service life (years)	ambient
—	3	3	other fluids (30 min)	—	ambient

Table B.1 *(continued)*

Test steps			**Environment**	**Number of pressure cycles**	**Temperature**
Two shell approach		**Single shell approach**			
Shell no. 1	Shell no. 2	Alternative single shell			
2	4	4	air	250 × service life (years)	low
—	5	5	other fluids (30 min)	—	ambient
3	6	6	air	250 × service life (years)	high

Following completion of the sequences, all MH assemblies shall be pressurized to destruction as per 6.2.4.4.2 or 6.2.4.4.3 and meet the acceptance criteria.

B.2 Salt water immersion test

B.2.1 General

This test is mandatory for all MH assemblies intended for underwater discharging/refilling or underwater applications. It is optional for other uses.

B.2.2 Set-up

The shell shall be unpainted but otherwise finished as for the intended application.

For shells comprised of Type II and Type III fibre-wrapped cylinders, the liner may be painted or protected from corrosion in any manner that is included in the design submission.

B.2.3 Immersion period

Two closed unpressurized shells shall be immersed for a period of between 1 h and 2 h in a well aerated aqueous solution containing at least 35 g/l of sodium chloride at a temperature not less than 20 °C.

After 2 h, the pressure of the shell shall be increased to and maintained at five-sixths the MDP for not less than 22 h. Pressure is then to be released.

B.2.4 Drying period

After the immersion period, the shells shall be taken out from the sodium chloride solution and subjected to natural drying conditions in ambient atmosphere for not less than 22 h.

The pressure of the shell shall be increased to and maintained at five-sixths the MDP for not less than 2 h. Pressure is then to be released.

B.2.5 Duration of test and acceptance criteria

The cycle consisting of the immersion and the drying period as per B.2.3 and B.2.4 shall be repeated 45 times.

On completion of the test, one of the two shells shall be pressurized to destruction as per 6.2.4.4.2 or 6.2.4.4.3 and meet the acceptance criteria. The other shell shall be subjected to the ambient cycle test of ISO 11119-2:2012, 8.5.5, and withstand 3 000 pressurization cycles at five-sixths the MDP without failure by burst or leakage.

The following parameters shall be monitored during the test and recorded:

a) the temperature of the sodium chloride solution, at least once a day;

b) the test pressure;

c) the duration of immersion;

d) the parameters specified in 6.2.4.4.2 or 6.2.4.4.3;

e) the parameters specified in ISO 11119-2:2012, 8.5.5.

Annex C
(informative)

Type approval certificate

This annex provides an example of a suitable form of a type approval certificate. Other formats are also acceptable.

TYPE APPROVAL CERTIFICATE

Issued by: ______________________________

(Authorized inspection authority)

____

applying ISO 16111 concerning

Metal hydride (MH) assemblies

Approval no. ____________________ Date ____________________

MH assembly design:

[Description of the family of MH assembly (drawing no.) which has received type approval]

MH assembly description and design criteria:

Maximum developed pressure (MDP): ____________ bar

Stress level at MDP: ____________ bar

Rated charging pressure (RCP): ____________ bar

Rated hydrogen capacity: ____________ g

Operating temperature range: ____________ °C

Service temperature range: ____________ °C

Service life: ____________ years

Number, location, size, flow capacity and type of pressure relief device (PRD):

PRD activation pressure (as applicable): ____________ bar

PRD activation temperature (as applicable): ____________ °C

Hydrogen absorbing alloy:

Means of solid particulate containment (as applicable):

Internal component (as applicable):

Exterior coating (as applicable):

Cooling system (as applicable):

Shell description and design criteria[1]**:**

Design and Construction Standard (e.g. ISO 9809-1):

Test pressure, p_h: ________________________ bar Outside diameter (nominal): __________ mm

Minimum guaranteed wall thickness, a': ______________________ mm

Shape of base: __________________________________

Length (nominal): ______________________ mm Water capacity (nominal): __________ l

Heat treatment: ______________________________

Material type and properties: Material: __________ *Re* _____________ MPa *Rg*: __________ MP

MH assembly manufacturer or agent

____

(Name and address of MH assembly manufacturer or its agent)

____

____

____

All information may be obtained from:

____

(Name and address of approving body)

I hereby certify that I have determined that the MH assembly design described on this type approval certificate complies in all respects to ISO 16111. The type test reports are attached hereto.

________________________________ ________________________________

Date Place

____

Signature of inspector

---

[1] Need not be completed if shell manufacturer’s drawing and acceptance certificate are attached.

Annex D
(informative)

Acceptance certificate

This annex provides an example of a suitable form of acceptance certificate. Other formats are also acceptable.

ACCEPTANCE CERTIFICATE

Acceptance certificate no.: ______ for metal hydride assemblies

A consignment of ______ MH assemblies consisting of ______ batches has been inspected and tested in accordance with ISO 16111.

Manufacturer of MH assembly: ____________________

Location: ____________________

Quantity: ____________________

Test date (month, year): ____________________

Shell manufacturer: ____________________

Location: ____________________ Batch number(s): __________

TECHNICAL DATA

Water capacity: nominal	______	l	Nominal length (without cap and without valve):	______	mm
Test pressure of shell, p_{h}:	______	bar	Nominal outside diameter, D:	______	mm
Minimum burst pressure of shell:	______	bar	Design and construction standard for shell:	______	
Maximum developed pressure (MDP):	______	bar	Stress level at MDP:	______	MPa
Rated charging pressure (RCP):	______	bar	Minimum guaranteed wall thickness of shell, a':	______	mm
Rated hydrogen capacity:	______	g	Drawing no.:	______	
Operating temperature range:	______	°C	Service temperature range:	______	°C
Pressure relief device(s) type, number, location:	______		Service life:	______	years

Markings[2]:

____________________ ____________________

Date The manufacturer

---

[2] To be quoted or drawing to be attached.

ACCEPTANCE TESTS

My record of tests and inspection for each batch of MH assemblies covered by this certificate is as follows[3]:

Shell-batch number	Covering serial Nos. ___________________ to. ___________________	Burst Test	
		Burst Pressure, bar	Enter “Pass “ or “Fail”

The above results represent sample MH assemblies selected from each batch. All other MH assemblies in the batch were subjected to a leak test at (enter temperature) °C, pressurized to RCP, and met the applicable.

Acceptance criteria of ISO 16111, 6.2.5.

A certified report of manufacture and test of the shells (acceptance certificate) is attached hereto.

Hydride-batch number	Covering serial Nos. ___________________ to. ___________________	MDP Test	
		Maximum Developed Pressure, bar	Enter “Pass “ or “Fail”

The above results represent sample MH assemblies selected from each batch. All other MH assemblies in the batch were subjected to a leak test at (enter temperature) °C, pressurized to RCP, and met the applicable.

Acceptance criteria of ISO 16111, 6.2.5.

A certified report of manufacture and test of the shells (acceptance certificate) is attached hereto. I hereby certify that the MH assemblies described on this acceptance certificate comply with the requirements of International Standard ISO 16111.

Special remarks: ____

____

____

---

[3] Need not be filled in if test reports are attached.

On behalf of: ____

____

____________________	____________________
Date	Signature of inspector

Bibliography

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[2] ISO 3690, *Welding and allied processes — Determination of hydrogen content in ferritic steel arc weld metal*

[3] ISO 6406, *Gas cylinders — Seamless steel gas cylinders — Periodic inspection and testing*

[4] ISO 7539-6, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens for tests under constant load or constant displacement*

[5] ISO 9587, *Metallic and other inorganic coatings — Pretreatment of iron or steel to reduce the risk of hydrogen embrittlement*

[6] ISO 9588, *Metallic and other inorganic coatings — Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

[7] ISO 10461, *Gas cylinders — Seamless aluminium-alloy gas cylinders — Periodic inspection and testing*

[8] ISO 11623, *Gas cylinders — Composite construction — Periodic inspection and testing*

[9] ISO 15330, *Fasteners — Preloading test for the detection of hydrogen embrittlement — Parallel bearing surface method*

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[13] ANSI/AIAA G-095-2004, *Guide to Safety of Hydrogen and Hydrogen Systems*

[14] API RP 934, *Materials and Fabrication Requirements for 2 1/4 Cr-1Mo and 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High Temperature, High Pressure Hydrogen Service*

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[16] ASTM B57, *Standard Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper*

[17] ASTM B849, *Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement*

[18] ASTM B850, *Standard Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement*

[19] ASTM B839, *Standard Test Method for Residual Embrittlement in Metallic Coated, Externally Threaded Articles, Fasteners, and Rod-Inclined Wedge Method*

[20] ASTM E1681, *Standard Test Method for Determining a Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials*

[21] ASTM F326, *Standard Test Method for Electronic Measurement for Hydrogen Embrittlement from Cadmium-Electroplating Processes*

[22] ASTM F519, *Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments*

[23] ASTM F1459, *Standard Test Method for Determination of the Susceptibility of Metallic Materials to Hydrogen Gas Embrittlement*

[24] ASTM F1624, *Standard Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique*

[25] ASTM F1940, *Standard Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners*

[26] ASTM F2078, *Standard Terminology Relating to Hydrogen Embrittlement Testing*

[27] ASTM G129, *Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking*

[28] ASTM G142, *Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both*

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[30] ASTM G148, *Standard Practice for Evaluation of Hydrogen Uptake, Permeation, and Transport in Metals by an Electrochemical Technique*

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DRAFT

New Zealand Standard

Public consultation draft

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Standards New Zealand

PO Box 1473, Wellington 6140

Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas
Energy Resources Aotearoa
Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
GNS
Hiringa Energy
HW Richardson Group
HyPotential
Methanex
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PEC
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DZ 17050.1:2024
(ISO/IEC 17050-1:2004, IDT)

New Zealand Standard

Conformity assessment Supplier’s declaration of conformity

Part 1: General requirements

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies general requirements for a supplier's declaration of conformity in cases where it is desirable, or necessary, that conformity of an object to the specified requirements be attested, irrespective of the sector involved.

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The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO/IEC 17050-1:2004 *Conformity assessment – Supplier's declaration of conformity − Part 1: General requirements*.

As this standard is reproduced from an international standard, the following applies:
(a) In the source text, 'this International Standard' should read 'this New Zealand standard';
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INTERNATIONAL STANDARD

ISO/IEC 17050-1

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2007-06-15

Conformity assessment — Supplier's declaration of conformity —

Part 1:
General requirements

Évaluation de la conformité — Déclaration de conformité du fournisseur —

Partie 1: Exigences générales

Reference number
ISO/IEC 17050-1:2004(E)

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of conformity assessment, the ISO Committee on conformity assessment (CASCO) is responsible for the development of International Standards and Guides.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

Draft International Standards are circulated to the national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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ISO/IEC 17050-1 was prepared by the ISO *Committee on conformity assessment* (CASCO).

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This first edition of ISO/IEC 17050-1, together with ISO/IEC 17050-2, cancels and replaces the second edition of ISO/IEC Guide 22:1996, *General criteria for supplier's declaration of conformity.*

ISO/IEC 17050 consists of the following parts, under the general title *Conformity assessment — Supplier's declaration of conformity*:

— *Part 1: General requirements*

— *Part 2: Supporting documentation*

This corrected version of ISO/IEC 17050-1:2004 incorporates the correction of the numbering of the list in 10.2, and an updated Bibliography.

Introduction

This part of ISO/IEC 17050 has been developed with the objective of providing general requirements for a supplier’s declaration of conformity.

It addresses one of the three types of attestation of conformity, namely attestation undertaken by the first party (e.g. the supplier of a product). Other types are second-party attestation (e.g. where a user issues an attestation for the product the user is using) or third-party attestation. Each of these three types is used in the market in order to increase confidence in the conformity of an object.

This part of ISO/IEC 17050 specifies requirements applicable when the individual or organization responsible for fulfilment of specified requirements (supplier) provides a declaration that a product (including service), process, management system, person or body is in conformity with specified requirements, which can include normative documents such as standards, guides, technical specifications, laws and regulations. Such a declaration of conformity can also make reference to the results of assessments by one or more first, second or third parties. Such references are not to be interpreted as reducing the responsibility of the supplier in any way.

These general requirements are applicable to all sectors. However, these requirements might need to be supplemented for specific purposes, for example for use in connection with regulations.

A supplier's declaration of conformity of a product (including service), process, management system, person or body to specified requirements can be substantiated by supporting documentation under the responsibility of the supplier. In cases where this is desirable, or necessary, reference is made to ISO/IEC 17050-2.

Conformity assessment — Supplier's declaration of conformity —

Part 1:
General requirements

1 Scope

This part of ISO/IEC 17050 specifies general requirements for a supplier's declaration of conformity in cases where it is desirable, or necessary, that conformity of an object to the specified requirements be attested, irrespective of the sector involved. For the purposes of this part of ISO/IEC 17050, the object of a declaration of conformity can be a product, process, management system, person or body.

This part of ISO/IEC 17050 does not define any particular object for the declaration of conformity.

Instead of "supplier's declaration of conformity", the term "declaration of conformity" can be used when appropriate.

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/IEC 17000:2004, *Conformity assessment — Vocabulary and general principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 17000 apply.

NOTE 1 "Supplier's declaration of conformity" is a "declaration" as defined in ISO/IEC 17000, i.e. first-party attestation.

NOTE 2 To avoid any confusion with attestation by certification bodies, the term "self-certification" is deprecated and should not be used.

4 Purpose of the declaration of conformity

The purpose of the declaration is to give assurance of conformity of the identified object to specified requirements to which the declaration refers, and to make clear who is responsible for that conformity and declaration. A supplier's declaration of conformity may be used alone or in conjunction with another conformity assessment procedure for regulatory or non-regulatory purposes.

5 General requirements

The issuer (issuing organization or person) of a declaration of conformity shall be responsible for issuing, maintaining, extending, reducing, suspending or withdrawing the declaration and the conformity of the object to the specified requirements.

The declaration of conformity shall be based on results of an appropriate type of conformity assessment activity (e.g. testing, measurement, auditing, inspection or examination) carried out by one or more first, second or third parties. Conformity assessment bodies involved, where applicable, should consult relevant International Standards, Guides and other normative documents.

Where a declaration of conformity is for a group of products of a similar type, it shall cover each individual product of the group. Where a declaration of conformity is for similar products delivered over a period of time, it shall cover each product as delivered or accepted.

It is recommended, as good conformity assessment practice, that the person reviewing the conformity assessment results be different from the signatory.

6 Contents of the declaration of conformity

6.1 The issuer of the declaration of conformity shall ensure that the declaration contains sufficient information to enable the recipient of the declaration of conformity to identify the issuer of the declaration, the object of the declaration, the standards or other specified requirements with which conformity is declared, and the person signing for and on behalf of the issuer of the declaration of conformity.

As a minimum, the declaration of conformity shall contain the following:

a) unique identification of the declaration of conformity;

b) the name and contact address of the issuer of the declaration of conformity;

c) the identification of the object of the declaration of conformity (e.g. name, type, date of production or model number of a product, description of a process, management system, person or body, and/or other relevant supplementary information);

d) the statement of conformity;

e) a complete and clear list of standards or other specified requirements, as well as the selected options, if any;

f) the date and place of issue of the declaration of conformity;

g) the signature (or equivalent sign of validation), name and function of the authorized person(s) acting on behalf of the issuer;

h) any limitation on the validity of the declaration of conformity.

6.2 Additional supporting information may be provided to relate the declaration to the conformity assessment results on which it is based, for example:

a) the name and address of any conformity assessment body involved (e.g. testing or calibration laboratory, inspection body, certification body);

b) reference to relevant conformity assessment reports, and the date of the reports;

c) reference to any management systems involved;

d) reference to the accreditation documents of conformity assessment bodies involved where the scope of accreditation is relevant to the declaration of conformity;

e) reference to the existence of associated supporting documentation, such as that described in ISO/IEC 17050-2;

f) additional information regarding certificates, registrations or marks that have been obtained;

g) other activities or programmes of the conformity assessment body (e.g. membership in an agreement group).

References in the documentation to conformity assessment results shall not misrepresent their applicability nor mislead the recipient of the declaration of conformity.

7 Form of declaration of conformity

See Annex A for an example of a declaration of conformity. The declaration of conformity may be in hardcopy, electronic media, or any other suitable medium.

8 Accessibility

A copy of the declaration of conformity may be included in other documentation, such as a statement, catalogue, invoice, user's instructions or website, relevant to the object of the declaration of conformity.

9 Product marking

If any marking is placed on the product to indicate the existence of a declaration of conformity, such marking shall be in such a format that it will not be confused with any certification mark. Such marking shall be traceable to the declaration of conformity.

10 Continuing validity of the declaration of conformity

10.1 The issuer of the declaration of conformity shall have procedures in place to ensure the continued conformity of the object, as delivered or accepted, with the stated requirements of the declaration of conformity.

10.2 The issuer of the declaration of conformity shall have procedures in place to re-evaluate the validity of the declaration of conformity, in the event of

a) changes significantly affecting the object’s design or specification,

b) changes in the standards to which conformity of the object is stated,

c) changes in the ownership or structure of management of the supplier, if relevant, or

d) relevant information indicating that the object may no longer conform to the specified requirements.

Annex A
(informative)

Supplier's declaration of conformity

A.1 Guidance to complete the form of declaration of conformity

NOTE Numbers 1) to 7) refer to the form shown in A.2.

1) Every declaration of conformity should be uniquely identified.

2) The responsible issuer should be unequivocally specified. For large organizations, it may be necessary to specify operational groups or departments.

3) a) The “object” should be unequivocally described so that the declaration of conformity may be related to the object in question.

3) b) For mass-produced products, it is not necessary to give individual serial numbers. In such cases it is sufficient to give the name, type, model number, etc.

4) For products, an alternative conformity statement may be: “As delivered, the object of the declaration described above is in conformity with the requirements of the following documents”.

5) Requirements documents should be listed with their identification numbers, titles and dates of issue.

6) Text should appear here only if any limitation on the validity of the declaration of conformity and/or any additional information are given. The latter information may, for example, correspond to 6.2 or may make reference to related product marking in accordance with Clause 9. Such product marking or other indication (e.g. on the product) may be an attachment to the declaration of conformity.

7) Full name and function of the signing person(s) authorised by the issuer's management to sign on its behalf should be given. The number of signatures, or equivalent, included will be the minimum determined by the legal form of the issuer’s organization.

A.2 Example of form of declaration of conformity

Supplier's declaration of conformity (in accordance with ISO/IEC 17050-1)

1) **No.** ....

2) **Issuer's name:** ....

Issuer's address: ....

....

3) **Object of the declaration:** ....

....

....

4) **The object of the declaration described above is in conformity with the requirements of the following documents:**

	Documents No.	Title	Edition/Date of issue
5)	....	....	....
	....	....	....
	....	....	....

Additional information:

6) ....

....

....

Signed for and on behalf of:

....

....

(Place and date of issue)

7) ....

(Name, function) (Signature or equivalent authorized by the issuer)

Bibliography

[1] ISO 9000:2000, *Quality management systems — Fundamentals and vocabulary*

[2] ISO 19011:2002, *Guidelines for quality and/or environmental management systems auditing*

[3] ISO/IEC 17020:1998, *General criteria for the operation of various types of bodies performing inspection*

[4] ISO/IEC 17021:2006, *Conformity assessment — Requirements for bodies providing audit and certification of management systems*

[5] ISO/IEC 17024:2003, *Conformity assessment — General requirements for bodies operating certification of persons*

[6] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

[7] ISO/IEC 17040:2005, *Conformity assessment — General requirements for peer assessment of conformity assessment bodies and accreditation bodies*

[8] ISO/IEC 17050-2:2004, *Conformity assessment — Supplier's declaration of conformity — Part 2: Supporting documentation*

[9] ISO/IEC Guide 65:1996, *General requirements for bodies operating product certification systems*

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New Zealand Standard

Public consultation draft

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IT MAY BE ALTERED BEFORE FINAL PUBLICATION

Standards New Zealand

PO Box 1473, Wellington 6140

Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas

Energy Resources Aotearoa

Fabrum

Fonterra Co-operative Group

Gas Appliance Industry

GasNZ

GNS

Hiringa Energy

HW Richardson Group

HyPotential

Methanex

New Zealand Hydrogen Council

PEC

WorkSafe New Zealand − Energy Safety

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Acknowledgement

Standards New Zealand gratefully acknowledges the contribution of time and expertise from all those involved in developing this standard.

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(ISO/IEC 17050-2:2004, IDT)

New Zealand Standard

Conformity assessment − Supplier's declaration of conformity

Part 2: Supporting documentation

Contents

Preface
[ISO] standard

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

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INTERNATIONAL STANDARD

ISO/IEC 17050-2

First edition
2004-10-01

Conformity assessment — Supplier's declaration of conformity —

Part 2:
Supporting documentation

Évaluation de la conformité — Déclaration de conformité du fournisseur —

Partie 2: Documentation d'appui

Reference number
ISO/IEC 17050-2:2004(E)

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This first edition of ISO/IEC 17050-2, together with ISO/IEC 17050-1, cancels and replaces the second edition of ISO/IEC Guide 22:1996, *General criteria for supplier's declaration of conformity.*

ISO/IEC 17050 consists of the following parts, under the general title *Conformity assessment — Supplier's declaration of conformity*:

— *Part 1: General requirements*

— *Part 2: Supporting documentation*

Introduction

A supplier’s declaration of conformity is a form of attestation of conformity to meet demands from the market and regulators for confidence. The acceptance of a supplier’s declaration of conformity could be enhanced by retaining documented information on which the supplier bases the declaration and making this documentation available upon request.

This part of ISO/IEC 17050 specifies requirements for the documentation to support a supplier’s declaration of conformity. Besides enhancing confidence in the supplier's declaration of conformity, such documentation may assist relevant authorities in their surveillance activities.

Conformity of a product (including service), process, management system, person or body to specified requirements, which can include normative documents such as standards, guides, technical specifications, laws and regulations, may need to be rigorously substantiated under the responsibility of the supplier, irrespective of the industry sector involved.

Conformity assessment — Supplier's declaration of conformity —

Part 2:
Supporting documentation

1 Scope

This part of ISO/IEC 17050 specifies general requirements for supporting documentation to substantiate a supplier’s declaration of conformity, as described in ISO/IEC 17050-1.

For the purposes of this part of ISO/IEC 17050, the object of a declaration of conformity can be a product, process, management system, person or body.

Instead of “supplier's declaration of conformity”, the term “declaration of conformity” can be used when appropriate.

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/IEC 17000:2004, *Conformity assessment —Vocabulary and general principles*

ISO/IEC 17050-1:2004, *Conformity assessment — Supplier's declaration of conformity — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 17000 apply.

NOTE 1 “Supplier's declaration of conformity” is a “declaration” as defined in ISO/IEC 17000, i.e. first-party attestation.

NOTE 2 To avoid any confusion with attestation by certification bodies, the term “self-certification” is deprecated and should not be used.

4 General requirements

4.1 Traceability

Supporting documentation shall be developed, kept, controlled and maintained in a way that allows traceability from a supplier’s declaration of conformity.

4.2 Availability

The issuer (issuing organization or person) of the declaration of conformity shall make supporting documentation available, as requested, to the relevant regulatory authority to the extent necessary to satisfy regulatory requirements. The issuer may make supporting documentation available to any other requesting person or body.

4.3 Retention period

The retention of supporting documentation shall be for a period in accordance with applicable laws and regulations, but may be longer at the discretion of the issuer. Specific needs of customers and other interested parties shall be considered.

5 Contents of the supporting documentation

5.1 The supporting documentation shall include, as applicable, the following information to demonstrate conformity with the declared requirements (see ISO/IEC 17050-1:2004, Clause 6 and Annex A):

a) description of the object of the declaration (product, process, management system, person or body);

b) design documentation (e.g. descriptions, diagrams, drawings, identification of the area of expertise and competence, specifications);

c) conformity assessment results, such as

   - description of methods used (e.g. auditing; audit procedures; batch testing; design review, verification and validation; inspection; sampling plan; serial testing; test methods; type testing) and reasons for their selection,
   - results (e.g. audit report, test report), and
   - evaluation of results, including deviations and concessions;

d) identification and relevant qualifications and technical competence of the first-, second- or third-party conformity assessment bodies involved, and details of their accreditation status (e.g. scope, name of the accreditation body).

5.2 Where necessary to demonstrate conformity to declared requirements, the following should also be included:

a) description of the management system relevant to the object of the declaration;

b) other relevant information (e.g. risk analysis, re-assessment procedures and schedules).

5.3 Any change in the supporting documentation described in 5.1 and 5.2 which affects the validity of the declaration of conformity shall be documented.

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DRAFT

New Zealand Standard

Public consultation draft

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DZ 17268:2024
(ISO 17268:2020, IDT)

New Zealand Standard

Gaseous hydrogen land vehicle refuelling connection devices

Contents

Preface

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To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard defines the design, safety, and operation characteristics of gaseous hydrogen land vehicle (GHLV) refuelling connectors. GHLV refuelling connectors consist of the following components, as applicable:
(a) Receptacle and protective cap (mounted on vehicle);
(b) Nozzle;
(c) Communication hardware.

This document is applicable to refuelling connectors which have nominal working pressures or hydrogen service levels up to 70 MPa. It is not applicable to refuelling connectors dispensing blends of hydrogen with natural gas.

This standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 17268:2020 *Gaseous hydrogen land vehicle refuelling connection devices*.

As this standard is reproduced from an international standard, the following applies:
(d) In the source text, 'this International Standard' should read 'this New Zealand standard';
(e) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 17268

Third edition
2020-02

Gaseous hydrogen land vehicle refuelling connection devices

Dispositifs de raccordement pour le ravitaillement des véhicules terrestres en hydrogène gazeux

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Contents

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 268, *Cryogenic vessels and specific hydrogen technologies applications*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 17268:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Clause 1, Clause 2, 3.1, 4.9. 5.8, 5.9, 5.17, 6.1, 6.9, 7.2, 7.5, 7.7, 7.8, 7.12.2, 7.12.3, 7.12.4, 7.16, 7.22, 7.25, 7.26, 7.27, 7.28, Clause 9, Table 1, Figure 3, Figure 4, Annex A, Annex B, Annex C, Annex D, Annex E and Annex F have been modified.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Gaseous hydrogen land vehicle refuelling connection devices

1 Scope

This document defines the design, safety and operation characteristics of gaseous hydrogen land vehicle (GHLV) refuelling connectors.

GHLV refuelling connectors consist of the following components, as applicable:

— receptacle and protective cap (mounted on vehicle);

— nozzle;

— communication hardware.

This document is applicable to refuelling connectors which have nominal working pressures or hydrogen service levels up to 70 MPa.

This document is not applicable to refuelling connectors dispensing blends of hydrogen with natural gas.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

ISO 1431-1, *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static and dynamic strain testing*

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

ISO 12103-1, *Road vehicles — Test contaminants for filter evaluation — Part 1: Arizona test dust*

ISO 15501-1, *Road vehicles — Compressed natural gas (CNG) fuel systems — Part 1: Safety requirements*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
communication hardware
infrared data association (IrDA) components which are used to transmit signals from the vehicle (*receptacle*) (3.15) to the dispenser (*nozzle*) (3.11) and designed to meet SAE J2799 or equivalent

3.2
component pressure rating

maximum pressure at which it is permissible to operate a component as specified by the manufacturer at a specified temperature

Note 1 to entry: Components designed to the maximum allowable pressure per the European Pressure Equipment Directive (PED) represent the component ratings by the manufacturer that is indicated by the value of "PS."

Note 2 to entry: See Table 1 for required component pressure ratings for various *pressure classes* (3.13) of fuelling *connectors* (3.3).

Note 3 to entry: Further guidance on dispenser pressure terminology is included in ISO 19880-1.

Table 1 — Dispensing system pressure levels and refuelling connector ratings

***NWP* (3.10) of vehicle (*receptacle*) (3.15) or *HSL* (3.7) of dispenser (*nozzle*) (3.11)**	***Pressure class* (3.13)**	***Maximum operating pressure (MOP)* (3.9)**	**Minimum dispenser component pressure rating (PS)**
Equal to NWP of the vehicle storage system per vehicle label		*1,25 × HSL/1,25 × NWP* *Highest fill pressure during normal fuelling*	*1,375 × HSL* *Highest permissible set-point for dispenser pressure protection in ISO 19880-1:—*, 8.2.2.3
11 MPa	H11	13,75 MPa	15,125 MPa
25 MPa	H25	31,25 MPa	34,375 MPa
35 MPa	H35 or H35HF[a]	43,75 MPa	48,125 MPa
70 MPa	H70	87,5 MPa	96,25MPa

[a] High-flow connectors for heavy-duty commercial vehicles.

3.3
connector

joined assembly of *nozzle* (3.11) and *receptacle* (3.15) which permits the transfer of hydrogen

3.4
cycle

process of making a positive connection between the *nozzle* (3.11) and the *receptacle* (3.15), pressurizing to the *maximum operating pressure* (3.9), depressurizing and disconnecting

3.5
dry helium

helium with a dew point adequate to prevent condensation during testing and at least 99 % pure

3.6
dry hydrogen

hydrogen which meets or exceeds the quality level in ISO 14687-2

3.7
hydrogen service level
HSL

pressure level used to characterize the hydrogen service of the dispenser based on the *NWP* (3.10) rating of the vehicle

Note 1 to entry: The numerical value of HSL also matches the number after the "H" in the *pressure class* (3.13).

Note 2 to entry: HSL is expressed in MPa.

3.8
leak test gas
gas for testing leaks that consists of *dry hydrogen* (3.6), or *dry helium* (3.5), or blends of a minimum 10 % of hydrogen or helium with nitrogen

3.9
maximum operating pressure
MOP
highest pressure that is expected for a component or system during normal operation

Note 1 to entry: Further guidance on dispenser pressure terminology is included in ISO 19880-1.

Note 2 to entry: The maximum operating pressure is 125 % of the *nominal working pressure* (3.10) or *hydrogen service level* (3.7), as applicable, for the purpose of testing of *nozzles* (3.11) and *receptacles* (3.15) in this document.

3.10
nominal working pressure
NWP
pressure of a full vehicle compressed hydrogen storage system at a gas temperature of 15 °C

Note 1 to entry: See ECE/TRANS/180/Add. 13 Global Technical Regulation No. 13 clause II-3.37.

Note 2 to entry: See Table 1 for NWPs covered in this document.

Note 3 to entry: Further guidance on pressure terminology is included in ISO 19880-1.

Note 4 to entry: NWP is also known as “settled pressure” in ISO 10286.

3.11
nozzle
device connected to a fuel dispensing system, which permits the quick connect and disconnect of fuel supply to the vehicle or storage system

3.12
positive locking device
device with the feature which requires actuation of an interlocking mechanism to achieve proper connection of the *nozzle* (3.11) to the *receptacle* (3.15) before pressure is applied

3.13
pressure class
non-dimensional rating of components that indicates the components are designed to dispense hydrogen to road vehicles at the required pressure and temperature

Note 1 to entry: See Table 1 for pressure classes of fuelling *connectors* (3.3).

Note 2 to entry: Further guidance on dispenser pressure terminology is included in ISO 19880-1.

3.14
protective cap
means to prevent dirt and other contaminants from getting into the inlet of the vehicle *receptacle* (3.15)

3.15
receptacle
device connected to a vehicle or storage system which receives the *nozzle* (3.11)

Note 1 to entry: This can also be referred to as a fuelling inlet of gas filling port in other documents.

4 General construction requirements

4.1 Nozzles and receptacles shall be designed in accordance with reasonable concepts of safety, durability and maintainability.

4.2 Nozzles and receptacles designed and tested in accordance with this document shall

a) prevent hydrogen fuelled vehicles from being filled by fuelling stations with working pressures and/or flow rates higher than the design values specified for the vehicle;

b) prevent hydrogen fuelled vehicles from being filled by other compressed gas fuelling stations, for example, natural gas and hydrogen-natural gas blends; and

c) prevent other gaseous fuelled vehicles from being filled by hydrogen fuelling stations.

4.3 Nozzles and receptacles shall be well fitted and manufactured in accordance with good engineering practice.

4.4 Nozzles and receptacles shall be

a) designed to minimise the possibility of incorrect assembly;

b) designed to be secure against displacement, distortion, warping or other damage;

c) constructed to maintain operational integrity under normal and reasonable conditions of handling and usage; and

d) designed with no self-evident means of defeating the safety features.

4.5 Nozzles and receptacles shall be manufactured of materials suitable and compatible for use with compressed hydrogen at the pressure and the temperature ranges to which they will be subjected as specified in 3.2, 5.8 and 6.9. Materials used in the construction of nozzles, receptacles and protective caps shall be non-sparking or spark-reducing. All pressure bearing and wetted components shall also be made from material that is compatible with deionised water. Non-metallic material compatibility shall be documented by the component manufacturer or an independent third party.

4.6 The nozzle shall be connected to or disconnected from the receptacle without the use of tools.

4.7 The H11 and H25 receptacles shall be mounted on the vehicle in compliance with ISO 15501-1. All other receptacles shall be mounted on the vehicle in compliance with the envelope requirements specified in Annex A.

4.8 Protective caps are intended to protect the receptacle from foreign debris and shall not hold pressure. Resistance shall be appropriate to prevent inadvertent dislodging. All protective caps shall have a retainer to attach them to the receptacle or vehicle.

4.9 Communications hardware which is supplied by the manufacturer and permanently integrated into the nozzle shall be attached to the nozzle and subjected to all of the nozzle tests. The communications hardware shall operate correctly upon completion of the all type and quality testing.

4.10 Nozzles and receptacles defined in this document can be used to fuel different types of GHLVs. The refuelling stations for these vehicles may have significantly different process limits and refuelling protocols. The nozzle and receptacle alone may not ensure that a GHLV cannot refuel at an incompatible station. If this occurs, the GHLV may be exposed to conditions outside of its intended limits, such as fuel container overheating. If this is a potential problem, the user and station manufacturer should develop additional controls to mitigate this risk.

4.11 As stated in ECE/TRANS/180/Add. 13 Global Technical Regulation No. 13 (Global technical regulation on hydrogen and fuel cell vehicles — 19 July 2013), “Assurance of capability to sustain multiple occurrences of over-pressurization due to fuelling station failure is provided by the requirement to demonstrate absence of leak in 10 exposures to 150 per cent NWP fuelling.” It is presupposed that nozzles and receptacles defined in this document are tested in this way to accommodate similar fuelling station over-pressurization occurrences.

5 Nozzles

5.1 Nozzles shall be in accordance with the dimensional requirements of 6.1 to ensure proper interchangeability. Nozzles shall couple with receptacles of equal or higher nominal working pressures and they shall be designed so that they will not couple with receptacles of lower nominal working pressures. The nozzle shall extend to within 1 mm of the stop ring for all nominal working pressures. Nozzles shall be designed so that they will not couple with gaseous fuelled vehicles other than GHLV.

5.2 Nozzles shall be one of the following three types.

a) TYPE A — A nozzle for use with dispensing hoses that may remain fully pressurized at dispenser shutdown. The nozzle shall not allow gas to flow until a positive connection has been achieved. The nozzle shall be equipped with an integral valve or valves, incorporating an operating mechanism which first stops the supply of gas and safely vents the trapped gas before allowing the disconnection of the nozzle from the receptacle. The operating mechanism shall ensure the vent connection is open before the release mechanism can be operated and the gas located between the nozzle shut-off valve and the receptacle check valve is safely vented prior to nozzle disconnection.

b) TYPE B — A nozzle for use with dispensing hoses that may remain fully pressurized at dispenser shutdown. A separate three-way valve connected directly, or indirectly, to the inlet of the nozzle shall be used to safely vent trapped gas prior to nozzle disconnection. The nozzle shall not allow gas to flow until a positive connection has been achieved. Venting shall be achieved prior to disconnection of the nozzle. External three-way valves shall be constructed and marked so as to indicate clearly the open, shut and vent positions.

c) TYPE C — A nozzle for use with dispensing hoses which are depressurized (0,5 MPa and below) at dispenser shutdown. The nozzle shall not allow gas to flow until a positive connection has been achieved. The function of preventing flow may be controlled by the dispenser as long as it is receiving a positive connection signal from the nozzle.

5.3 Nozzles shall be designed for a life of 100 000 cycles with manufacturer specified maintenance. The three-way valve used for actuating Type B nozzles shall meet the same number of cycles as the nozzle (i.e. 100 000 cycles).

5.4 The act of venting, or de-pressurizing, of the connection space between all nozzle types and receptacles shall be performed prior to disconnection. A provision shall be made for the venting or de-pressurizing of all nozzle types to be directed to a safe location.

5.5 The means for attaching the nozzle to the fuel dispensing system hose shall not rely on the joint between the male and female threads for sealing, such as tapered pipe threads.

5.6 The H11 and H25 nozzles shall fit within the envelope described in ISO 15501-1. All other nozzles shall fit within the envelope specified in Annex A.

5.7 Nozzles shall have a means to prevent the ingress of solid matter from upstream sources. For example, the requirement shall be deemed met if the nozzle has a filter upstream of adequate size to protect its functionality.

5.8 The nozzle shall be designed to operate at ambient temperatures ranging from −40 °C to 65 °C and at hydrogen gas temperatures ranging from −40 °C to 85 °C.

5.9 The nozzle shall be designed so that it does not freeze on the receptacle for more than 30 s after fuelling.

5.10 The nozzle shall not have any mechanical means of opening the receptacle check valve.

5.11 The appearance of the nozzle and receptacle shall be such as to clearly suggest the proper method of use.

5.12 It shall not be possible to deliver gas using any nozzles unless the nozzle and receptacle are connected properly and positively locked.

5.13 It shall not be possible to remove a nozzle when the contained pressure is greater than 1,0 MPa.

5.14 Upon disconnection, all types of nozzles shall stop the flow of gas. No hazardous condition shall result from disconnection.

5.15 Unpressurized nozzles shall require an axial force to connect and lock or unlock and disconnect the device of less than or equal to 90 N. On a secondary positive locking device which incorporates a rotary locking mechanism, the torque to lock or unlock the locking means shall not exceed 1 N·m. On a secondary positive locking device which incorporates an axial locking mechanism, the force to lock or unlock the locking means shall not exceed 90 N.

5.16 Pressurized Type A and B nozzles shall be capable of being disconnected with forces less than 450 N and torques less than 5 N·m.

5.17 Communication hardware which is supplied with the nozzle by the manufacturer shall be attached to the nozzle and subjected to the following design verification tests indicated by the corresponding subclause number:

7.6 Dropping

7.8 Valve operating handle

7.10 Abnormal loads

7.11 Low and high temperatures

7.12 Durability and maintainability

7.17 Corrosion resistance

7.18 Deformation

7.19 Contamination

7.20 Thermal cycle

7.21 Pre-cooled hydrogen exposure

7.25 User abuse

7.26 Freezing

If the communication hardware consists of electrical connectors, wires, covers or infrared (IR) filters, it shall be included as part of the tests.

If the IrDA receiver is replaceable in the field then the nozzle may be tested without the IrDA receiver. If the IrDA receiver is integrated into the nozzle or receptacle and cannot be replaced in the field, it shall be integrated into the nozzle during the tests. The IrDA transmitter may be tested without being integrated into a receptacle.

The communication hardware shall be fully operational upon completion of the above design verification tests as demonstrated by 7.28.

6 Receptacles

6.1 Standard receptacle dimensions: A receptacle shall be in accordance with the design specifications detailed in Annex B.

NOTE The main O-ring seal for all pressure ratings less than 70 MPa is situated at the leading edge of the receptacle. For the 70 MPa receptacle, the main O-ring seal is situated in the bore of the receptacle. The 70 MPa receptacle also includes an O-ring at the leading edge of the receptacle to seal with nozzles having pressure ratings less than 70 MPa.

In order to address freezing issues, the contact surface area between the nozzle and the receptacle on the back diameter (25 mm) may be reduced by modifying the shape of the receptacle body in this area. Annex F shows an example hex design which meets this criterion. The receptacle with the reduced contact area shall be in accordance with this document.

6.2 Receptacles shall be in accordance with this document. The failure of any test conducted with the receptacle and nozzle test samples shall constitute a failure of the receptacle design.

6.3 Receptacles shall be designed for a life of 15 000 cycles and 15 years with manufacturer specified maintenance.

6.4 Receptacle designs, which employ means on the back diameter to accommodate mounting, or for mounting accessories or marking purposes, shall not have such means extend beyond the back diameter dimensions of the profile specified in Annex B, as applicable. Acceptable means shall include wrench flats, protective cap anchoring grooves, use of hex stock, undercutting for marking, and threads for protective caps. Such receptacle designs shall not compromise proper nozzle interchangeability.

6.5 The receptacle shall be equipped with an internal check valve to prevent the escape of gas. The check valve shall be of the non-contact type, opening by differential pressure only.

6.6 The means for attaching the receptacle to the vehicle fuel system shall not rely on the joint between the male and female threads for sealing, such as tapered pipe threads.

6.7 Receptacles shall be designed so that they are either tolerant of solid contamination or have a means to protect themselves from said contamination to maintain safe functionality. For example, the requirement shall be deemed met if the receptacle has a filter upstream of adequate size to protect the functionality of the check valve. A receptacle shall have a means to prevent the ingress of fluids and foreign matter when disconnected.

6.8 The receptacle shall have provisions to be firmly attached to the vehicle and shall be in accordance with the applicable abnormal load tests specified in 7.10.

6.9 The receptacle shall be designed to operate at hydrogen gas temperatures ranging from −40 °C to 85 °C.

7 Design verification test procedures

7.1 General requirements

Nozzles and receptacles shall meet the requirements of this document.

7.2 Test conditions

Unless otherwise stated

a) tests shall be conducted at 20 °C ± 5 °C;

b) all pressure tests shall be conducted with leak test gas unless otherwise noted;

c) all leak tests shall be conducted with leak test gas;

d) test fluids and devices shall be at equilibrium conditions with the test environment at the beginning of all tests: and

e) unless otherwise specified, the tolerances for testing temperatures and pressures are:

For low temperatures: T_{-3}^{0} °C

For high temperatures: T_{0}^{+3} °C

For pressures: P_{0}^{+3} % of the stated value

7.3 Nozzle tests

Nozzle tests shall be performed with the test fixtures identified under Annex C, Annex D or Annex E, as applicable. If a test fixture identified under Annex C, Annex D or Annex E is not specified, then receptacles specified under Annex B shall be used. A new receptacle test sample shall be used for each nozzle test. The failure of any test conducted with the nozzle and receptacle test sample shall constitute a failure of the nozzle design.

7.4 Receptacle tests

Receptacles shall be evaluated with nozzle(s) which have met the requirements of this document. The failure of any test conducted with the receptacle and nozzle test samples shall constitute a failure of the receptacle design.

7.5 User — Machine interface

This test shall be performed to verify the connection and disconnection forces and torques of an unpressurized and pressurized device.

The testing shall be performed at room temperature with the minimum temperature as specified in 5.8.

The disconnection forces and torques shall be applied in a direction that tends to disconnect and release the nozzle. The torque shall be applied to the disconnection/release actuator or three-way valve. For example, if there is a handle, the torque shall be applied through axis rotation of the nozzle handle equal to the exterior handling surface of the nozzle mechanism and in such a direction that tends to unhook and release the nozzle.

All nozzle types shall be connected to a receptacle using the tight test fixture specified in Annex D. The gas pressure in the assembly shall be less than 0,1 MPa. The force to connect and lock or unlock shall meet the requirements in 5.15 and 5.16.

All nozzle types shall be connected to a receptacle using the loose test fixture specified in Annex C. The gas pressure in the assembly shall be set to 1,0 MPa. It shall not be possible to remove the nozzle from the receptacle.

A Type A or B nozzle shall be connected to a receptacle using the loose test fixture specified in Annex C. The gas pressure in the assembly shall be set to 7,5 MPa, 50 % and 100 % of the hydrogen service level.

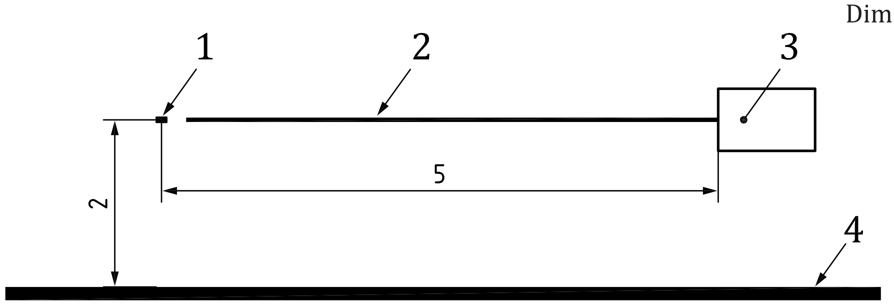
Upon disconnection, all types of nozzles shall stop the flow of gas. No hazardous condition shall result from disconnection.

7.6 Dropping

This test shall be performed to verify that a nozzle can safely withstand a drop of 2 m under −40 °C conditions.

A nozzle conditioned at −40 °C for 24 h shall be connected to a 5 m length of the appropriately rated fuelling hose, and then dropped 2 m onto a concrete floor as shown in Figure 1. The nozzle shall be dropped ten times within 5 min of removal from the conditioning chamber, then pressurized to the maximum operating pressure and subjected to ten additional drops within another 5 min.

Dimensions in metres



Key

1 support

2 11 mm diameter fuelling hose

3 nozzle

4 concrete floor

Figure 1 — Test arrangement for dropping test

Following all drops described previously, the nozzle shall be capable of normal connection to the receptacle. In addition, the nozzle shall meet the requirements of the leakage tests specified in 7.7 and 7.11, as well as the hydrostatic strength test specified in 7.16.

7.7 Leakage at room temperature

These tests shall be performed to verify the leakage rate of nozzle, receptacle, connector and receptacle check valve at room temperature using the loose and tight test fixtures specified in Annexes C and D, respectively.

Tests shall be conducted at 0,5 MPa and 150 % of the nominal working pressure or hydrogen service level, as applicable. All devices shall be checked for leakage from the time of connection, through pressurization, to the time of disconnection.

The pressurized leak test gas shall be applied to the inlet of the connector, the disconnected nozzle and the outlet of the disconnected receptacle, to verify the leakage rate of the nozzle.

To verify the leakage rate of the receptacle check valve, pressurized leak test gas shall be applied to the inlet of the connector. The nozzle shall be quickly disconnected and the receptacle check-valve checked for leakage.

Following the tests described above, the nozzle, receptacle, connector and receptacle check valve shall be bubble free for 1 min. If bubbles are detected, then the leak rate shall be measured by either an external vacuum test using leak test gas (global accumulation test), or an equivalent method to show that the leak rate is less than 20 cm^3/h of hydrogen at 20 °C.

The permitted leakage rate is applicable to tests with 100 % hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 % hydrogen.

7.8 Valve operating handle

This test shall be performed to verify that nozzles equipped with operating handles can withstand a maximum force without damage.

A 200 N force shall be applied to the valve operating handle at the point furthest away from the axis of rotation in both the opening and closing directions. The test shall be performed with the nozzle properly connected to the loose test fixture specified in Annex C, and with the nozzle intentionally, improperly engaged relative to the receptacle.

Following the tests, the nozzle shall maintain safe operating functionality.

7.9 Receptacle vibration resistance

This test shall be performed to verify receptacle and protective cap resistance to vibration.

The receptacle and protective cap shall be secured in a test apparatus and vibrated at each integer frequency from 5 Hz to 60 Hz for 8 min at each frequency. The amplitude of the vibration shall be at least 1,5 mm from 5 Hz to 20 Hz, 1,2 mm from 20 Hz to 40 Hz, and 1 mm from 40 Hz to 60 Hz. The tests shall be conducted once in the axial direction, and again in the radial direction.

Following the tests, there shall be no visible damage to the receptacle and protective caps. The receptacle shall meet the requirements of all the receptacle leakage tests specified in 7.7 and 7.11, as well as the hydrostatic strength test specified in 7.16.

7.10 Abnormal loads

This test shall be performed to verify that the nozzle and receptacle can withstand abnormal loads in service.

The connected nozzle and receptacle may be subjected to the following abnormal loads in service:

a) pulls along the nozzle or receptacle longitudinal axis;

b) moments applied to the end fitting of the nozzle.

The connected nozzle and receptacle shall be able to withstand abnormal loads of a = 1 000 N, b = 120 N·m without distortion or damage.

Also, the connected nozzle and receptacle shall be able to withstand abnormal loads of a = 2 000 N; b = 240 N·m without leakage. The moment arm shall be measured from the point of attachment of the receptacle to the vehicle body to the hose inlet of the nozzle.

The nozzle and receptacle test fixture shall be tested in the pressurized and non-pressurized condition. During the pressurized test the nozzle and receptacle test fixture shall be pressurized to maximum operating pressure. The appropriate "loose fit" test fixture (see Annex C) shall be used for this test. The test fixture shall be mounted as a cantilever to a supporting member. For the purposes of this test, the supporting member shall be capable of withstanding the specified loads without displacement or deflection. The nozzle shall be properly connected to the test fixture.

Following the tests, the nozzle and connector shall meet the requirements of the appropriate leakage tests specified in 7.7 and 7.11, as well as the hydrostatic strength test specified in 7.16.

7.11 Low and high temperatures

7.11.1 Purpose

These tests shall be performed to verify leakage rate and operation of nozzle, receptacle and connector at low and high temperatures.

7.11.2 General

Prior to conditioning, the devices shall be purged with nitrogen and then sealed from atmosphere under a pressure of 7 MPa leak test gas. All tests shall be conducted while the devices are continuing to be exposed to the specified test temperatures. The outlet of the device shall be plugged and the test pressure shall be applied to the inlet of the device.

7.11.3 Leakage tests

7.11.3.1 Fuelling connection devices shall be leak tested in accordance with the test conditions listed below after 2 h of conditioning for the components and leak detector (if used):

a) The nozzle and receptacle coupled, conditioned at −40 °C and pressurized at 0,5 MPa and maximum operating pressure.

b) The nozzle and receptacle coupled, conditioned at 50 °C and pressurized at 1 MPa and maximum operating pressure.

c) The receptacle uncoupled, conditioned at −40 °C and pressurized at 0,5 MPa and maximum operating pressure.

d) The receptacle uncoupled, conditioned at 85 °C and pressurized at 1 MPa and maximum operating pressure.

e) The nozzle uncoupled, conditioned at −40 °C and pressurized at 0,5 MPa and maximum operating pressure.

f) The nozzle uncoupled, conditioned at 50 °C and pressurized at 1 MPa and maximum operating pressure.

7.11.3.2 Pressurized leak test gas shall be applied to the test components. The external body shall then be checked for bubble tight leakage using

a) at −40 °C, immersion in a 100 % denatured ethyl alcohol mixture for 1 min; and

b) at 50 °C or 85 °C, immersion in 50 °C or 85 °C water for 1 min.

7.11.3.3 Following the tests, the nozzle, receptacle and connector shall be bubble free for 1 min or have a leak rate less than 20 cm^3/h at 20 °C.

The permitted leakage rate is applicable to tests with 100 % hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 % hydrogen.

7.11.4 Operation tests

The devices shall function under the following conditions.

a) The nozzle and receptacle connected and disconnected ten times when conditioned at −40 °C and pressurized to maximum operating pressure.

b) The nozzle and receptacle connected and disconnected ten times when conditioned at 85 °C and pressurized to maximum of working pressure.

Following the tests, the devices shall connect and disconnect normally and deliver gas.

7.12 Durability and maintainability

7.12.1 Purpose

These tests shall be performed to verify that the nozzle, receptacle, receptacle check valve and connector can withstand durability cycling.

7.12.2 Nozzle durability test

During the following tests, all devices shall be maintained according to the manufacturer's instructions.

Requirements for maintenance at less cycles than specified by the manufacturer shall be considered not in accordance with this document.

The nozzle shall be capable of withstanding 100 000 cycles. For the purpose of this test, one cycle of operation for Type A, B and C nozzles shall consist of the following:

a) properly connecting the nozzle to the receptacle test fixture;

b) pressurizing the connector to maximum operating pressure using leak test gas;

c) depressurizing the connector;

d) disconnecting the nozzle.

While disconnected the test fixture shall be rotated relative to the nozzle at random or equal degree increments throughout this test.

The receptacle test fixture shall be replaced at 15 000 cycle intervals as specified in Table 2 below.

Table 2 — Test fixture selection for nozzle durability tests

Number of cycles	Figure	Geometry
0 to 15 000	Annex D	Tight fit
15 001 to 30 000	Annex D	Tight fit
30 001 to 45 000	Annex C	Loose fit
45 001 to 60 000	Annex C	Loose fit
60 001 to 75 000	Annex D	Tight fit
75 001 to 90 000	Annex D	Tight fit
90 001 to 100 000	Annex C	Loose fit

Following 100 000 cycles of operation, the nozzle shall be subjected to 10 pressure cycles to 150 % of the hydrogen service level using the appropriate receptacle from Annex B.

After the 10 additional pressure cycles are complete, the nozzle locking mechanism shall be checked at the normal disconnect pressure to ensure it is properly engaged on the receptacle.

The nozzle shall then meet the requirements of 7.5, 7.7, 7.11 (−40 °C conditions only) and 7.15. The nozzle shall meet the requirements of 7.7 when tested with the appropriate simulated wear pattern test fixture shown in Annex E, as applicable.

After 15 000 cycles, the worn receptacle test fixtures shall not be in excess of wear patterns shown in Annex E as applicable and shall meet the requirements of 7.7.

7.12.3 Receptacle check valve durability test

The receptacle check valve shall be capable of withstanding 15 000 operational cycles. For the purposes of this test, one cycle of operation shall consist of the following:

a) properly connecting the receptacle to the nozzle test fixture;

b) pressurizing the connector to the hydrogen service level in 12 pulses using leak test gas;

c) depressurizing the connector by first venting the upstream side of the receptacle check valve and then lowering the pressure on the downstream side of the receptacle check valve to between 0 and a maximum of 0,5 MPa prior to the next cycle.

Following 15 000 cycles of operation, the receptacle check valve shall then be subjected to 24 h of flow at the inlet/outlet flow conditions that cause the most severe chatter.

Following the test, the receptacle check valve shall meet the requirements of the leakage tests specified in 7.7, 7.11 (−40 °C conditions only) and 7.15.

7.12.4 Receptacle durability test

The receptacle shall be capable of withstanding 15 000 operational cycles. For the purposes of this test, one cycle of operation shall consist of the following:

a) properly connecting the receptacle to the nozzle;

b) pressurizing the connector to the maximum operating pressure using leak test gas;

c) holding the maximum operating pressure for 30 s, minimum;

d) depressurizing the nozzle;

e) disconnecting the nozzle;

f) depressurizing the receptacle.

Following 15 000 cycles of operation, the receptacle shall be subjected to 10 pressure cycles to 150 % of the nominal working pressure.

Following the successful completion of the tests, the receptacle shall then meet the requirements of the leakage tests specified in 7.7, 7.11 (−40 °C conditions only) and 7.15.

7.12.5 Connected nozzle and receptacle durability test

A nozzle test fixture or a receptacle test fixture, as applicable, shall be connected to the device under test. The outlet of the receptacle shall be open to atmospheric pressure. The supply port of the nozzle shall be connected to a supply system which will supply sufficient leak test gas as required below.

Each nozzle and receptacle shall be cycled for 30 cycles. Each cycle shall consist of a total of the full flow of gas with the supply pressure starting at the hydrogen service level. A cycle shall be 2 s in length and the supply pressure shall not fall below 80 % hydrogen service level at the end of each cycle. The test supply system shall not limit the flow during this test.

Following the tests, the connected nozzle and receptacle shall then meet the requirements of the leakage tests specified in 7.7.

7.13 Sealing material aging test

7.13.1 Purpose

These tests shall be performed to verify sealing material resistance to aging.

7.13.2 Oxygen aging test procedure

Sealing materials shall be listed and rated by the manufacturer as being resistant to oxygen aging. Samples of synthetic material parts shall be subjected to 96 h of exposure at 70 °C and at 2 MPa. This test shall be conducted in accordance with ISO 188.

Following the tests, synthetic material parts of fuelling connection devices shall not crack or show visible evidence of deterioration.

7.13.3 Ozone aging test procedure

Sealing materials exposed to the atmosphere without the continuous presence of internal gas pressure (e.g. receptacle face seal O-ring) shall be listed and rated by the manufacturer as being resistant to ozone aging. Samples of synthetic material parts shall be stressed to 20 % elongation and exposed for a period of 120 h to air at 40 °C with a volume fraction of ozone of $5 \times 10^{-7.}$ This test shall be conducted in accordance with ISO 1431-1.

Following the tests, synthetic material parts of fuelling connection devices shall not crack or show visible evidence of deterioration.

7.14 Non-metallic material hydrogen resistance test

This test shall be performed to verify wetted non-metallic material resistance to hydrogen.

Representative samples of wetted non-metallic material shall be prepared, measured and weighed. The samples shall then be immersed in hydrogen at the nominal working pressure, or hydrogen service level, as applicable, for 168 h at 20 °C ± 5 °C. Following this time period, the test pressure shall be reduced to atmospheric pressure in less time than the seals would have to depressurize in actual service, not to exceed 1 s.

Following the tests, the test samples shall not exhibit evidence of explosive decompression damage. In addition, the samples shall not swell more than 25 %, shrink more than 1 % and incur a weight loss in excess of 10 %.

7.15 Electrical resistance

This test shall be performed to verify the electrical resistance of the connector.

The electrical resistance of the connector shall be measured.

The electrical resistance of the connected receptacle and nozzle shall not be greater than 1 000 Ω either in the pressurized or unpressurized state.

7.16 Hydrostatic strength

These tests shall be performed to verify the hydrostatic strength of the nozzle, receptacle and connector using the loose and tight test fixtures specified in Annexes C and D, respectively.

Because the hydrostatic strength test is a terminal test, the test samples shall not be used for any other subsequent testing.

Outlet openings of the uncoupled nozzle, the uncoupled receptacle and the connector shall be plugged and valve seats or internal blocks made to assume the open position. A hydrostatic pressure of 3 times the maximum operating pressure shall be applied to the nozzle, to the receptacle as well as the connector for a period of at least 3 min.

During the test, the uncoupled nozzle, the uncoupled receptacle and the connector shall not leak.

7.17 Corrosion resistance

7.17.1 Purpose

These tests shall be performed to verify nozzle and receptacle resistance to corrosion.

7.17.2 General

New samples shall be used. Protective caps shall be in place. Vent holes in the protective caps shall not be plugged. Process connections may be plugged.

7.17.3 Nozzle test

The nozzle and the receptacle shall be supported in a horizontal position. The nozzle shall be exposed for 96 h to a salt spray as specified in ISO 9227.

Throughout the test, the temperature within the test chamber shall be maintained between 33 °C and 36 °C. The salt spray solution shall consist of a mass fraction of 5 % of sodium chloride and 95 % distilled water.

A pressure of 0,5 MPa of air shall also be continuously applied to the inlet of the nozzle. The nozzle shall be operated once an hour to dispense air (to the atmosphere through a dummy receptacle) during the first eight-hour test period.

Immediately following the 96 h test the nozzle shall be rinsed and gently cleaned of salt deposits.

The nozzle shall not show evidence of corrosion or loss of protective coatings and shall meet the requirements of the leakage tests specified in 7.7.

7.17.4 Receptacle test

The receptacle shall be supported in a horizontal position and shall be exposed for 1 000 h to a salt spray as specified in ISO 9227. Throughout the test, the temperature within the test chamber shall be maintained between 33 °C and 36 °C. The salt spray solution shall consist of a mass fraction of 5 % sodium chloride and 95 % distilled water.

Immediately following the 1 000 h test, the areas of receptacles protected by the protective caps shall be examined. The receptacle shall then be rinsed and gently cleaned of salt deposits.

The receptacle shall not show evidence of corrosion or loss of protective coatings. The receptacle shall then meet the requirements of the leakage tests specified in 7.7.

7.18 Deformation

This test shall be performed to verify that field connected/assembled parts can withstand a specified installation over-torque.

The nozzle and the receptacle shall be connected and assembled to 150 % of the manufacturer's assembly torque.

While still connected and assembled, the connector shall meet the requirements of the leakage tests specified in 7.7 and the hydrostatic strength test specified in 7.16.

7.19 Contamination test

This test shall be performed to verify that the nozzle and receptacle can withstand contamination.

A tank or vessel shall be filled to a depth of 100 mm ± 5 mm with a solution/suspension having a volume fraction of 5 % salt and sand in accordance with A4 coarse grade test dust of ISO 12103-1, or the equivalent dissolved/suspended in distilled water. The connection end of the nozzle and receptacle shall be dipped into the solution/suspension for 1 s to 5 s and removed. The nozzle and receptacle shall be dipped in a manner that the entire connection area is submerged without touching the bottom.

After dipping both the nozzle and receptacle in the solution/suspension, the receptacle and nozzle shall be connected. The coupled pair shall have leak test gas at the maximum operating pressure blown through for 5 s for 10 consecutive cycles. The nozzle and receptacle shall not be cleaned during the test.

The connector shall be subjected to the leakage test specified in 7.7 after each cycle.

7.20 Thermal cycle test

This test shall be performed to verify that the nozzle and receptacle can withstand thermal cycling.

The nozzle, receptacle, and a connector shall be pressurized to the hydrogen service level. The components shall be subjected to an external temperature of 85 °C within 0,5 h, and soaked at that temperature for 2 h. The components shall then be subjected to an external temperature of −40 °C in less than 1 h and soaked at that temperature for 2 h. Finally, the external temperature shall be returned to 15 °C within 0,5 h to complete the cycle. This cycle shall be repeated 100 times.

The nozzle, receptacle and connector shall meet the requirements of the leakage tests specified in 7.7 and 7.11, as well as the hydrostatic strength test specified in 7.16.

7.21 Pre-cooled hydrogen exposure test

This test shall be performed to verify that the nozzle and receptacle can withstand exposure to pre-cooled hydrogen during fuelling. If the nozzle manufacturer recommends methods to address nozzle freeze-lock, then these methods shall be used for this test.

The connector shall be subjected to pre-cooled hydrogen gas at −40 °C at a flow rate of 30 g/s at 15 °C and 90 % relative humidity for a minimum of 3 min. The nozzle shall be depressurized, then disconnected within 30 s and re-connected to another dry receptacle after a two-minute hold period. This test shall be repeated 10 times.

This test procedure shall be repeated for an additional ten cycles, except that the hold period shall be increased to 15 min.

The nozzle, receptacles and connector shall meet the requirements of the leakage tests specified in 7.7 and 7.11. Failure to disconnect the nozzle within 30 s shall constitute failure of the test.

7.22 Misconnected nozzle test

This test shall be performed to verify that a misconnected Type C nozzle shall not flow gas, leak, or disconnect. A uniform and an asymmetrical load test shall be conducted respectively. The test shall be performed on the following test fixtures (see Table 3):

Table 3 — Misconnected nozzle test configurations

Nozzle	Receptacle fixture			
H35	H35 Nominal	H35 Worn	H70 Nominal	H70 Worn
H70	—	—	H70 Nominal	H70 Worn

The test shall be conducted with all hardware and gases at room temperature. The test fixture may be submerged underwater to detect leaks.

In order to test a uniform load, a series of thin shims of uniform thickness with a 30 mm outside diameter and a 27 mm inside diameter shall be inserted in the space between the nozzle and the stop ring of the receptacle to create a misconnected condition as shown in Figure 2. If it is not possible to manufacture a shim small enough to create a misconnected condition, the receptacle stop ring position shall be adjusted to accommodate the shim (see Figure 3).

In addition, an asymmetrical load test shall be conducted using a series of 90° arc shims with a 30 mm outside diameter and a 27 mm inside diameter. The shims shall be placed in only one arbitrary quadrant.

For both uniform and asymmetrical load tests, the connector shall be subjected to leak test at 10 MPa for 1 min and additional shims shall be continued to be added until the nozzle requires more than 1 000 N to connect or the nozzle does not flow gas.

The nozzle shall not flow gas in the misconnected state.

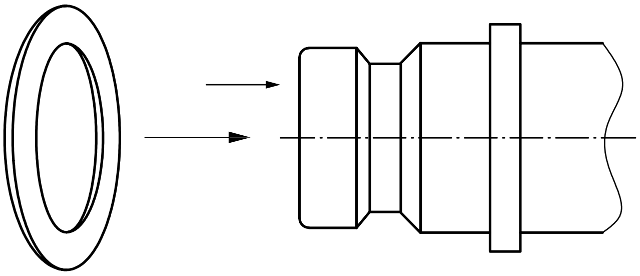
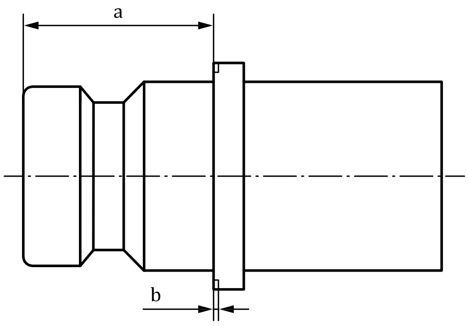


Figure 2 — Use of shims to create a misconnected connector



Key

a 30 mm for 35 MPa and 40 mm for 70 MPa

b adjustment depth

Figure 3 — Adjustment of stop ring position to accommodate a shim

7.23 Upward/downward nozzle compatibility test

7.23.1 General

This test shall be performed to verify that a nozzle shall connect to a receptacle rated to a higher nominal working pressure, and to verify that a nozzle shall not connect to a receptacle rated to a lower nominal working pressure.

7.23.2 Upwards nozzle compatibility test

The nozzle shall be connected to representative receptacles rated to a higher nominal working pressure and pressurized with leak test gas.

The connector shall meet the requirements of the leakage tests specified in 7.7.

7.23.3 Downwards nozzle compatibility test

Attempts shall be made to connect the nozzle to representative receptacles of maximum length tolerance rated to a lower nominal working pressure.

The nozzle shall not connect to representative receptacles rated to a lower nominal working pressure.

7.24 Washout test

This test shall be performed to verify that the main internal O-ring seal of an H70 receptacle does not washout when connected with a nozzle rated to a lower nominal working pressure.

The connector shall be subjected to hydrogen gas at a flow rate of 65 g/s (+2 g/s) and at the maximum operating pressure for a minimum of 10 s. This test shall be repeated 10 times with a delay of at least 5 s between bursts.

The test shall be conducted at temperatures of -40^{+5}_{0} °C and 85^{+5}_{0} °C with the unpressurized connector preconditioned for 30 min at the test temperature.

There shall be no displacement of the internal O-ring seal(s) after the test. The receptacle shall then meet the requirements of the leakage tests specified in 7.7 and 7.11.

7.25 User abuse test

This test shall be performed to verify that the nozzle and receptacle can withstand repeated abnormal loads that may be applied by a user.

The appropriate “loose fit” test fixture (see Annex C) shall be used for this test. The test fixture shall be mounted as a cantilever to a supporting member. For the purposes of this test, the supporting member shall be capable of withstanding the specified loads without displacement or deflection. The nozzle shall be properly connected to the test fixture.

The nozzle and receptacle test fixture shall be tested in the non-pressurized condition.

Connect the nozzle to the test fixture and suspend a weight of 5 kg to the nozzle to simulate the weight of the fuelling hose. Rotate the nozzle 180° reciprocally for 500 rotations.

Following the test, the nozzle shall be able to be removed from the test fixture, and the nozzle and connector shall meet the requirements of the appropriate leakage tests specified in 7.7 and 7.11.

7.26 Freezing test

This test shall be performed to verify that a nozzle and receptacle do not freeze together for more than 30 s after fuelling.

The test shall be performed with one nozzle and three receptacles (see Figure 4) with the standard dimensions shown in Annex B. If the nozzle manufacturer recommends methods to address nozzle freeze-lock, then these methods shall be used for this test.

a) Throughout the test, the temperature within the test chamber shall be maintained at 30 °C and 95 % relative humidity. The nozzle shall be dried before the test in order to not affect the test results.

b) The nozzle and receptacles with their protective caps attached and accompanying equipment shall be conditioned at 30 °C until they reach an equilibrium temperature. The temperature shall be confirmed by measurement of the surface of the nozzle and receptacles.

c) Connect the nozzle to the first receptacle and simulate the fuelling by passing hydrogen through the interface for 3 min at the following conditions:

   - Gas temperature: -40^{+3}_{0} °C.
   - Gas flow gate: 650 g/min ± 50 g/min.

   The gas temperature shall be measured as close to the nozzle as possible.

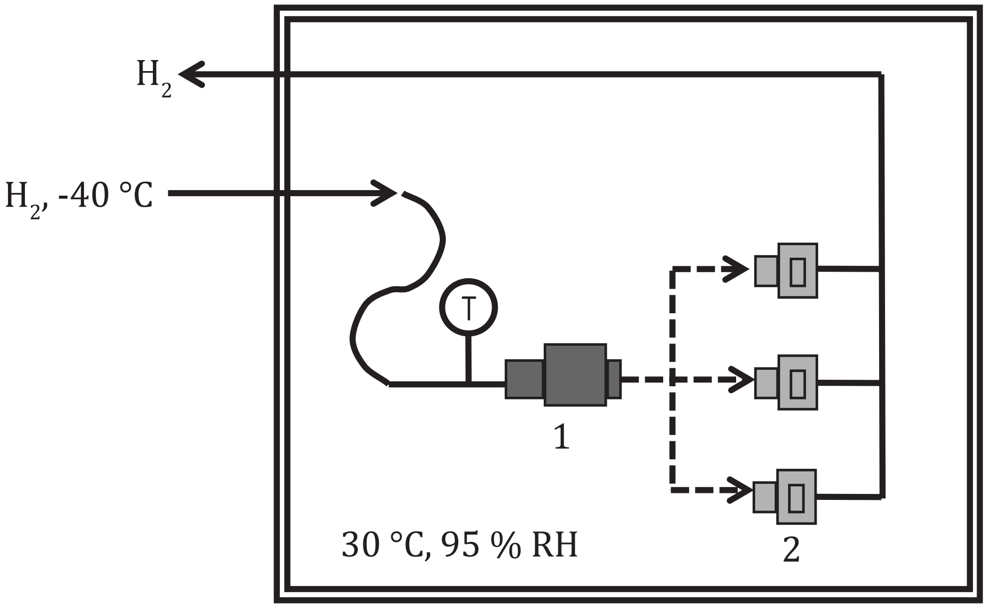
d) Disconnect the nozzle from the first receptacle using the standard procedure, wipe the moisture from the receptacle and replace its protective cap. The forces to disconnect the nozzle shall not exceed the requirements in 7.5.

e) Wait 7 min± 0,1 min and repeat steps c) and d) with the second receptacle.

f) Wait 7 min ± 0,1 min and repeat steps c) and d) with the third receptacle.

g) Repeat steps c) through f) for a total of twelve tests.

h) If at any time the time to release the nozzle from the receptacle exceeds 30 s, then the nozzle is considered frozen and the test shall end. After 12 successful tests, the nozzle shall be deemed to have met the requirements of 5.9.



Key

1	nozzle
2	receptacles
RH	relative humidity
T	gas temperature

Figure 4 — Example of test setup for freezing test

7.27 Rocking test

This test shall validate that a receptacle and nozzle connection is not damaged after repeated moments applied to the end of the nozzle.

The hardware shall be supported in a horizontal position by a member capable of withstanding the load of this test without displacement or deflection. The nozzle shall be attached to a hose pressurized to the hydrogen service level.

The nozzle shall be capable of withstanding 2 500 cycles at a frequency of less than 1 cycle per second of the following loads:

a) a moment of 24 N·m applied in one direction;

b) a moment of 24 N·m applied in the opposite direction.

Following the test there shall be no visible damage to the receptacle nor any displacement of the receptacle seal(s). Following the tests, the receptacle shall then meet the requirements of the leakage tests specified in 7.7.

7.28 Communication test

This test assumes that the communication hardware used on the nozzle is an IrDA system designed to meet SAE J2799 or equivalent.

This test shall be performed to verify that the communication hardware is operational after completion of the design verification tests listed in 5.17.

After each test listed in 5.17, the IrDA transmitter or receiver shall be tested with a functioning counterpart. If the communication hardware consists of covers or IR filters, it shall be included as part of the test.

The transmitter and receiver shall be positioned 55 mm apart at an orientation of 30° from direct alignment.

The following signals shall be transmitted and correctly received:

- ID=SAE_2799
- VN=01.00
- TV=50.00*
- RT=H70
- FC=Abort
- FC=Dyna
- MP=87.50
- MT=358.15

8 Instructions

Manufacturers of receptacles and nozzles shall provide clear and concise printed instructions and diagrams in a form that can be easily understood and are adequate for:

a) proper field assembly;

b) installation;

c) safe operation by all users, including a statement that end users shall consider the pressure and flow capabilities of the system to which they are installed;

NOTE See ISO 19880-1 for use of nozzles.

d) suitability and use; and

e) transport, storage and handling.

Special tools required for connection of receptacles to tubing shall be clearly identified in the instructions.

Nozzles that have been subjected to 10 over-pressurization occurrences shall be removed from service.

In addition, the manufacturer shall provide clear instructions on the required maintenance and required periodic inspection of components as well as the expected service life of the receptacle and nozzle including the expected service life of components, if different.

9 Marking

9.1 Markings required by this clause shall be in a legible and easily understandable form. These markings shall be embossed, cast, low stress stamped or otherwise formed in the part or a permanently attached plate. This includes markings baked into an enamelled surface. Permanently attached marking plates shall be securely attached by mechanical means. All markings shall be at least 2,5 mm high.

Nozzles and receptacles shall bear the following information:

a) the manufacturer's or dealer's name, trademark or symbol;

b) the model designation;

c) the appropriate pressure class, H11, H25, H35, H35HF or H70;

d) component pressure rating (nozzles only);

e) the applicable Type A, B or C (nozzles only);

f) in the case of Type A nozzle, the direction of the ON and OFF operation of the actuating mechanism;

g) marking for traceability of receptacles in suitable lots; nozzles shall carry individual serial numbers;

h) a reference to this document, i.e. ISO 17268:2020;

9.2 Nozzles may also bear the following non-mandatory information:

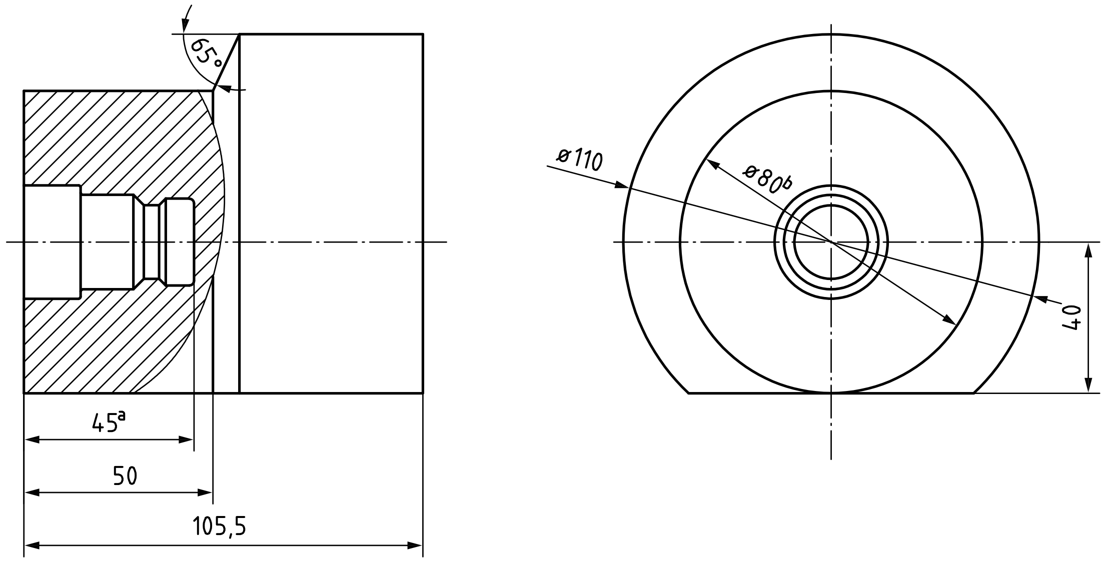
a) the statement: pressure relief valve (PRV) set-point ≤ 1,375 × NWP; or

b) the statement: rated to 1,375 × NWP.

Annex A
(normative)

Receptacle/nozzle interface envelope

Dimensions in millimetres



NOTE Depending on the vehicle design, the overall depth of the fuelling cavity doesn't need to be as large as indicated here.

[a] Minimum length of the receptacle that shall be clear of provisions for attachment of receptacle or protective cap.

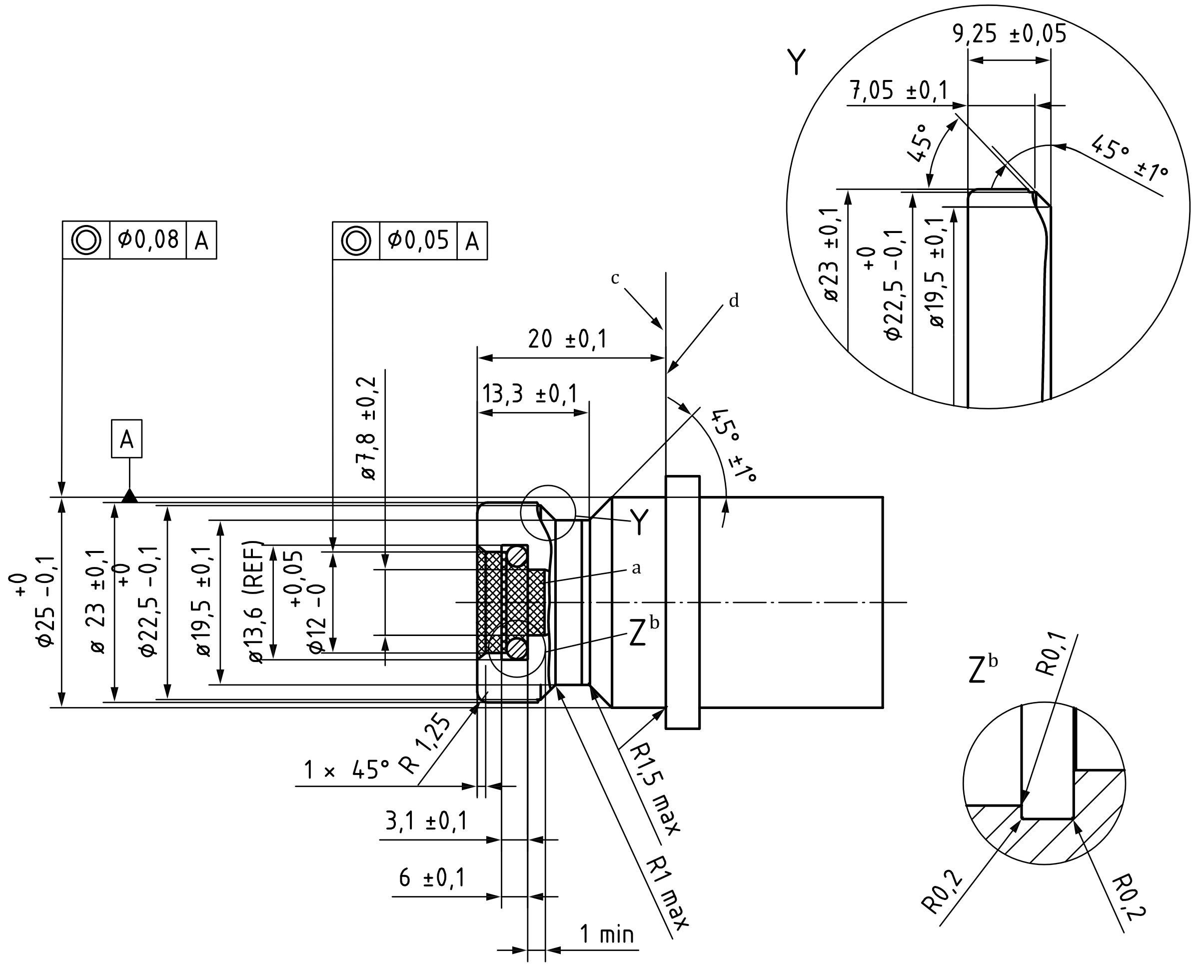
[b] For minimum coupling clearance only. System designers shall ensure that the dust or protective cap operates freely in the provided space.

Figure A.1 — Receptacle/nozzle interface envelope

Annex B
(normative)

Hydrogen receptacles

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Unless otherwise specified, surface finish roughness average (Ra) shall be 0,4 µm to 3,2 µm.

[a] Shaded area represents an area, which shall be kept free of all components except for the seal. Surface finish Ra shall be 0,8 µm ± 0,05 µm.

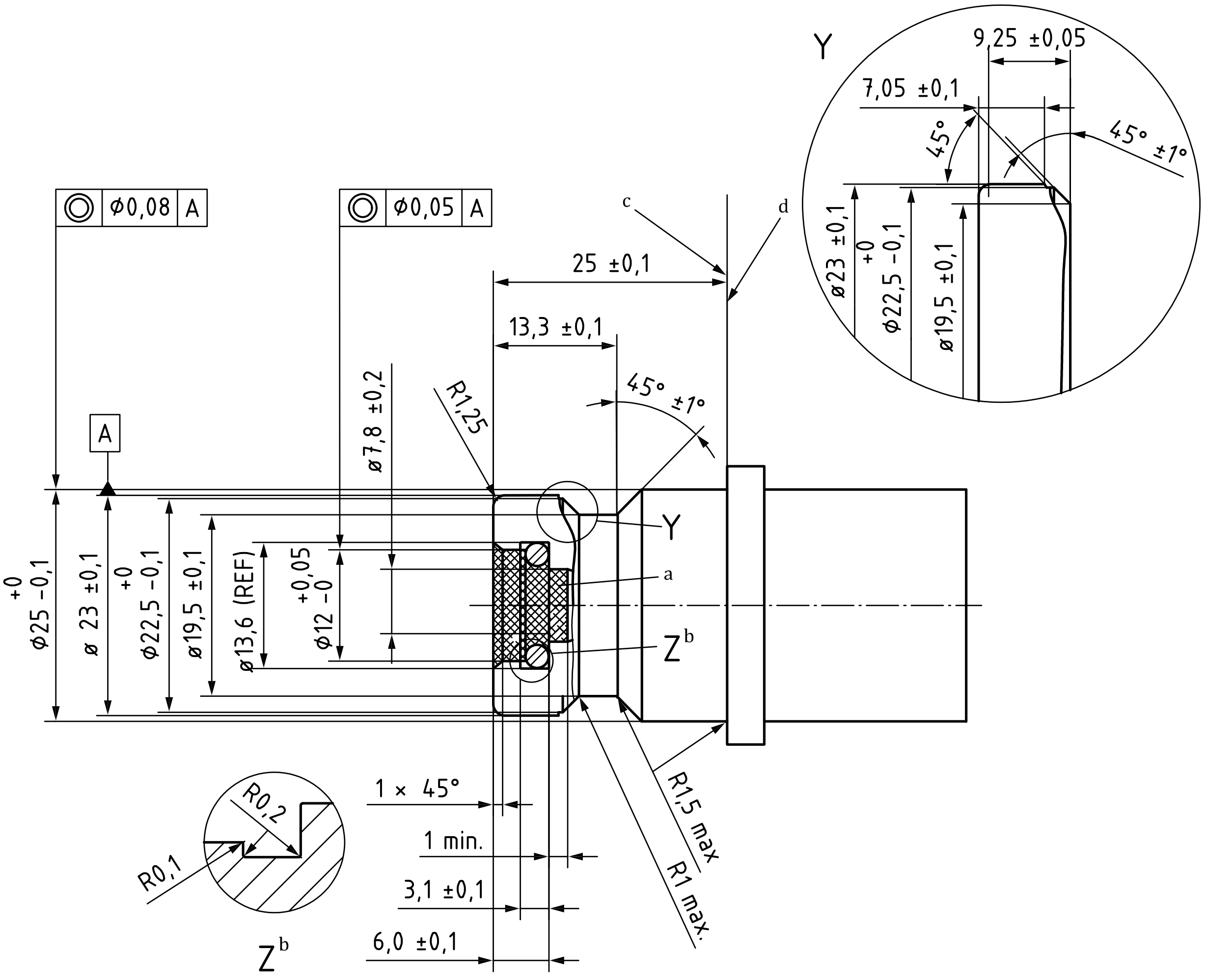
[b] Reference sealing material surface to a no. 110 O-ring with the following dimensions: internal diameter: 9,19 mm ± 0,13 mm; width: 2,62 mm ± 0,08 mm.

[c] Nozzle side: No part of the nozzle assembly shall extend beyond the receptacle stop ring.

[d] Vehicle side: The stop ring shall have a continuous shape that has an effective diameter of 30 mm or more and a thickness greater than 5 mm.

Figure B.1 — H11 hydrogen receptacle

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Unless otherwise specified, surface finish Ra shall be 0,4 µm to 3,2 µm.

[a] Shaded area represents an area, which shall be kept free of all components except for the seal. Surface finish Ra shall be 0,8 µm ± 0,05 µm.

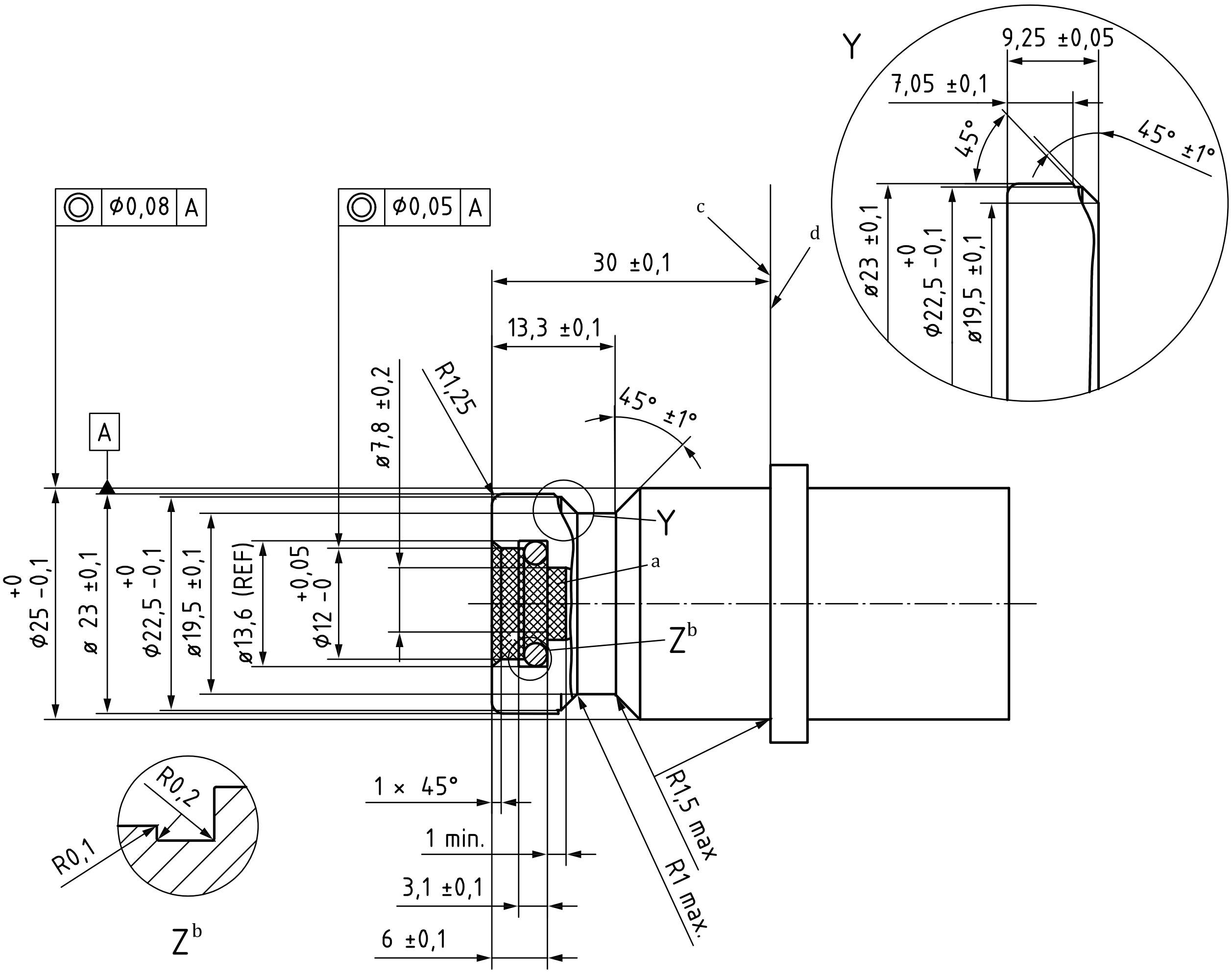
[b] Reference sealing material surface to a no. 110 O-ring with the following dimensions: internal diameter: 9,19 mm ± 0,13 mm; width: 2,62 mm ± 0,08 mm.

[c] Nozzle side: No part of the nozzle assembly shall extend beyond the receptacle stop ring.

[d] Vehicle side: The stop ring shall have a continuous shape that has an effective diameter of 30 mm or more and a thickness greater than 5 mm.

Figure B.2 — H25 hydrogen receptacle

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Unless otherwise specified, surface finish Ra shall be 0,4 µm to 3,2 µm.

[a] Shaded area represents an area, which shall be kept free of all components except for the seal. Surface finish Ra shall be 0,8 µm ± 0,05 µm.

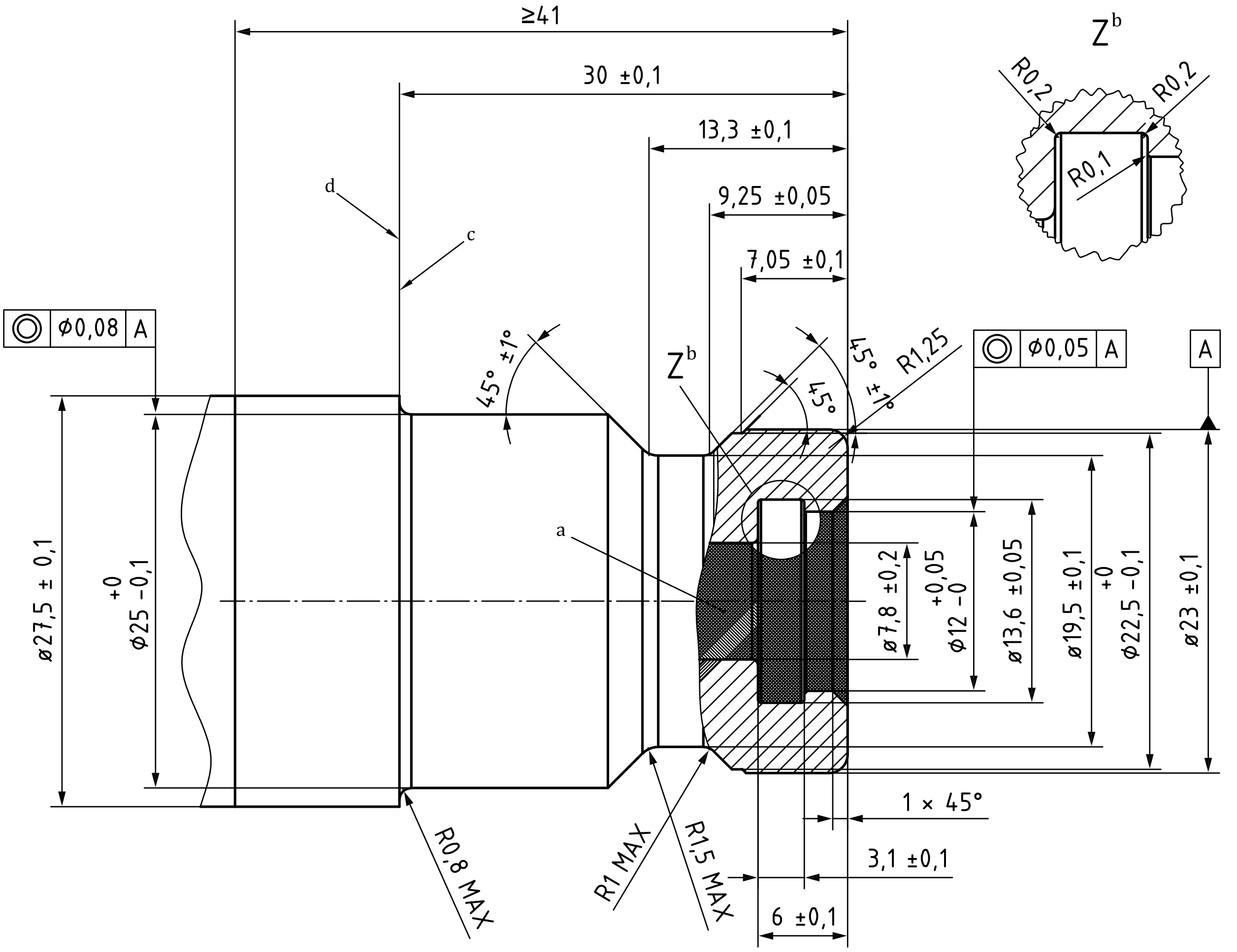
[b] Reference sealing material surface to a no. 110 O-ring with the following dimensions: internal diameter: 9,19 mm ± 0,13 mm; width: 2,62 mm ± 0,08 mm.

[c] Nozzle side: No part of the nozzle assembly shall extend beyond the receptacle stop ring.

[d] Vehicle side: The stop ring shall have a continuous shape that has an effective diameter of 30 mm or more and a thickness greater than 5 mm.

Figure B.3 — H35 hydrogen receptacle

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Unless otherwise specified, surface finish Ra shall be 0,4 µm to 3,2 µm.

[a] Shaded area represents an area, which shall be kept free of all components except for the seal. Surface finish Ra shall be 0,8 µm ± 0,05 µm.

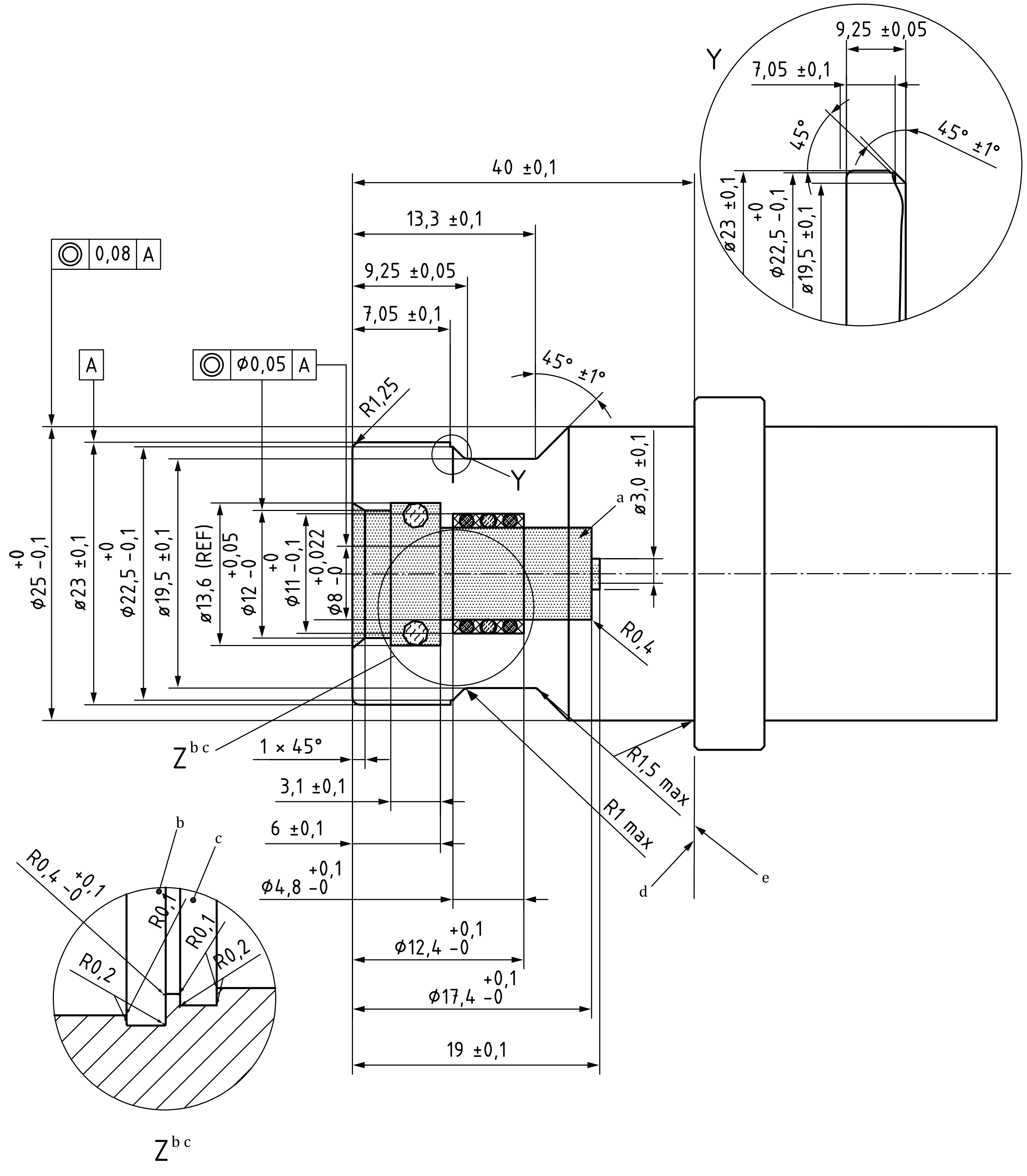
[b] Reference sealing material surface to a no. 110 O-Ring with the following dimensions: internal diameter: 9,19 mm ± 0,13 mm; width: 2,62 mm ± 0,08 mm.

[c] Nozzle side: No part of the nozzle assembly shall extend beyond the receptacle stop ring.

[d] Vehicle side: The stop ring shall have a continuous shape that has an effective diameter of 30 mm or more and a thickness greater than 5 mm.

Figure B.4 — H35HF hydrogen receptacle (high flow for commercial vehicle applications)

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB).

The seal part on the nozzle side shall meet the requirements of Figure B.6.

[a] Shaded area represents an area, which shall be kept free of all components except for the seals and anti-extrusion rings. Surface finish Ra shall be 0,8 µm ± 0,05 µm.

[b] Reference sealing material surface to a no. 110 O-Ring with the following dimensions: internal diameter: 9,19 mm ± 0,13 mm; width: 2,62 mm ± 0,08 mm.

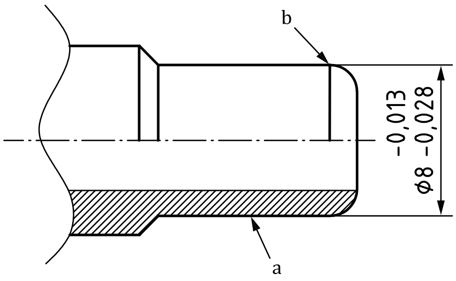
[c] Reference sealing material surface to a no. 011 O-Ring with the following dimensions: internal diameter: 7,65 mm ± 0,13 mm; width: 1,78 mm ± 0,08 mm, mounted with two suitable anti extrusion rings. Unless otherwise specified, surface finish Ra shall be 0,4 µm to 3,2 µm.

[d] Nozzle side: No part of the nozzle assembly shall extend beyond the receptacle stop ring.

[e] Vehicle side: The stop ring shall have a continuous shape that has an effective diameter of 30 mm or more and a thickness greater than 5 mm.

Figure B.5 — H70 hydrogen receptacle

Dimensions in millimetres



[a] Surface finish Ra shall be 0,8 µm ± 0,05 µm.

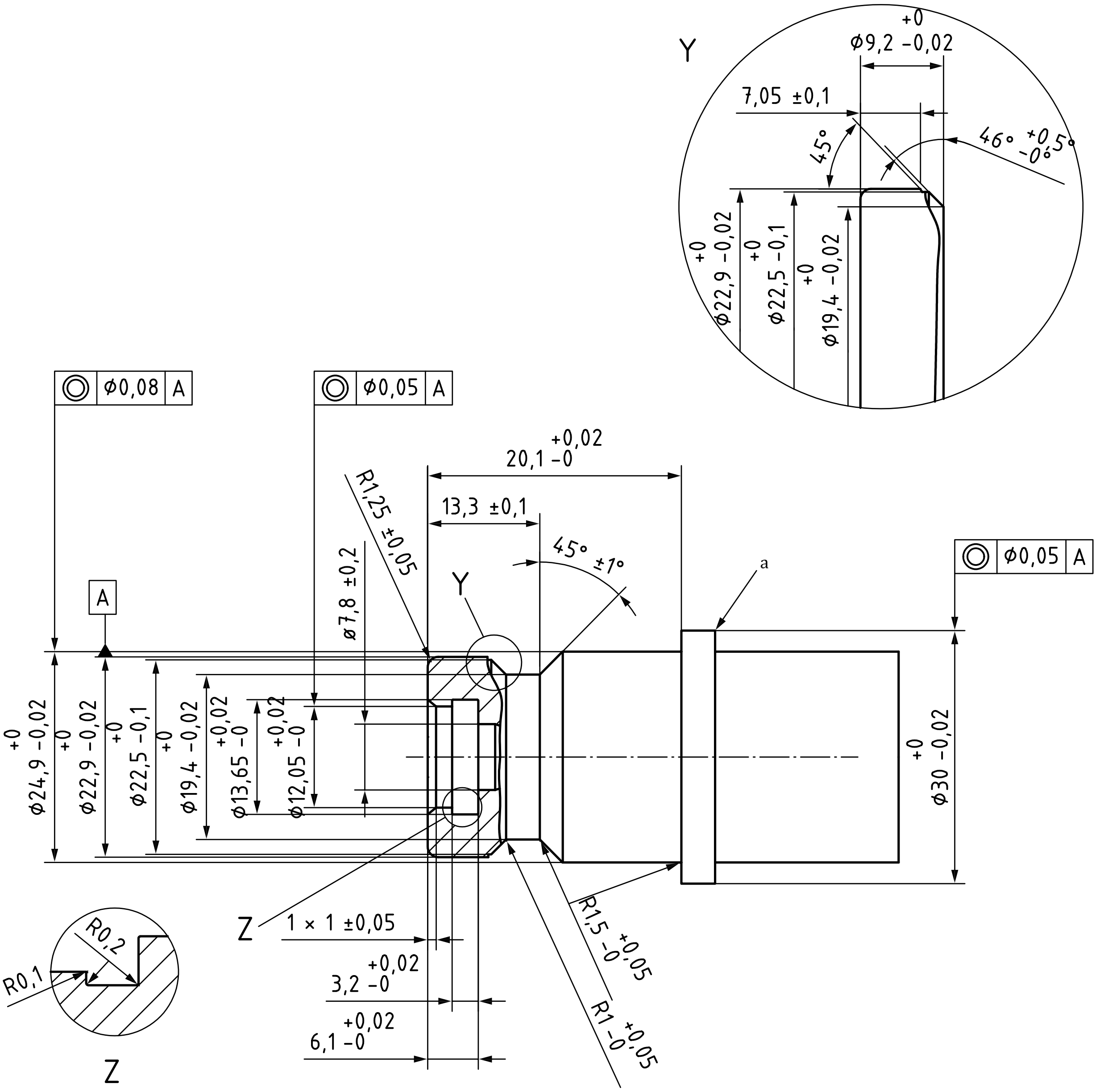
[b] The leading chamfer of nozzle pin shall extend part rear anti-extrusion ring of the receptacle.

Figure B.6 — Seal part on the 70 MPa nozzle side

Annex C
(normative)

Loose fit test fixtures

Dimensions in millimetres

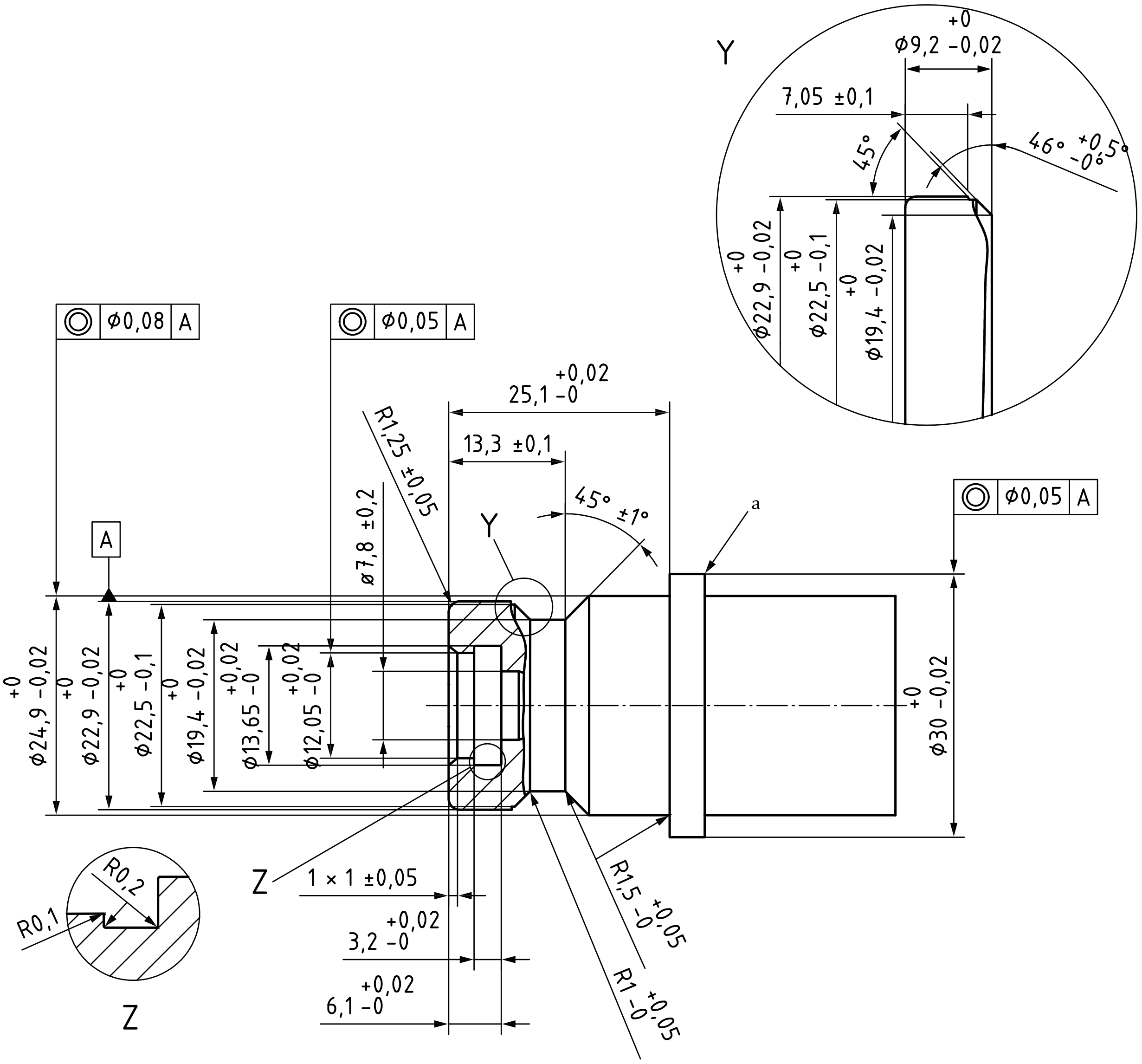


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure C.1 — H11 loose fit test fixture

Dimensions in millimetres

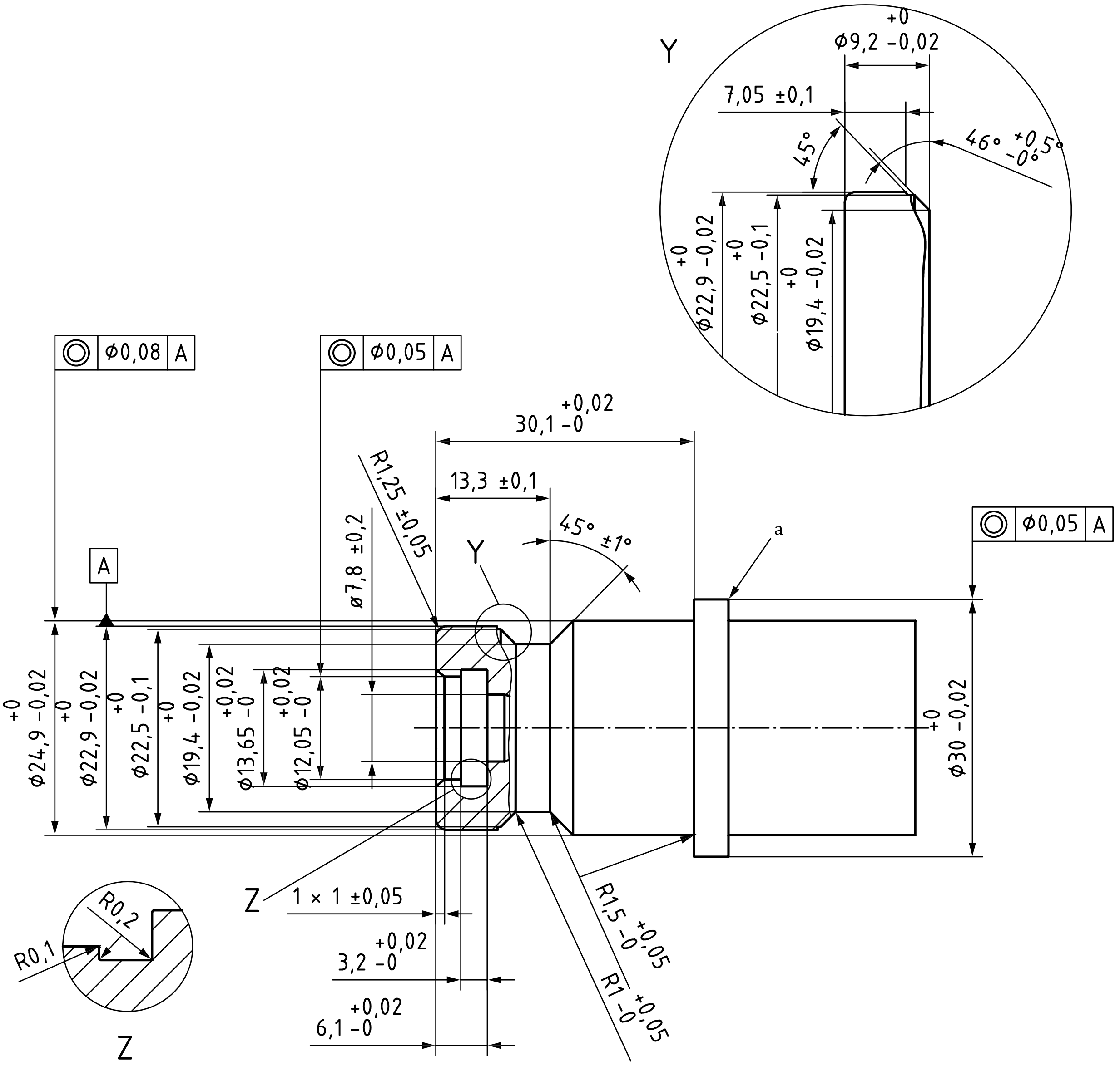


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure C.2 — H25 loose fit test fixture

Dimensions in millimetres

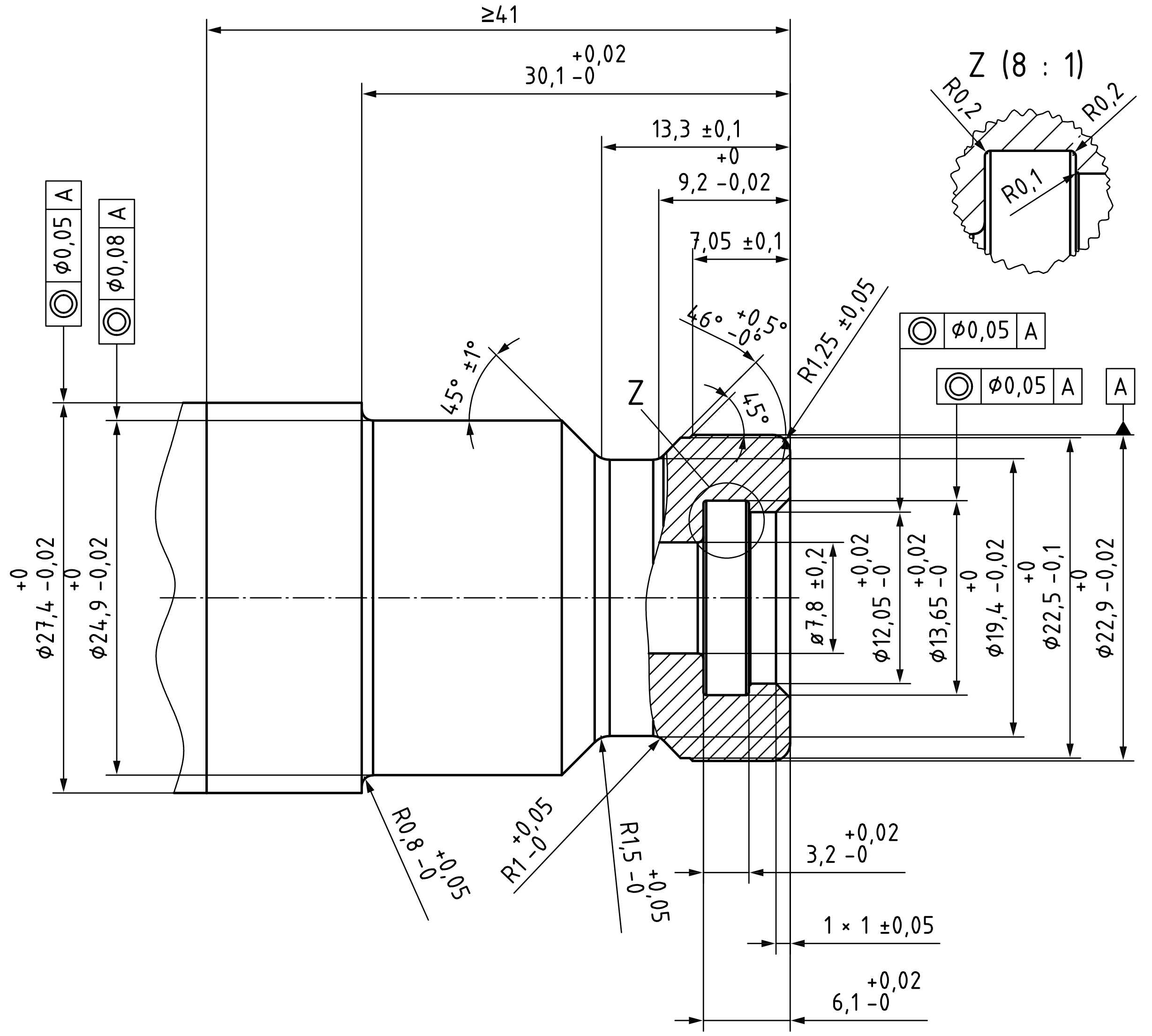


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure C.3 — H35 loose fit test fixture

Dimensions in millimetres

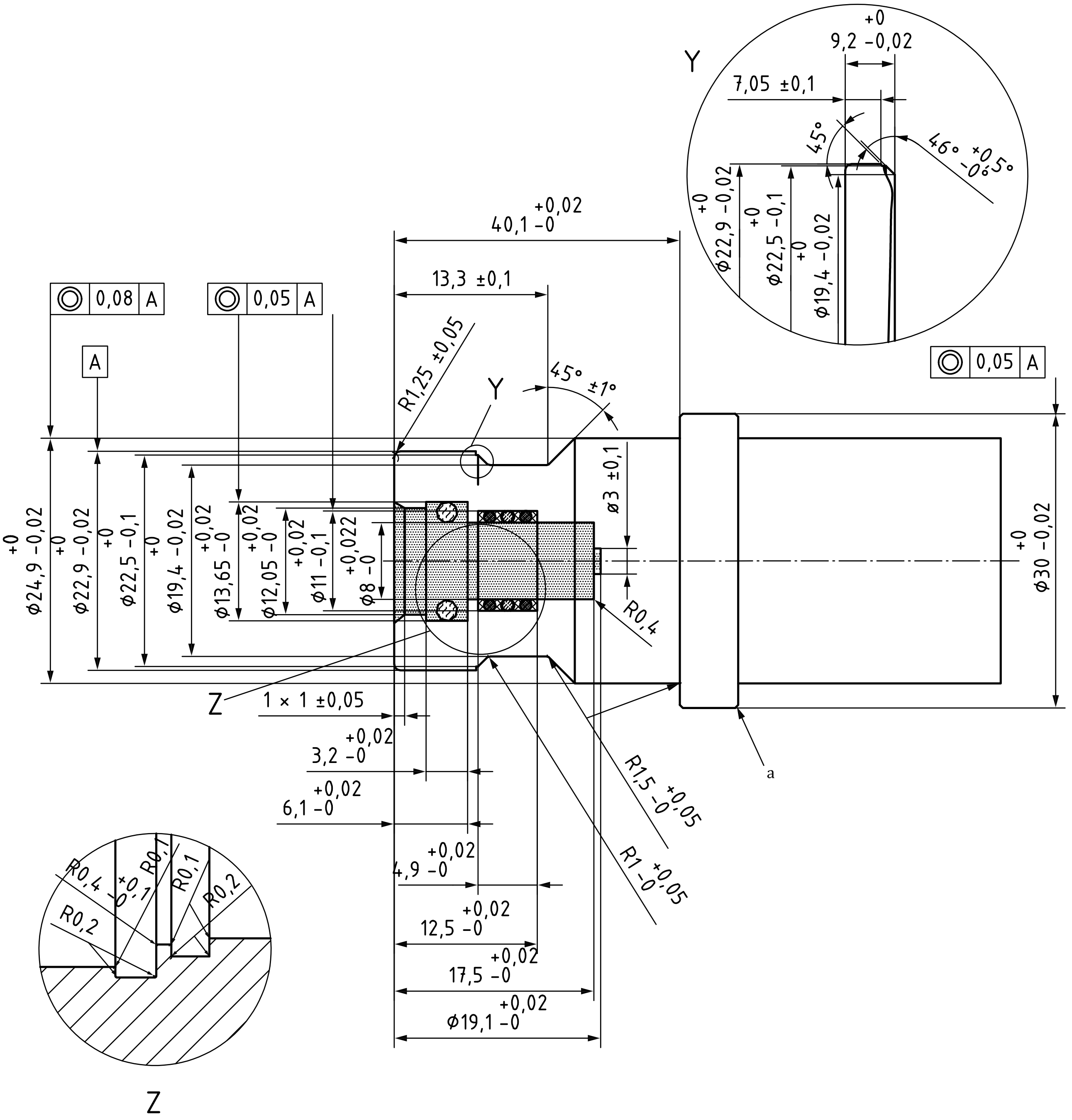


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure C.4 — H35HF loose fit test fixture

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

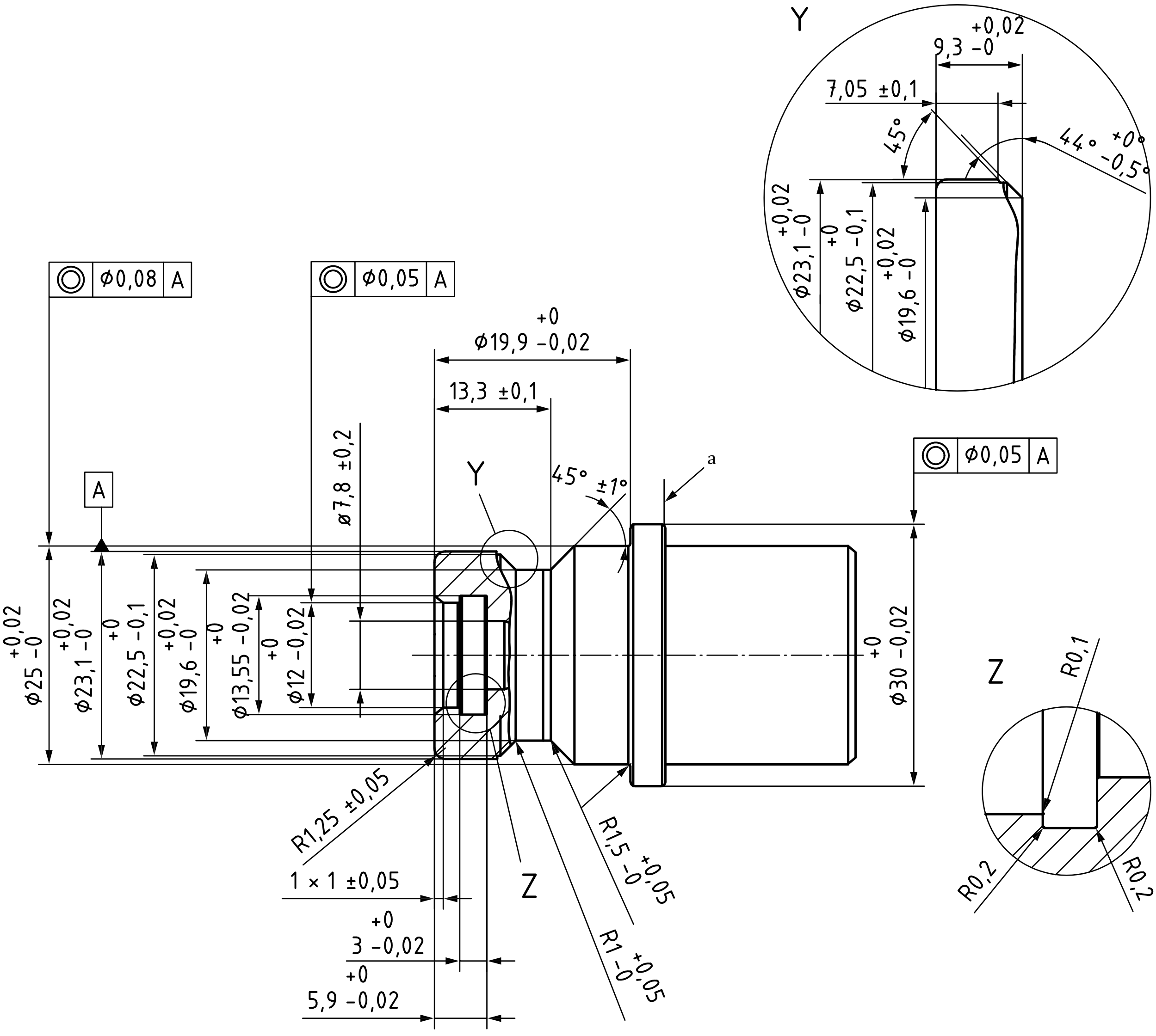
[a] The stop ring shall have a thickness greater than 5 mm.

Figure C.5 — H70 loose fit test fixture

Annex D
(normative)

Tight fit test fixtures

Dimensions in millimetres

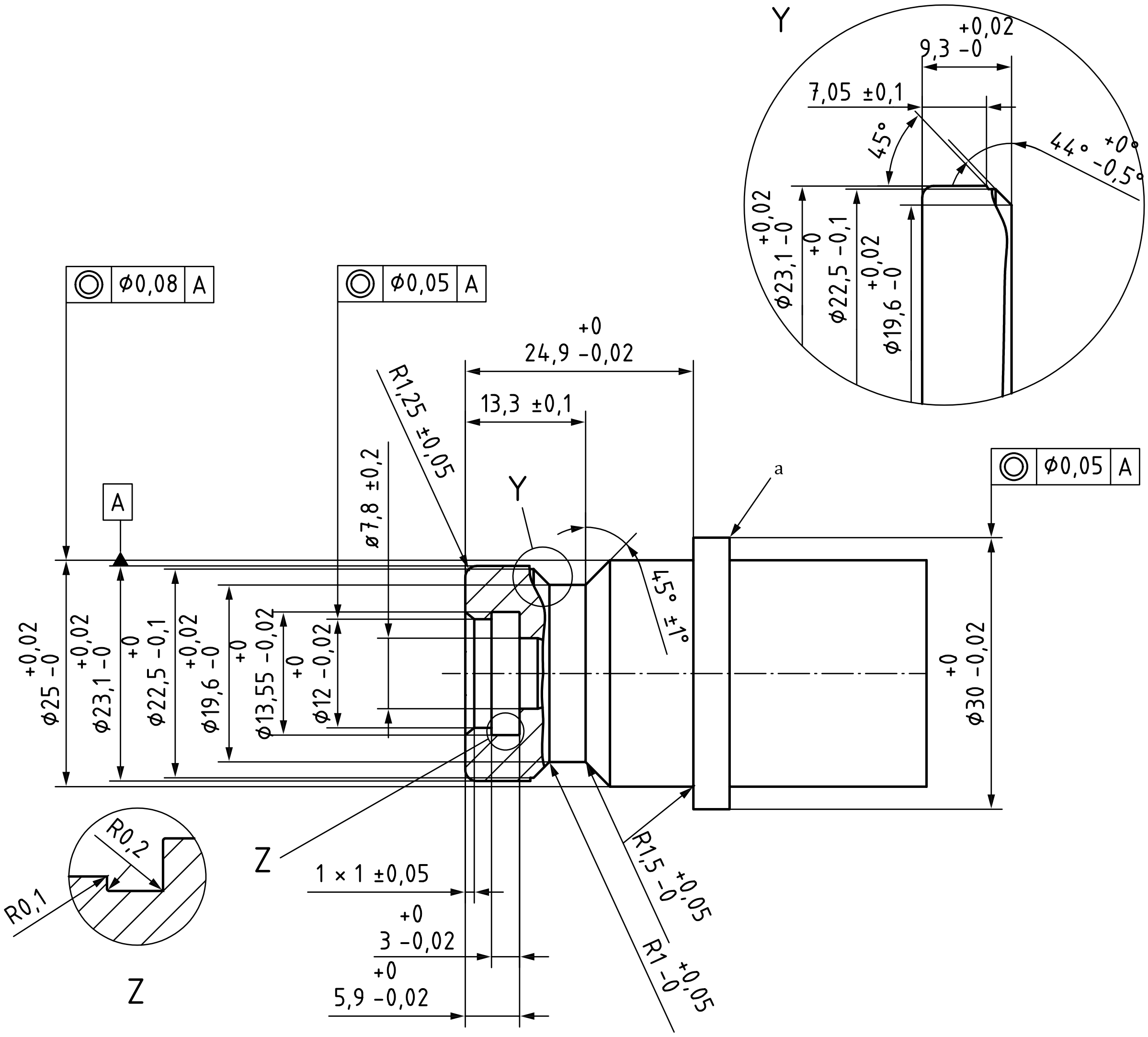


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure D.1 — H11 tight fit test fixture

Dimensions in millimetres

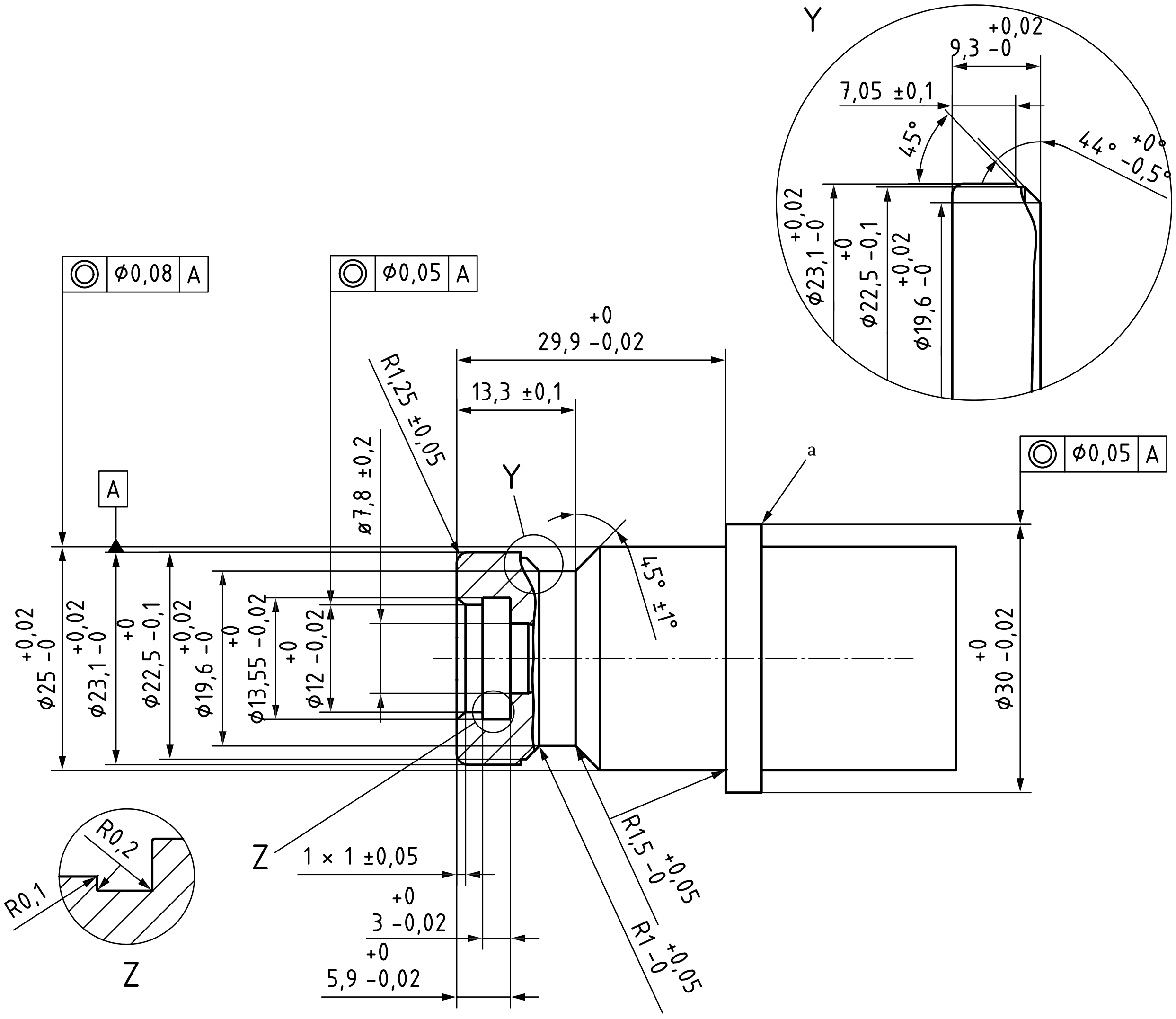


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure D.2 — H25 tight fit test fixture

Dimensions in millimetres

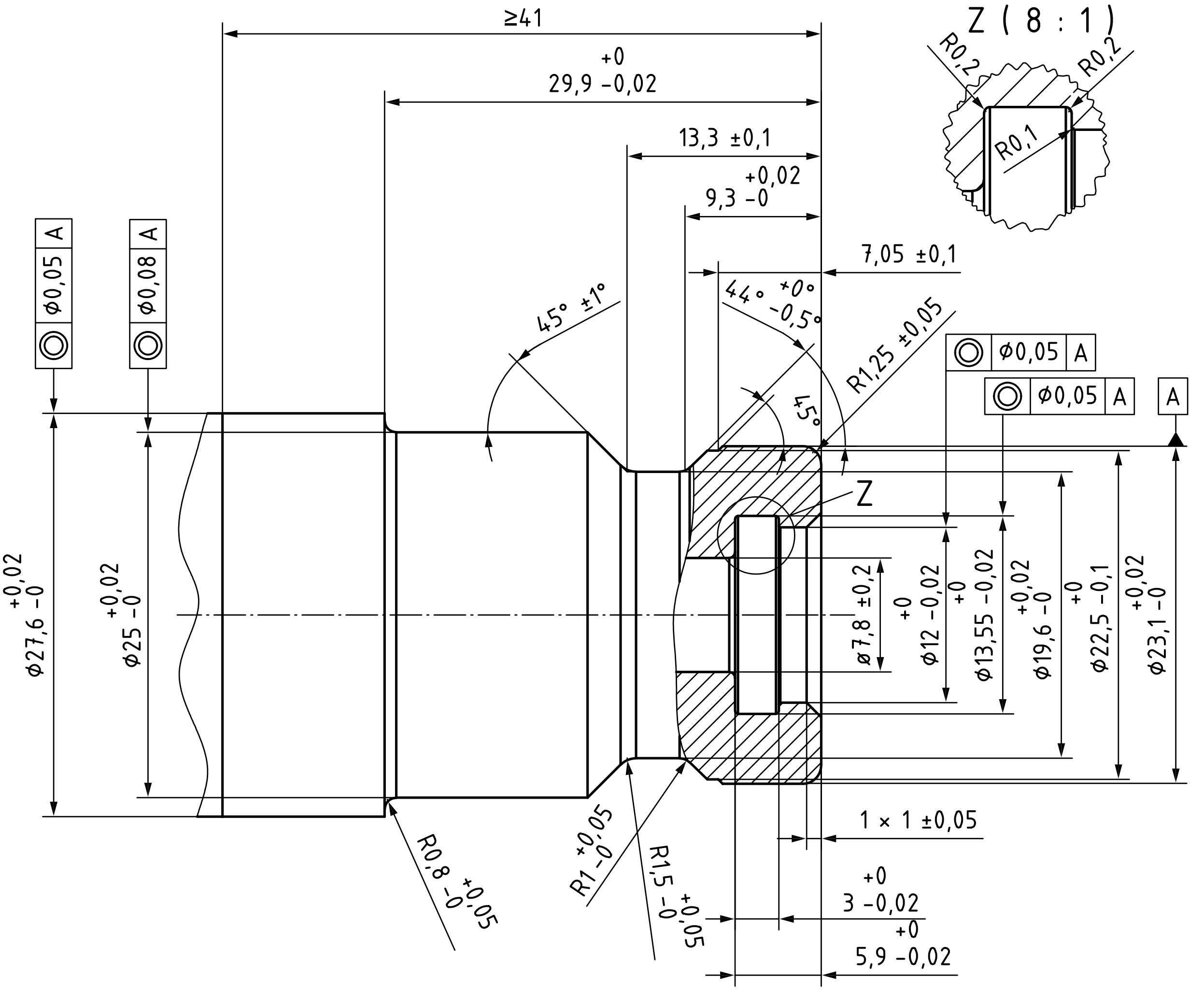


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure D.3 — H35 tight fit test fixture

Dimensions in millimetres

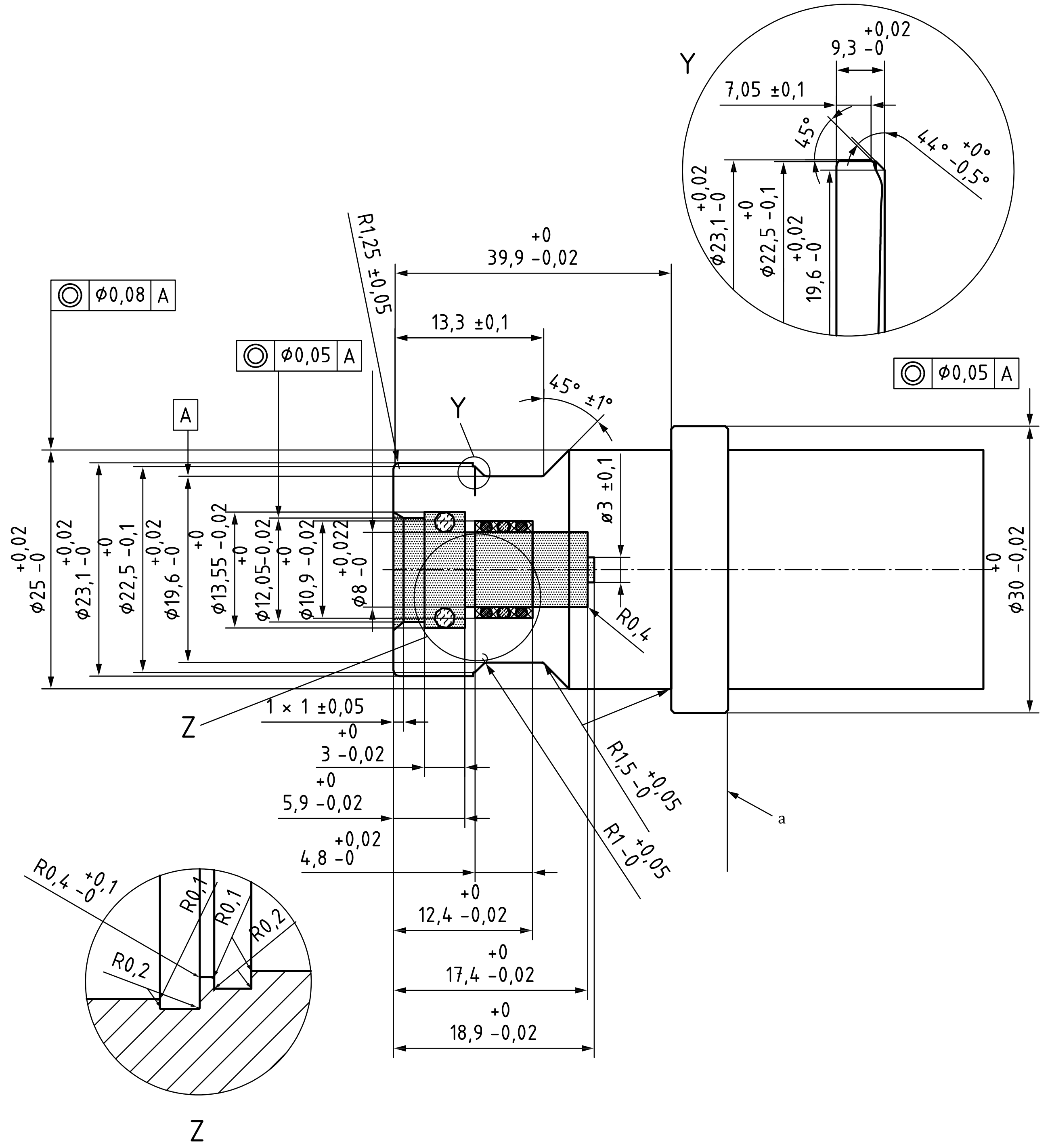


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure D.4 — H35HF tight fit test fixture

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

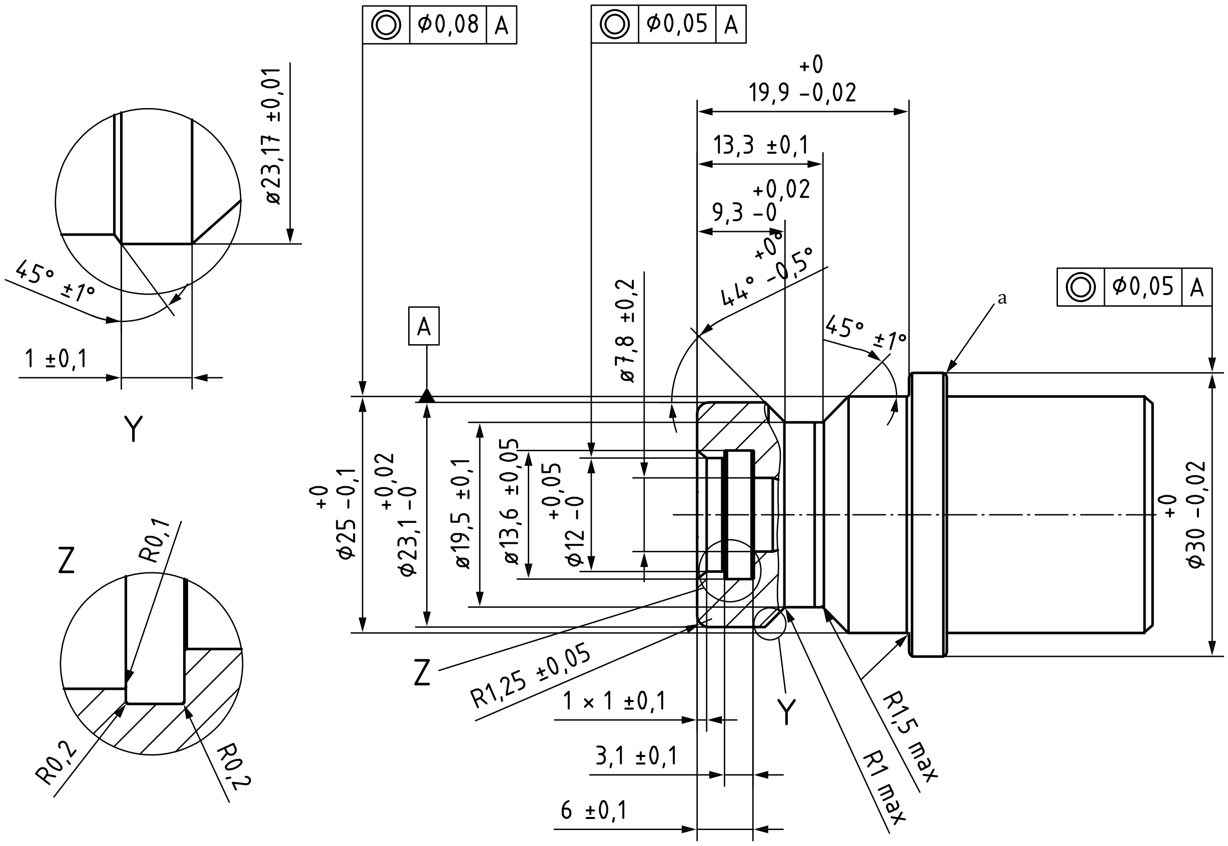
[a] The stop ring shall have a thickness greater than 5 mm.

Figure D.5 — H70 tight fit test fixture

Annex E
(normative)

Wear pattern test fixtures

Dimensions in millimetres

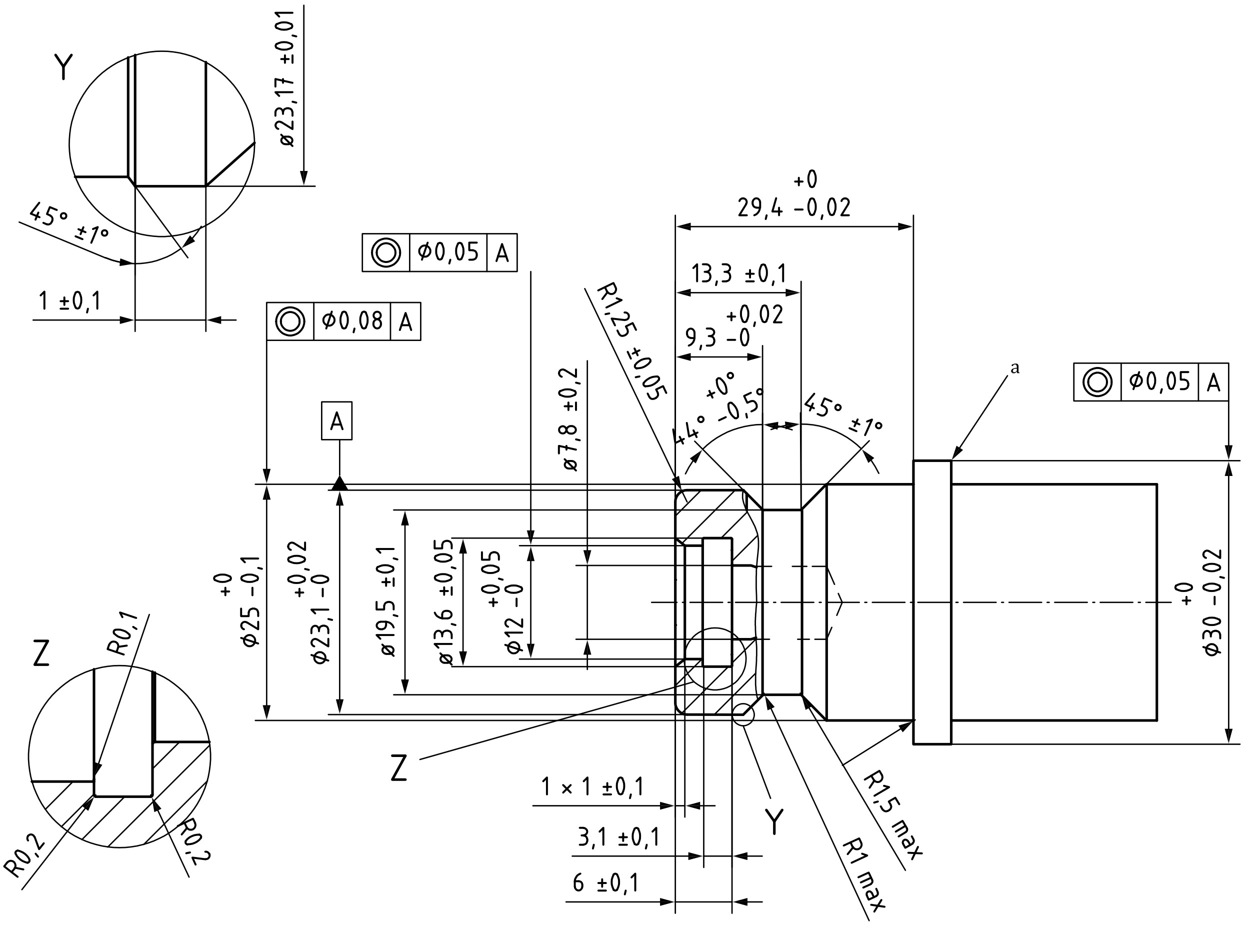


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure E.1 — H11 wear pattern test fixture

Dimensions in millimetres

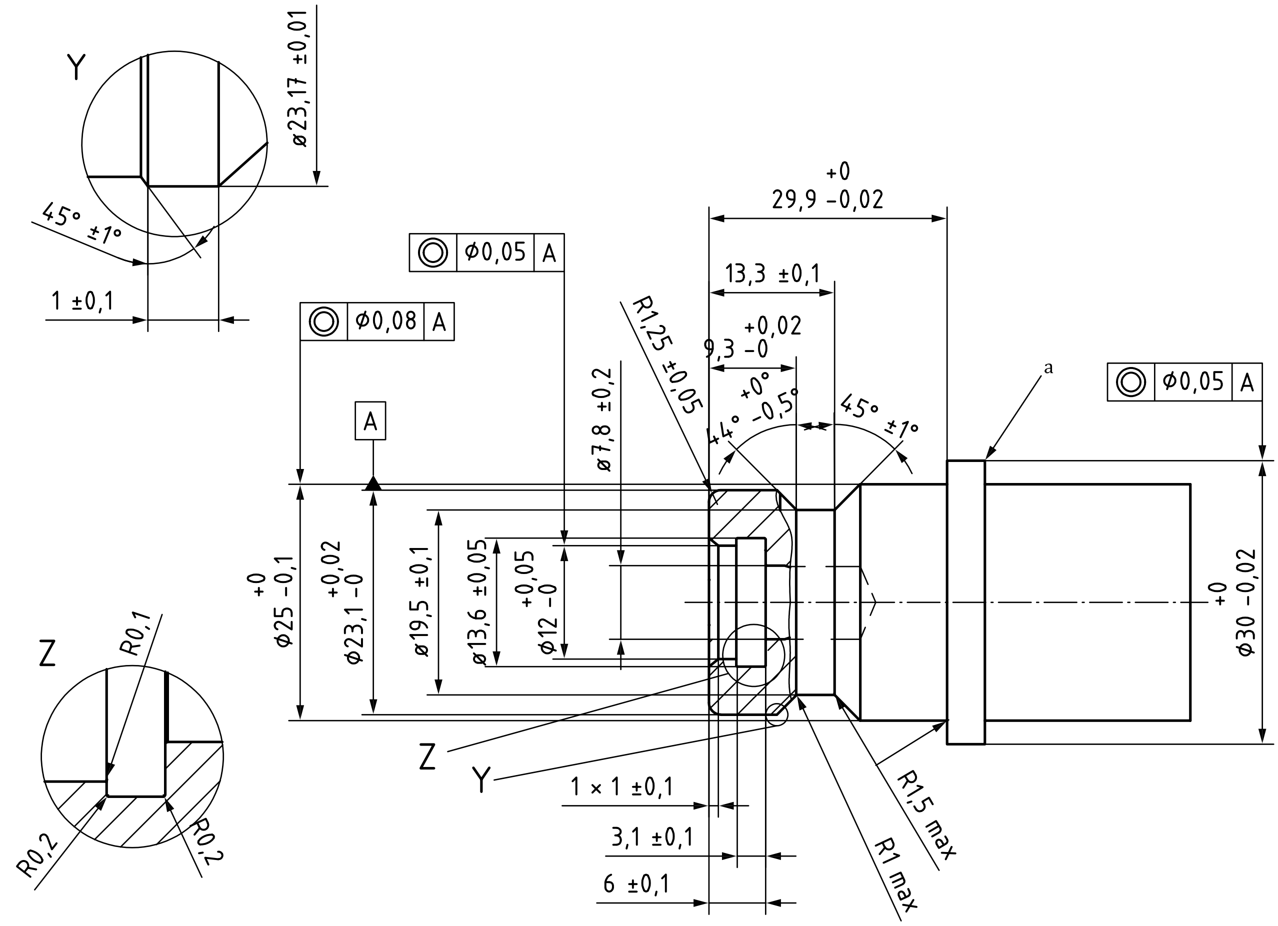


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure E.2 — H25 wear pattern test fixture

Dimensions in millimetres

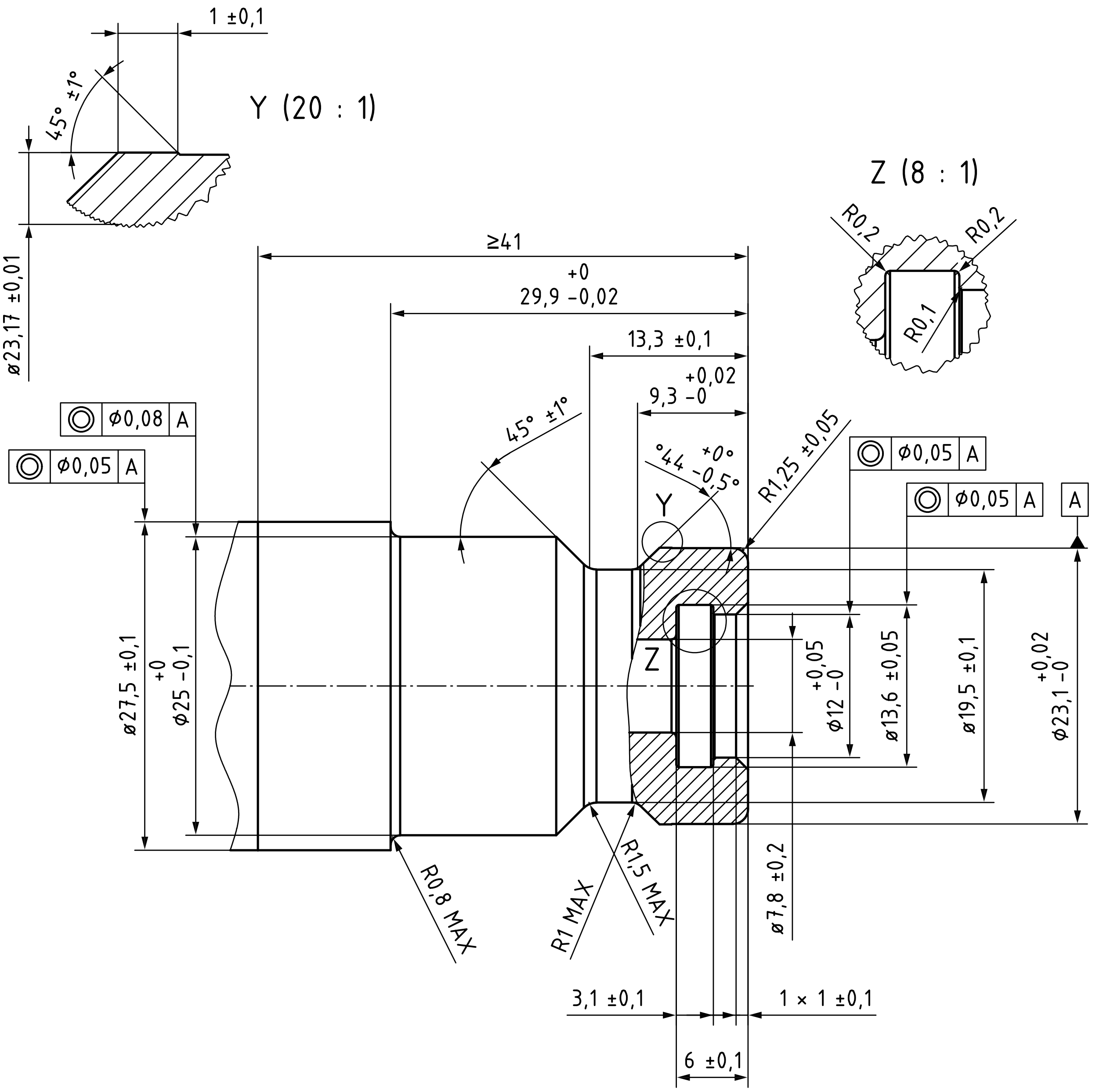


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure E.3 — H35 wear pattern test fixture

Dimensions in millimetres

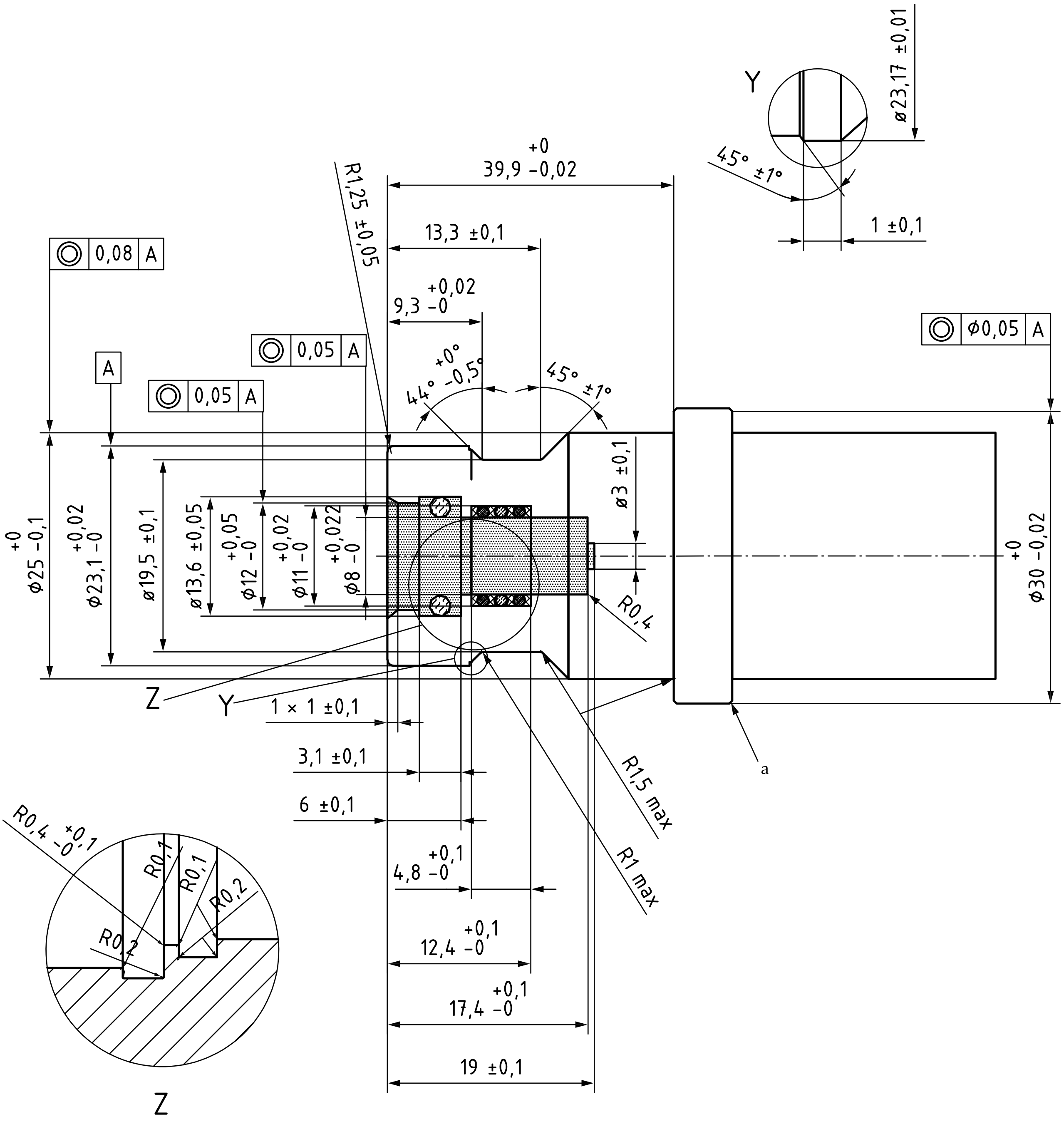


The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure E.4 — H35HF wear pattern test fixture

Dimensions in millimetres



The material shall demonstrate hydrogen compatibility as described in 4.5 and a minimum hardness of 80 Rockwell B (HRB). Surface finish Ra shall be 0,4 µm ± 0,05 µm.

[a] The stop ring shall have a thickness greater than 5 mm.

Figure E.5 — H70 wear pattern test fixture

Annex F
(informative)

Example hex design

Dimensions in millimetres

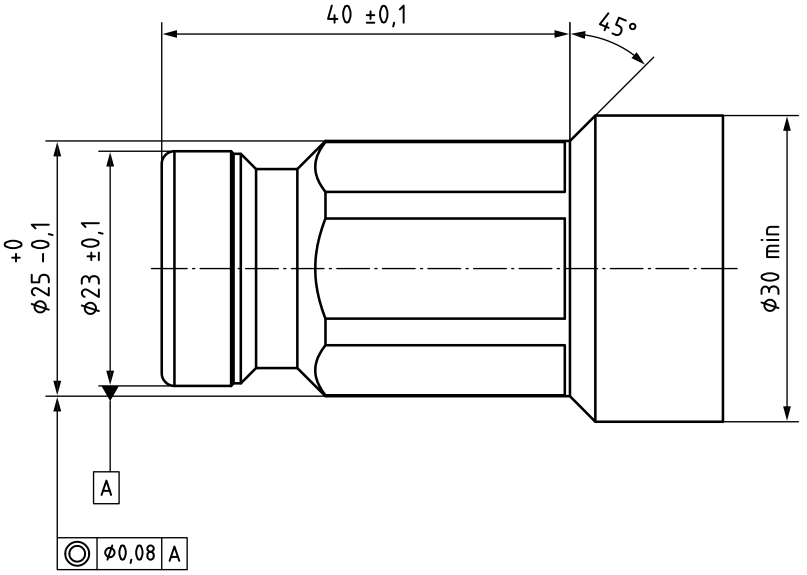


Figure F.1 — Example hex design

NOTE This design is an example countermeasure against freezing issues. It is not to be utilized in the misconnected nozzle test specified in 7.22.

Bibliography

[1] ISO 10286, *Gas cylinders — Terminology*

[2] ISO 14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

[3] ISO 19880-1:—[1], *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*

[4] SAE J2799, *Hydrogen Surface Vehicle to Station Communications Hardware and Software*

[5] ECE/TRANS/180/Add. 13 Global Technical Regulation No. 13 — Global technical regulation on hydrogen and fuel cell vehicles

[6] Pressure Equipment Directive (PED) 2014/68/EU, DIRECTIVE 2014/68/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment

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New Zealand Standard

Public consultation draft

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Standards New Zealand

PO Box 1473, Wellington 6140

Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas
Energy Resources Aotearoa
Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
GNS
Hiringa Energy
HW Richardson Group
HyPotential
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New Zealand Standard

Gaseous hydrogen − Fuelling stations

Part 3: Valves

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 19880-3:2018 *Gaseous hydrogen – Fuelling stations – Part 3: Valves.* Its objective is to specify the requirements and test methods for the safe performance of high-pressure gas valves used in gaseous hydrogen stations of up to the H70 designation.

This document covers the following gas valves:

(a) Check valves;
(b) Excess-flow valves;
(c) Flow-control valves;
(d) Hose-breakaway devices;
(e) Manual valves;
(f) Pressure-safety valves;
(g) Shut-off valves.

As this standard is reproduced from an international standard, the following applies:

(h) In the source text, 'this International Standard' should read 'this New Zealand standard';
(i) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 19880-3

First edition
2018-06

Gaseous hydrogen — Fuelling stations —

Part 3: Valves

Carburant d'hydrogène gazeux — Stations-service —

Partie 3: Vannes

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Contents

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 197, *Hydrogen technologies*.

A list of all parts in the ISO 19880 series can be found on the ISO website.

Introduction

Over the course of several years, international efforts have been initiated for the development of regulations, codes and standards that are required for the introduction of hydrogen energy systems. Hydrogen has unique properties and therefore presents unique safety concerns.

One of the many hydrogen energy applications is the automobile sector for which commercialization begun recently. For the success of this application, however, hydrogen infrastructure for fuelling vehicles is as essential as the hydrogen vehicles themselves. Thus, the development of safety standards for fuelling stations and components is of paramount importance.

This document provides safety performance requirements and test methods for valves to be used in gaseous hydrogen environment. Valves are critical to the safety of hydrogen fuelling stations, because they control the flow of gaseous hydrogen, shut it down in an emergency and, at the same time, may become a potential source of hydrogen release or leakage.

This document will facilitate the development of hydrogen infrastructure that is needed to pave a way for the widespread deployment of hydrogen-fuelled vehicles. Benefits to be gained by the implementation of this document include: the establishment of a certain level of safety performance for valves, a safety-critical component; the streamlining of the design and construction processes for fuelling stations by providing standardized components; and the promotion of public acceptance of hydrogen stations through the transparency of the international standardization processes.

This document is based on the Canadian Standards Association references CSA HGV3.1-2013, ANSI/CSA HGV 4.4-2013, ANSI/CSA HGV 4.6-2013 and ANSI/CSA HGV 4.7-2013.

This document is not intended to exclude any specific technologies that meet the performance requirements herein.

This document is to be applied in conjunction with other International Standards relevant to hydrogen fuelling stations and components.

Gaseous hydrogen — Fuelling stations —

Part 3:
Valves

1 Scope

This document provides the requirements and test methods for the safety performance of high pressure gas valves that are used in gaseous hydrogen stations of up to the H70 designation.

This document covers the following gas valves:

- check valve;
- excess flow valve;
- flow control valve;
- hose breakaway device;
- manual valve;
- pressure safety valve;
- shut-off valve.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
allowable temperature range
minimum and maximum temperatures for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure

3.2
component pressure rating
maximum allowable pressure at which it is permissible to operate a component as specified by the manufacturer at a specified temperature

Note 1 to entry: Further guidance on dispenser pressure terminology is found in ISO 19880-1.

3.3
Cv value

<flow coefficient> coefficient to represent the flow rate of fluid that a valve is capable of handling

Note 1 to entry: Cv is the flow coefficient of a valve with the fluid at 15,56 °C under a pressure difference of 6 894 N/m^2.

Note 2 to entry: There are different types of flow coefficients including Cv, Kv and Av.

3.4
dispenser

system downstream of the hydrogen supply system comprising all equipment necessary to carry out the vehicle fuelling operation, through which the compressed hydrogen is supplied to the vehicle

Note 1 to entry: As an example, the dispenser can include a dispenser cabinet, gas flow meter, a fuelling hose and fuelling nozzle attachments.

3.5
hydrogen service level
HSL

pressure level in MPa used to characterize the hydrogen service of the dispenser based on the NWP rating of the vehicleNote 1 to entry: The numerical value of HSL also matches the number after the “H” in Pressure Class.

Note 1 to entry: Hydrogen service level is expressed in MPa.

3.6
maximum allowable working pressure
MAWP

maximum pressure permissible in a system at the temperature specified for the pressure

Note 1 to entry: The maximum allowable working pressure may also be defined as the design pressure, the maximum allowable operating pressure, the maximum permissible working pressure, or the maximum allowable pressure for the rating of pressure vessels and equipment manufactured in accordance with national pressure vessel codes.

3.7
maximum operating pressure
MOP

highest pressure that is expected for a component or system during normal operation

3.8
valve

device by which the flow of a fluid may be started, stopped or regulated, using a movable part which opens or obstructs passage

3.8.1
check valve

valve which allows gas to flow in only one direction

3.8.2
excess flow valve

valve which automatically shuts off or limits the gas flow when the flow exceeds a set design value

3.8.3
flow control valve

gas flow restricting device, installed downstream of a pressure regulator, which controls gas flow

3.8.4
breakaway device
device on the fuelling hose that disconnects the hose from the dispenser when a tension limit is exceeded and blocks the flow of hydrogen from the dispenser, e.g. if the vehicle moves away with the fuelling hose connected to the vehicle

Note 1 to entry: This device is treated as a type of valve according to 3.8.

3.8.5
manual valve
hand-operated device for controlling the flow of gas

3.8.6
pressure safety valve
PSV
pressure activated valve that opens at a specified set point to protect the system from burst and recloses when the pressure falls below the set point

3.8.7
shut-off valve
on/off valve for controlling the flow of gas, which is pneumatically or electrically actuated

4 General requirements

4.1 General

This document defines proof of design (type) tests for valves, designed and manufactured under existing standards that are intended for use in hydrogen fuelling stations.

The requirements contained within this document are intended to provide performance-based tests to verify capability of valves for high pressure hydrogen service but not to prevent alternative methods to demonstrate acceptable capability. Valves that have extensive, successful service at comparable design conditions with similarly proportioned components made of the same or like material are not required to perform verification tests defined in Clauses 5 through 12 of this document if allowed by applicable codes and regulations.

Components shall comply with all construction specifications set forth herein, or their construction shall demonstrate at least equivalent performance.

4.2 Intended use

The quality of hydrogen fuel dispensed to vehicles is defined in ISO 14687. The design, manufacture and operation of valves constructed in accordance with this document shall not introduce contamination to the hydrogen passing through or in contact with them.

4.3 Material requirements

Resistance to chloride stress corrosion cracking shall be taken under consideration if selecting stainless steel materials. Resistance to sustained load cracking shall be taken under consideration if selecting aluminum materials.

Materials normally in contact with hydrogen shall be determined to be acceptable in hydrogen service, with particular attention to hydrogen embrittlement and hydrogen accelerated fatigue. Materials and design shall be such that there will be no significant change in the functioning of the device, deformation or mechanical change in the device, and no harmful corrosion, deformation or deterioration of the materials.

Non-metallic materials normally in contact with hydrogen shall be determined to be acceptable in hydrogen service. Consideration shall be given to the fact that hydrogen diffuses through these materials much more easily than through metals; therefore, the suitability of materials shall be verified.

Non-metallic materials shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of service conditions and lifetime as specified by the manufacturer.

Materials shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation.

The material chemical and physical properties necessary for operational safety shall not be significantly affected within the scheduled lifetime of the equipment unless replacement is foreseen.

When selecting materials and manufacturing methods, due account shall be taken of:

- material's corrosion and wear resistance;
- electrical conductivity;
- impact strength;
- aging resistance;
- effects of temperature variations;
- effects arising when materials are combined (for example, galvanic corrosion);
- effects of ultraviolet radiation;
- degradation effects of hydrogen on the mechanical performance of a material.

Guidance to account for the degradation effects of hydrogen on the mechanical performance of a material can be found in ISO/TR 15916.

4.4 Product quality

The manufacturer shall establish production processes with quality control measures to ensure that production valve(s) meet requirements established in this document. As part of this requirement, a hydraulic proof pressure test at 150 % and a gas leak test at 100 % of the component pressure rating shall be conducted. Alternatively a gas leak test at 125 % of the component pressure rating may be conducted.

5 General test methods

5.1 General

General test requirements for all valves are outlined in 5.2 to 5.11. Where additional test requirements exist for specific types of valves, these are included in Clauses 6 to 12.

Any component to be installed downstream of the precool system shall be subject to a cold gas in warm valve test.

5.2 Test conditions

5.2.1 Test sample

A new valve may be used for each test specified. When a series of valves that differ in size only is to be evaluated, three representative samples shall be chosen. At a minimum the smallest, largest and one intermediate size valves shall be evaluated.

5.2.2 Pressure

Unless otherwise stated, all pressures noted within this document are gauge pressure. For general applications, the component pressure rating of the valve to be tested shall be used as is. Since the component pressure rating is to be greater or equal to the system MAWP, the following is permitted:

a) For dispenser applications, the component pressure rating of the valve may be replaced with the MAWP of the dispenser system in which the valve is to be used.

b) For applications in other pressure systems, the component pressure rating of the valve may be the MAWP of such a pressure system.

5.2.3 Normal test temperature

Unless otherwise stated, any test at room temperature shall be conducted at 20 °C (± 5) °C.

5.2.4 Specified test temperature

The tests in these requirements shall be conducted at −40 °C (+0 °C, −3 °C) and at 85 °C (+3 °C, −0 °C) where the valve is used in a dispenser. If the manufacturer specifies the temperature range for use, the test temperatures are the minimum and the maximum of the range.

5.2.5 Test media

Test media as specified in these requirements shall be:

a) hydrogen for leak tests;

b) hydrogen for permeation;

c) hydrogen for gas pressure cycle test;

d) liquids (e.g., water or oil) for hydrostatic strength tests;

e) hydrogen, helium, nitrogen or dry air for all other tests.

5.2.6 Test sequence

For any valve type, the tests described in 5.3, 5.4, 5.5, 5.6 and 5.7 shall be performed in this sequence using the same test sample.

5.3 Hydrogen gas pressure cycle test

5.3.1 General

For the details of test methods for particular valves, see the applicable part of this document.

The method specified in this clause is general in nature and applicable even to miscellaneous valves.

A valve shall withstand 102 000 hydrogen gas pressure cycles without damage or leakage. The replacement of valve seals shall be acceptable at intervals of 16 000 cycles. Prior to conducting this test the valve shall comply with 5.4 at room temperature only.

5.3.2 Test method

The outlet of the valve shall be plugged and the inlet shall be attached to hydrogen pressure supply. The valve shall be in the open position unless otherwise provided in the clause applicable to a specific valve to be tested. Cycling shall be between less than 5 % of the component pressure rating and the component pressure rating (+3 %, −0 %) within a period of not less than 6 s (10 cycles per minute). 100 000 cycles shall be completed at room temperature, with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for operation, apply the minimum temperature instead of −40 °C and the maximum temperature instead of 85 °C.

5.4 Leakage

5.4.1 General

Prior to conditioning, purge the valve with nitrogen and then seal it at approximately 30 % of component pressure rating.

Conduct all tests while the valve is continuously exposed to the specified test temperatures. The device shall either be bubble-free or have a leakage rate of less than 10 cm^3/h (normal) of hydrogen gas using the following test method. This criterion is applicable to all general and specific leakage tests.

This test shall be conducted for 1 min each at two temperature conditions: −40 °C (+0 °C, −3 °C) and 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for use, the test temperatures are the minimum and the maximum of the range.

5.4.2 External leakage test

The valve under test and the test gas (hydrogen) shall be maintained at the required test temperature for 1 h prior to and during the test.

The test pressure shall be at least 100 % of the component pressure rating. A flow measuring device or other method capable of indicating the allowable leak rate shall be used.

5.4.3 Internal leakage test

The internal leakage test is applicable only to valves having a closed position. The aim of this test is to check the pressure tightness of the closed system.

Connect the inlet or outlet (as applicable) of a valve, with the appropriate mating connection, while leaving the opposite connection or connections open.

The valve under test and the test gas (hydrogen) shall be maintained at the required test temperature for 1 h prior to and during the test.

The pressure for the high pressure test shall be at least 100 % of component pressure rating, and the pressure for the low pressure test shall be 2,5 % or less of the component pressure rating. A flow measuring device capable of indicating the allowable leak rate shall be used.

5.5 Worst case fault pressure cycle test

Valves shall be capable of withstanding the pressure expected to occur in a fault condition of the system.

This test shall be conducted at room temperature only. The test media should be hydrogen.

The inlet of the valve shall be connected to a source capable of supplying the necessary test pressure with the outlet closed. Follow the test method of the hydrogen gas cycle test for the valve. Cycling shall be between 5 % or less of 110 % of the component pressure rating and at least 110 % of the component pressure rating (+3 %, −0 %) within a period of not less than 6 s (10 cycles per minute). After ten cycles, the valve shall be tested in accordance with 5.4.2 and 5.4.3 with no leakage.

5.6 Proof pressure test

The inlet of the valve shall be connected to a source capable of supplying the necessary test pressure.

Test media shall be liquid. With the valve open and its outlet sealed, and the valve seats or internal blocks made to assume the open position, the pressure shall be slowly increased to 150 % of the component pressure rating and maintain that pressure for 10 min and the device under test shall be checked for leakage. The valve shall not have any leakage.

5.7 Hydrostatic strength test

5.7.1 Test pressure

This is a test to be conducted following the proof pressure test of 5.6.

Valves shall be capable of withstanding without rupture the test pressure of 2,4 times the component pressure rating. When the country or region in which the valve is being put on the market/is intended for use has its own regulation, the test pressure should follow the regulation. The pressure for hydrostatic strength test shall be included in the marking on the valve. If it is impossible to do so in the marking, it shall be included in its literature.

NOTE The ultimate strength criteria are based on the fatigue limit of metals. No fatigue is expected to occur as long as the maximum stress is less than 50 % of the ultimate strength. Since the dispenser MOP is 1,25 times the HSL and component pressure rating is at least 1,375 x HSL, the maximum stress during normal cycling is less than 38 % of ultimate strength and is acceptable for dispenser service.

5.7.2 Test method

This test shall be conducted at room temperature only. This is a destructive test and the valves used in the test shall not be used for any subsequent tests or applications.

If the valve leaks during pressurization to the hydrostatic test pressure of 2,4 times the component pressure rating, it is not considered a failure as long as the pressure has exceeded 150 % the component pressure rating at the time leakage occurs and the hydrostatic test pressure is subsequently achieved.

Upon completing the proof pressure test of 5.6, don’t reduce the pressure from 150 % of the component pressure rating. The pressure is then increased to the applicable hydrostatic test pressure. This pressure shall be sustained for 1 min without rupturing the valve. Leakage is permitted above 150 % of the component pressure rating, and a means may be used to reduce the leakage rate, if any, when performing this test.

5.8 Excess torque resistance test

A valve designed to be connected directly to threaded fittings or pipes shall be capable of withstanding without deformation, breakage or leakage, a torque of 150 % of the rated installation value, according to the following test procedure.

a) Test an unused valve, applying the torque adjacent to the fitting.

b) For a valve having a threaded connection or threaded connections, apply the torque for 15 min, release it, then remove the valve and examine it for deformation and breakage.

c) Subject the valve to the leakage test specified in 5.4.

NOTE The value of 150 % is based on ISO 12619-2.

5.9 Bending moment test

A valve shall be capable of operation without cracking, breaking or leaking when tested according to the following procedure.

a) Assemble the connections of the valve, leak-tight, to an appropriate mating connection or connections, representative of design intent. After assembly, the length of the inlet piping shall be at least 300 mm (see Figure 1).

b) The outlet connections shall be rigidly supported, at least 25 mm from the valve outlet, except in the following cases:

   - if the valve has an integral mounting means independent of the inlet and outlet connections, the valve shall be mounted using the integral mounting means specified by the manufacturer;
   - if the valve is intended to be mounted by either the integral mounting means or the component outlet, the mounting means that produces the most severe test condition shall be used.

c) Check this assembly for leaks prior to subjecting it to procedure d).

d) With the valve in the closed position, the system shall be pressurised to 5 % of the specified component pressure rating and the appropriate minimum weight as specified in Table 1 shall then be suspended on the inlet fitting, without shock, 300 mm from the inlet of the valve for 15 min. Without removing the weight, the valve shall then be tested for leakage as specified in 5.4.

   NOTE Depending on how this test is performed, raising the load to compensate buoyancy can be necessary.

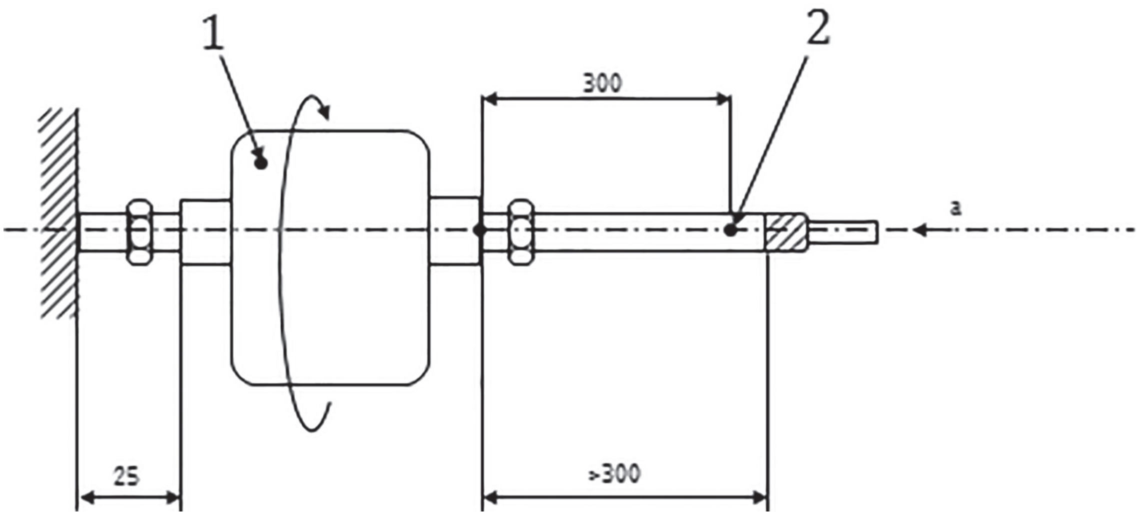
e) Conduct procedure d) 4 times, rotating the valve 90° around the horizontal axis between each test. Between procedures, open and close (if applicable) the valve 3 times with the bending moment removed.

f) At the completion of the above tests, remove the valve and examine it for deformation; then subject it to the leakage test according to 5.4.

Table 1 shows the pipe diameters and their corresponding bending moments.

Table 1 — Load for bending moment test

Outside diameter of pipe mm	**Weight** kg
3,18	0,9
6,95	1,6
9,53	2,3
12,7	4,5
19,1	8,2
25,4	14,5



Key

1 component

2 force point

a 5 % of the MAWP (4 × 90° rotation).

Figure 1 — Test method of bending moment

5.10 Non-metallic materials test

5.10.1 General

A non-metallic material such as resin or rubber in contact with high pressure hydrogen gas expands when the pressure of hydrogen decreases in a short time from a high level. When the pressure is reduced rapidly, blisters can occur in the material. To evaluate the effects of expansion and blisters, non-metallic materials shall be tested according to the following procedure.

5.10.2 Test method

a) The outlet of the valve shall be plugged and the inlet shall be attached to hydrogen pressure supply.

b) Apply hydrogen at the component pressure rating for minimum of 70 h at room temperature.

c) Following this period, rapidly reduce the test pressure to atmospheric pressure.

d) The valve shall comply with 5.4.

5.11 Cold gas in warm valve test

This test is applicable to the valves that are used where pre-cooled gas is carried.

The valve shall be subjected to pre-cooled hydrogen gas at −40 °C (+0 °C, −3 °C) at a flow rate of 30 g/s for a minimum of 3 min. For those valves which have ports open to the atmosphere or external moving parts, this test shall be conducted at 90 % relative humidity (ambient conditions). The valve shall be depressurised and re-pressurised after a 2 min hold period at room temperature.

This test shall be repeated 10 times. Then the test procedure shall be repeated for additional 10 cycles, except that the hold period shall be increased to 15 min. Upon completion of the test, the valve shall comply with 5.4.

6 Check valves

6.1 Applicability

The tests required to be carried out are indicated in Table 2.

Table 2 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 6.2)		×
External leakage (Clause 5.4.2)	×[a]	
Internal leakage (Clause 6.4)		×
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	
Hydrostatic strength (Clause 5.7)	×	
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×	
Non-metallic material (Clause 5.10)	×	

[a] Not applicable for check valves built into other components.

6.2 Hydrogen gas pressure cycle test

A valve shall withstand 102 000 hydrogen gas pressure cycles without damage or leakage. The replacement of valve seals shall be acceptable at intervals of 16 000 cycles.

The inlet of the valve shall be connected to hydrogen pressure supply. Apply the component pressure rating with the outlet closed. The pressure shall then be vented from the check valve inlet. Then open the outlet to relieve the pressure. Cycling shall be between less than 5 % of the component pressure rating and the component pressure rating (+3 %, −0 %) within a period of not less than 6 s.

100 000 cycles shall be completed at room temperature with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for use, the test temperature of −40 °C is the minimum temperature and the test temperature of 85 °C is the maximum temperature.

The valve shall comply with 6.3 to 6.7 upon completion of the 102 000 cycles.

6.3 External leakage test

The test specified in 5.4.2 shall be conducted as stated.

6.4 Internal leakage test

Connect the outlet of the check valve with the appropriate mating connection, while leaving the opposite connection or connections open.

The valve under test and the test gas shall be maintained at the required test temperature for 1 h prior to and during the test.

The pressure for the high pressure test shall be at least 100 % of component pressure rating, and the pressure for the low pressure test shall be 10 % or less of the component pressure rating. A leakage measuring device capable of indicating the allowable leak rate shall be used. Leakage shall be no more than 10 cm^3/h (normal).

6.5 Worst case fault pressure cycle test

The test specified in 5.5 shall be conducted as stated.

6.6 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

6.7 Hydrostatic strength test

The test specified in 5.7 shall be conducted as stated.

6.8 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

6.9 Bending moment test

The test specified in 5.9 shall be conducted as stated.

6.10 Non-metallic material test

The tests specified in 5.10 shall be conducted as stated.

7 Excess flow valves

7.1 General

Excess flow valves include:

- Internal excess flow valve, installed inside the cylinder or cylinder valve;
- External excess flow valve, installed outside the cylinder or cylinder valve;
- Shut-off type excess flow valve, that stops flow when in the closed position;
- Flow-limiter type excess flow valve, that limits flow when activated.

NOTE Devices reset manually or automatically when the excess flow condition is no longer present.

7.2 Tests

7.2.1 Classification

There are many types of excess flow valves available. This document provides requirements for two different designs: internal and external excess flow valves. A valve of either design can be one of two different types: shut-off or flow-limiter. A shut-off valve should have a means of resetting after activation. As excess flow valve designs vary, and so will the tests required.

The function of an excess flow valve can also be achieved in other ways. For example, instead of using a mechanical device, an electronic system can be adopted to ensure the closing or limiting of the gas flow from the cylinder in an accident.

7.2.2 Applicability

The tests required to be carried out are indicated in Table 3.

Table 3 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 5.3)	×	
External leakage (Clause 5.4.2)	×	
Internal leakage (Clause 7.2.5)		×
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	
Hydrostatic strength (Clause 5.7)	×	
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×	
Non-metallic material (Clause 5.10)	×	
Operation cycle test (Clause 7.2.11)		×
Operation test (Clause 7.2.12)		×
Pressure impulse test (Clause 7.2.14)		×

7.2.3 Hydrogen gas pressure cycle test

The test specified in 5.3 shall be conducted as stated.

The valve shall comply with 7.2.4 to 7.2.8 upon completion of the 102 000 cycles.

7.2.4 External leakage test

The test specified in 5.4.2 shall be conducted as stated.

7.2.5 Internal leakage test

The test specified in 5.4.3 shall be conducted as stated.

The internal leakage test shall only be conducted on shut-off type excess flow valves with manual reset in closed position.

7.2.6 Worst case fault pressure test

The tests specified in 5.5 shall be conducted as stated.

7.2.7 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

7.2.8 Hydrostatic strength test

Thee test specified in 5.7 shall be conducted as stated in open position.

The purpose of the hydrostatic strength test is to establish the strength of the housing.

7.2.9 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

7.2.10 Bending moment test

The test specified in 5.9 shall be conducted as stated.

7.2.11 Non-metallic material test

The tests specified in 5.10 shall be conducted as stated.

7.2.12 Operation cycle test

The excess flow valve shall be subjected to 20 cycles at a differential pressure equal to the excess flow trip or choking point. One cycle shall consist of one trip or flow-limiting event and one reset or opening. Upon completion of the test, the valve shall comply with 7.2.4, 7.2.5 and 7.2.13.

7.2.13 Operation test

Measure the activation flow or ΔP and the flow of the excess flow valve when it activates. Perform the test using the activation conditions stated by the manufacturer; the measured flows and pressures shall meet the manufacturer's specified flow and pressure.

7.2.14 Pressure impulse test

The excess flow valve shall withstand 100 pressure pulses, as follows:

a) If the excess flow valve is external, connect both inlet and outlet to a pipe or tube of the type specified by the manufacturer and of at least 1 m in length each.

b) If the excess flow valve is internal, the valve containing the excess flow valve to be tested shall be connected securely by a suitable fitting to a pressurised source of nitrogen or hydrogen. Connect the outlet to a pipe or tube of the type specified by the manufacturer and of at least 1 m in length.

c) Both the outlet and inlet of the excess flow valve shall be conditioned at atmospheric pressure.

d) The component pressure rating shall be instantaneously applied to the valve inlet.

e) c) and d) shall be repeated 100 times.

f) Test the component in the same way with a reverse flow direction. Following the pressure impulse test, conduct a test according to 7.2.12.

8 Flow control valves

8.1 General

This clause applies to the following:

a) pneumatically actuated valves;

b) electrically actuated valves;

c) pressure regulators (fixed set-point or pneumatically actuated).

Electrically actuated valves shall also meet the requirements of “intrinsically safe” as defined in IEC 60079-0.

8.2 Tests

8.2.1 Applicability

The tests required to be carried out are indicated in Table 4.

Table 4 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 5.3)	×	
External leakage (Clause 5.4.2)	×	
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	
Hydrostatic strength (Clause 5.7)	×	
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×	
Non-metallic material (Clause 5.10)	×	
Operation test under full pressure load (Clause 8.2.10)		×

8.2.2 Hydrogen gas pressure cycle test

The test specified in 5.3 shall be conducted as stated.

The valve shall comply with 8.2.3 to 8.2.6 upon completion of the 102 000 cycles.

8.2.3 External leakage test

The test specified in 5.4.2 shall be conducted as stated.

8.2.4 Worst case fault pressure test

The test specified in 5.5 shall be conducted as stated.

8.2.5 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

8.2.6 Hydrostatic strength test

The test specified in 5.7 shall be conducted as stated.

8.2.7 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

8.2.8 Bending moment test

The test specified in 5.9 shall be conducted as stated.

8.2.9 Non-metallic material test

The test specified in 5.10 shall be conducted as stated.

8.2.10 Operation test under full pressure load

The inlet of the valve shall be connected to hydrogen pressure supply with the outlet closed. With the valve opened, apply the pressure of its component pressure rating to the inlet. Maintain the pressure and then close and open the valve under the same pressure load within a period of not less than 6 s (10 cycles per minute). This constitutes one cycle.

100 000 cycles shall be completed at room temperature with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for use, the test temperature of −40 °C is the minimum temperature and the test temperature of 85 °C is the maximum temperature.

The valve shall comply with 8.2.3 upon completion of the 102 000 cycles.

9 Hose breakaway devices

9.1 Specific design requirements

9.1.1 General

In addition to the general design requirements of Clause 4, the following requirements listed in 9.1.2 to 9.1.4 apply.

9.1.2 Electrical conductivity

The electrical resistance between the extreme ends of a hose breakaway device shall not exceed 10 Ω. The resistance shall be measured at atmospheric pressure and while being exposed to an internal pressure equal to the manufacturer's specified component pressure rating.

9.1.3 Containment of/controlled relieving of hydrogen when uncoupled

The breakaway shall be designed according to one of the following:

1) The hose breakaway on the fuelling line shall incorporate double shut-off features that isolate both sides of the connection when uncoupled. When uncoupled (for example, in a drive-away event), both the part that remains on the dispenser (inlet component) and the part that decouples with the vehicle (outlet component) seal.

2) The hose breakaway on the fuelling line shall incorporate shut-off features that isolate the dispenser side of the connection when uncoupled, but relieve the hydrogen from the part that decouples with the vehicle in a safely controlled manner, for example, through a maximum 1,5 mm orifice.

9.1.4 Separation

The hose breakaway device shall separate upon application of a maximum pull force of 1 000 N but not less than 220 N when the device is installed as specified by the manufacturer.

9.2 Tests

9.2.1 Applicability

The tests required to be carried out are indicated in Table 5.

Table 5 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 5.3)	×	
External leakage (Clause 9.2.3)		×
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	

[a] Not applicable for devices with an unfixed end.

Table 5 *(continued)*

Test	General test requirement	Specific test requirement
Hydrostatic strength (Clause 9.2.4)		×
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×[a]	
Non-metallic material (Clause 5.10)	×	
Separation test (Clause 9.2.8)		×
Impact test (Clause 9.2.9)		×
Drop test (Clause 9.2.10)		×
Twisting test (Clause 9.2.11)		×
Cold gas in warm valve test (Clause 5.11)		×

[a] Not applicable for devices with an unfixed end.

9.2.2 Hydrogen gas pressure cycle test

The test specified in 5.3 shall be conducted as stated.

The valve shall comply with 9.2.3 to 9.2.6 upon completion of the 102 000 cycles.

9.2.3 External leakage test

9.2.3.1 General

A hose breakaway device shall not leak more than 10 cm^3/h (normal) when tested using hydrogen or hydrogen in accordance with the following test method.

This test will be performed both on the coupled device as well as the uncoupled inlet half attached to the test gas supply system. The uncoupled outlet half shall also be tested if it is of a non-relieving design.

9.2.3.2 Test method

This test shall be conducted at −40 °C (+0 °C, −3 °C) and at 85 °C (+3 °C, −0 °C). The hose breakaway devices shall be conditioned and maintained at the required test temperature for not less than 2 h per 25,4 mm of maximum diameter of the device prior to test and during the test.

The inlet of the hose breakaway device under test shall be connected to a system capable of supplying clean test gas at 100 % of the manufacturer's specified component pressure rating and to a flow measuring device or means capable of indicating the allowable leak rate.

With the hose breakaway device in the normal assembled configuration and with its outlet plugged, test gas shall be slowly admitted and maintained at 100 % of the specified component pressure rating. When equilibrium conditions are attained, the leakage shall be measured.

The leakage rate under any test condition shall not exceed 10 cm^3/h (normal) using hydrogen as the test medium.

9.2.4 Worst case fault pressure test

The test specified in 5.5 shall be conducted as stated.

9.2.5 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

9.2.6 Hydrostatic strength test

9.2.6.1 General

Hose breakaway devices shall be capable of withstanding a test pressure equal to 2,4 times the component pressure rating without rupture. Because the hydrostatic strength test is a terminal test, do not use these test samples for any further testing.

9.2.6.2 Test method (coupled):

This test shall be conducted at room temperature only.

The inlet of the coupled hose breakaway device shall be connected to a suitable hydrostatic system. Care shall be taken to remove all air or other test gas from the device and the test system. With the device open and its outlet sealed, the pressure shall be slowly increased to 2,4 times the component pressure rating. The test pressure shall be held for 3 min without rupture.

If the coupled device uncouples during pressurization it is not considered a failure as long as the pressure has exceeded 150 % of the component pressure rating at the time of uncoupling. If the coupled device does uncouple, a fixture is to be added to hold it together and the test shall be repeated.

If the coupled device leaks during pressurization it is not considered a failure as long as the pressure has exceeded 150 % of the component pressure rating at the time when leakage occurs.

9.2.6.3 Test method (uncoupled):

Each of the port end connections of the uncoupled hose breakaway devices (inlet and outlet halves) shall be connected to a suitable hydrostatic system. Care shall be taken to remove all air or other test gas from the device and the test system. The test pressure shall be slowly increased to 2,4 times the component pressure rating or observe the relevant national requirements, if available. The test pressure shall be held for 5 min without rupture.

In the event of testing an outlet half with the “relieving” option included, the device shall have the bleed-down orifice plugged and be subjected to a full hydrostatic strength test uncoupled.

9.2.7 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

9.2.8 Bending moment test

The test specified in 5.9 shall be conducted as stated. If the breakaway device is not fixed at either end, this test is not applicable.

9.2.9 Non-metallic material test

The test specified in 5.10 shall be conducted as stated.

9.2.10 Separation test

9.2.10.1 General

When tested in accordance with the following method, the hose breakaway device shall separate upon application of a pull force within the range specified in 9.1.4. Upon separation under the pressurised condition, the flow of gas from the inlet component shall cease, and the flow of gas from the outlet component shall either

1) cease within 1 s, or

2) bleed down the attached hose in accordance with 9.1.3 2).

The hose breakaway device will be tested against the requirements of 9.2.12.

9.2.10.2 Test method

The hose breakaway device being tested shall be installed as specified by the manufacturer in a simulated dispenser/hose assembly.

The test shall be conducted at four different temperature and pressure combinations as shown in Table 6. For reusable devices, one sample shall be provided. The sample shall be tested for a total of 20 times, 5 times at each of the listed temperature/pressure combinations. For “one time use” devices, 8 samples shall be provided. Two “one time use” samples shall be tested at each of the listed temperature/pressure combinations.

The hose breakaway device being tested shall be maintained at the required test temperature for at least 2 h per 25,4 mm of maximum diameter of the device prior to the test and shall remain conditioned throughout the test.

A direct tensile force shall be applied beginning at a force less than 220 N and increasing until the device separates. The device shall separate and, if pressurised, the flow of gas from the inlet half shall cease and shall not continue to leak in accordance with 9.2.3. The flow of gas from the outlet half shall either

1) cease and not continue to leak in accordance with 9.2.3, or

2) control the depressurization of the hose.

A reusable device sample shall then be reassembled for subsequent testing.

Upon completion of the test specified above, each “one time use” sample shall comply with 9.2.3 in the separated configuration. The reusable sample shall comply with 9.2.3 both in the separated configuration and when reassembled.

If the device is intended for connection directly to a rigid assembly such as the dispenser, the above tests shall be repeated on new samples with the pull force directed at angles specified by the manufacturer as the most critical.

The test method is summarized in Table 6.

Table 6 — Separation test

	Temperature	Internal pressure	Number of times to test the reusable sample[a]	Number of “one time use” samples to test[b]
1	−40 °C	Atmospheric	5	2
2	85 °C	Atmospheric	5	2
3	−40 °C	Component pressure rating	5	2
4	85 °C	Component pressure rating	5	2

[a] One sample, tested 20 times.

[b] Total samples, each tested once.

9.2.11 Impact test (Applicable to rigid-mount devices)

9.2.11.1 General

A hose breakaway device shall be capable of withstanding the impact of 20 Nm per 25,4 mm of tubing nominal diameter (based on connector size) without separating, leaking, cracking or breaking. If the breakaway device is mounted to the dispenser with a guide, this test is not applicable.

9.2.11.2 Test method

This test shall be conducted with a hose breakaway device conditioned at −40 °C (+0 °C, −3 °C) for 2 h per 25,4 mm of maximum diameter of the device.

The device shall be supported by securing it to an appropriate nipple or coupling mounted on a rigid surface so that the free length of the nipple or coupling is not greater than 25,4 mm. The outlet end of the device shall have an appropriate fitting. The test device shall be arranged so that the centre of impact shall be 6,5 mm from the extreme outlet end.

The device shall then be successively struck four times at right angles to the longitudinal centre line of the outlet gas pathway, with the device being turned 90° after each impact. The device shall not separate during this test. After each impact, the device shall be examined visually for cracks and breakage. Upon completion of the above procedure, the device shall comply with 9.2.3 and 9.2.10.

9.2.12 Drop test

9.2.12.1 General

A hose breakaway device shall be capable of withstanding a drop from a height of 1,8 m without separating, leaking, cracking or breaking.

9.2.12.2 Test method

If the inline hose breakaway device may come into contact with the ground when attached to a dispenser, it shall be attached to a fuelling hose of 4,6 m in length in the connected configuration and conditioned at −40 °C (+0 °C, −3 °C) for 2 h per 25,4 mm of the maximum diameter of the device. Then drop it from a height of 1,8 m onto a concrete floor as shown in Figure 2. The device shall be dropped 5 times and then pressurised to the component pressure rating. Drop the pressurised device 5 more times. Upon completing the drops, disconnect the device and repeated the above procedures on the disconnected halves; except that the pressurised halve of a "one time use" device shall be dropped only once. However, the device shall be dropped 10 times without any pressure applied if the outlet of the device is not capable of being pressurised.

In the case of a rigid-mount hose breakaway device or the inline hose breakaway device that does not come into contact with the ground, the disconnected half on the vehicle side shall be attached to a fuelling hose of 4,6 m in length, conditioned at −40 °C (+0 °C, −3 °C) for 2 h per 25,4 mm of the maximum diameter of the device and then dropped from a height of 1,8 m onto a concrete floor as shown in Figure 2. The test device shall be dropped 5 times, then pressurised to the component pressure rating and subjected to 5 additional drops; except that the pressurised half of a "one time use" device shall be dropped only once. The test device shall be dropped 10 times without any pressure applied if the outlet of the device is not capable of being pressurised.

Upon completion of the above procedure, the disconnected halves of "one time use" devices shall comply with 9.2.3, while "reusable" devices shall comply with 9.2.3 in the separated configuration and with 9.2.3 and 9.2.6 in the reassembled configuration.

Dimension in millimetres

Key

1	suitable support
2	fuelling hose
3	device
4	concrete floor

Figure 2 — Drop test

9.2.13 Twisting test

9.2.13.1 General

Using a torque up to 20,5 Nm a hose breakaway device shall withstand 50 000 cycles of twisting due to torque rotation. This test does not apply to devices not capable of rotation at 20,5 Nm.

9.2.13.2 Test method

Rotation shall be checked at 0 MPa and at the manufacturer's specified component pressure rating. Hose breakaway devices that can be rotated under both pressure conditions shall have half of the required cycles conducted at 0 MPa and half of the required cycles at the manufacturer's specified component pressure rating (applied by suitable means with clean dry tests gas). Devices that can be rotated only at 0 MPa or only at maximum pressure shall have the 50 000 cycles conducted only at that pressure.

The device inlet shall be securely connected to a suitable, rigidly mounted fitting. The outlet shall be plugged and attached to an apparatus capable of rotating the device through 180° at a maximum of 10 cycles per minute. A cycle shall consist of rotating the movable portions of the device 180° and then back to their original position.

The device shall be rotated for 25 000 cycles at −40 °C (+0 °C, −3 °C) and 25 000 cycles at 85 °C (+3 °C, −0 °C). Following cycling, the device shall comply with 9.2.3 and 9.2.10.

If the device is intended for connecting directly to a rigid assembly such as the dispenser, a pull force of 89 N at the manufacturer's specified angles shall be applied during rotation. This pull force need not be applied to inline devices.

9.2.14 Cold gas in warm valve test

The test specified in 5.11 shall be conducted as specified. The valve shall comply with the leakage tests specified in 9.2.3.

10 Manual valves

10.1 Construction and assembly

A manual valve with 90° rotation from “on” to “off” position shall be provided with rigidly secured stops to limit rotation. The valve handle shall be perpendicular to the direction of flow in the “off” position.

10.2 Tests

10.2.1 Applicability

The tests required to be carried out are indicated in Table 7.

Table 7 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 5.3)	×	
External leakage (Clause 5.4.2)	×	
Internal leakage (Clause 5.4.3)	×	
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	
Hydrostatic strength (Clause 5.7)	×	
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×	
Non-metallic material (Clause 5.10)	×	
Maximum flow shut-off (Clause 10.2.9)		×
Operation test (Clause 10.2.10)		×
Excess torque operation (Clause 10.2.11)		×

10.2.2 Hydrogen gas pressure cycle test

The test specified in 5.3 shall be conducted as stated.

The valve shall comply with 10.2.3 to 10.2.7 upon completion of the 102 000 cycles.

10.2.3 External leakage test

The test specified in 5.4.2 shall be conducted as stated.

10.2.4 Internal leakage test

The test specified in 5.4.3 shall be conducted as stated.

10.2.5 Worst case fault pressure test

The test specified in 5.5 shall be conducted as stated.

10.2.6 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

10.2.7 Hydrostatic strength test

The test specified in 5.7 shall be conducted as stated.

10.2.8 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

10.2.9 Bending moment test

The test specified in 5.9 shall be conducted as stated.

10.2.10 Non-metallic material test

The tests specified in 5.10 shall be conducted as stated.

10.2.11 Maximum flow shut-off test

10.2.11.1 General

A valve shall function properly when gas is passing through it at the component pressure rating and the maximum flow rate.

10.2.11.2 Test method

This test shall be performed with the valve at a temperature of −40 °C (+0 °C, −3 °C). If the manufacturer specifies the minimum temperature for use, the test temperatures is the minimum temperature.

The inlet of the valve shall be connected to a system capable of supplying clean test gas at the component pressure rating through a tube or pipe the size of which is equal to or greater than the valve inlet connection. During the test, the supply pressure shall not fall below 80 % of the component pressure rating. With the outlet of the valve open to the atmosphere, the valve shall be subjected to a flow of the test gas and shall be capable of completely closing.

At the completion of this test, each valve shall be subjected to the test of and comply with 5.4.2 and 5.4.3.

10.2.12 Operation test

A manual valve should withstand 300 open/close cycles without damage or leakage.

The outlet of the valve shall be open to a vent and the inlet shall be attached to hydrogen pressure supply. For safety, it is recommended to conduct this test with equipment that allows remote operation of the valve. With the manual valve in the closed position, apply pressure to its inlet to reach the component pressure rating. Stop pressurization but maintain the inlet pressure at the component pressure rating. Open the manual valve to release pressure. Repeat this close/open procedure 150 times at −40 °C (+0 °C, −3 °C) and another 150 times at 85 °C (+3 °C, −0 °C). At the completion of this operation test, the valve shall be subjected to the leak testing described in 10.2.3 and 10.2.4.

10.2.13 Excess torque operation test

This test is not applicable to manual valves with 90° rotation from “on” to “off” position.

With no pressurization, close the valve by applying to its handle at least 150 % of the torque specified for its operation, and then open it to its fully open position. Repeat this procedure 20 times. At the completion of this test, the valve shall be subjected to the leak testing described in 10.2.3 and 10.2.4.

11 Pressure safety valves (PSV)

11.1 Applicability

The tests required to be carried out are indicated in Table 8.

Table 8 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 11.2)		×
External leakage (Clause 11.3.1)		×
Seat leakage (Clause 11.3.2)		×
Worst case fault pressure cycle (Clause 11.4)	×	
Proof pressure (Clause 11.5)	×	
Hydrostatic strength (Clause 11.6)		×
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 11.8)		×
Non-metallic material (Clause 5.10)	×	
Operation test (Clause 11.10)		×

11.2 Hydrogen gas pressure cycle test

The test shall be conducted in such a way that the PSV would not activate to open under a test pressure of its component rating. Examples include: a high set point or the use of a mechanical lift restrictor. The PSV shall withstand 102 000 cycles of hydrogen gas pressure cycle between less than 5 % of the component pressure rating and the component pressure rating (+3 %, −0 %) within a period of not less than 6 s (10 cycles per minute). 100 000 cycles shall be completed at room temperature, with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C).

If the manufacturer specifies the temperature range for operation, apply the minimum temperature instead of −40 °C and the maximum temperature instead of 85 °C.

The replacement of valve seals shall be acceptable at intervals of 16 000 cycles. The valve shall comply with 11.3 to 11.6 upon completion of the 102 000 cycles.

11.3 PSV leakage tests

11.3.1 External leakage test

External leakage tests shall comply with 5.4.2. The test pressure for the shell on the discharge side of the seat shall be 100 % of the manufacturer’s stated maximum back pressure for which the PSV is designed. The test pressure for the inlet to the seat shall be 100 % component pressure rating. In order to prevent activation during testing of the portion of the valve from the inlet to the seat, a mechanical lift restrictor as recommended by the valve manufacturer shall be fitted. The mechanical lift restrictor should only be fitted after completion of tests on the discharge side of the valve seat. Test the PSV at −40 °C (+0 °C, −3 °C), 20 °C ± 5 °C and 85 °C (+3 °C, −0 °C).

11.3.2 Seat leakage test

The seat leakage test is intended to test the pressure tightness of the valve seat and shall be carried out after adjustment of the valve set pressure. Tests shall comply with 5.4.3 using a test pressure of 90 % of set pressure.

11.4 Worst case fault pressure test

The test specified in 5.5 shall be conducted with a means to prevent the activation of the PSV. The outlet of the PSV shall not be plugged for this test.

11.5 Proof pressure test

The test specified in 5.6 shall be conducted with a means to prevent the activation of the PSV. The outlet of the PSV shall not be plugged for this test.

11.6 Hydrostatic strength test

The test specified in 5.7 shall be conducted as stated.

If the PSV discharge pressure rating is lower than the valve inlet, the portion between the valve inlet and the seat shall be tested independently from the shell on the discharge side of the seat.

The test pressure for the shell on the discharge side of the seat shall be 2,4 times the manufacturer's stated maximum back pressure for which the PSV is designed.

In order to test the portion of the valve from the inlet to the seat, a mechanical lift restrictor or suitable blanking device as recommended by the valve manufacturer shall be fitted. The test pressure for the inlet to the seat shall be 2,4 times the component pressure rating.

For the purposes of this test, the PSV's mechanism shall be removed and its orifice blocked.

11.7 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

11.8 Bending moment test

The test specified in 5.9 shall be conducted as stated with the following provisions for pressure safety valves.

Valves shall be tested in the orientation as specified by the manufacturer and shall be mounted in line with recognised standards giving sufficient support to inlet and outlet piping as to prevent excessive external loading to the valve body.

11.9 Non-metallic material test

The tests specified in 5.10 shall be conducted as stated.

11.10 Operation test

Verify the opening and re-seating pressures of the PSV. The opening pressure shall be equal to the set pressure ±5 % at 20 °C ± 5 °C, and ±5 % at −40 °C (+0 °C, −3 °C) and 85 °C (+3 °C, −0 °C).

Three randomly selected samples shall be subjected to the following test procedure. This test has three steps, which shall be conducted in the order given. Appropriate test media shall be chosen (i.e. air, nitrogen, or hydrogen). If the test medium is not hydrogen, then the calculated flow values shall be corrected for hydrogen.

a) Establish the opening and re-seating values for the samples at 20 °C ± 5 °C. Do this by first slowly pressurizing the inlet of the sample to 110 % of the set pressure, noting the value at which it first opens.

b) Lower the inlet pressure until the PSV re-seats; note that value. The valves are considered to have passed if all the following requirements are met:

  - opening pressures at ±5 % of the manufacturer's set pressure;
  - re-seating pressures at no less than 90 % of the set pressure;
  - re-seating pressures within ±5 % of the average re-seating pressure.

c) Repeat a) and b) at −40 °C (+0 °C, −3 °C) and 85 °C (+3 °C, −0 °C). At each test temperature, the following criteria shall be met:

  - opening pressures at ±10 % of the manufacturer's set pressure;
  - re-seating pressures at no less than 80 % of the set pressure;
  - re-seating pressures within ±10 % of the average re-seating pressure.

12 Shut-off valves

12.1 Classification

Shut-off valves are classified as follows:

- Class A – A valve which is cycled as a normal part of the appliance or system operation.
- Class B – A valve which is cycled to shut off gas flow to a component or components for the purpose of service, replacement or system shutdown applications.

12.2 Construction and assembly

Diaphragm type valves in which a flexible diaphragm constitutes the gas seal and which utilize control gas on the atmospheric side of the diaphragm shall have the atmospheric side of the main diaphragm enclosed in a gas-tight casing with a means to bleed the control gas.

Diaphragm type valves which do not utilize control gas on the atmospheric side of the diaphragm shall have the atmospheric side of the main diaphragm enclosed in a gas-tight casing with a means to vent hydrogen to a safe location in the event of diaphragm rupture.

In addition to the requirements of this document, electrically actuated valves shall also meet the requirements of "intrinsically safe" as defined in IEC 60079-0.

12.3 Tests

12.3.1 Applicability

The tests required to be carried out are indicated in Table 9.

Table 9 — Tests applicable

Test	General test requirement	Specific test requirement
Hydrogen gas pressure cycle (Clause 12.3.2)		×
External leakage (Clause 5.4.2)	×	
Internal leakage (Clause 5.4.3)	×	
Worst case fault pressure cycle (Clause 5.5)	×	
Proof pressure (Clause 5.6)	×	

Table 9 *(continued)*

Test	General test requirement	Specific test requirement
Hydrostatic strength (Clause 5.7)	×	
Excess torque resistance (Clause 5.8)	×	
Bending moment (Clause 5.9)	×	
Non-metallic material (Clause 5.10)	×	
Operation test under full pressure load (Clause 12.3.11)		×
Maximum flow shut-off (Clause 12.3.12)		×
Cold gas in warm valve test (Clause 12.3.13)		×

12.3.2 Hydrogen gas pressure cycle test

12.3.2.1 General

A Class A valve shall withstand 102 000 hydrogen gas pressure cycles without damage or leakage. The replacement of valve seals shall be acceptable at intervals of 16 000 cycles.

A Class B valve shall withstand 100 cycles of opening and closing at room temperature.

12.3.2.2 Test method

The inlet of the valve shall be connected to hydrogen pressure supply with the outlet open. With the valve closed, the component pressure rating is applied to the inlet. Stop the test gas supply. Then open the valve and depressurize. Close the valve when the pressure is completely released from it. This constitutes one cycle.

Cycling shall be between less than 5 % of the component pressure rating and the component pressure rating (+3 %, −0 %) within a period of not less than 6 s.

100 000 cycles shall be completed at room temperature, with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for use, the test temperatures are the minimum and the maximum of the range.

The Class A valve shall comply with 12.3.3 to 12.3.7 upon completion of the 102 000 cycles.

12.3.3 External leakage test

The test specified in 5.4.2 shall be conducted as stated.

12.3.4 Internal leakage test

The test specified in 5.4.3 shall be conducted as stated.

12.3.5 Worst case fault pressure test

The test specified in 5.5 shall be conducted as stated.

12.3.6 Proof pressure test

The test specified in 5.6 shall be conducted as stated.

12.3.7 Hydrostatic strength test

The test specified in 5.7 shall be conducted as stated.

12.3.8 Excess torque resistance test

The test specified in 5.8 shall be conducted as stated.

12.3.9 Bending moment test

The test specified in 5.9 shall be conducted as stated.

12.3.10 Non-metallic material test

The tests specified in 5.10 shall be conducted as stated.

12.3.11 Operation test under full pressure load

A Class A valve shall be connected to hydrogen pressure supply with the outlet closed. With the valve opened, apply the component pressure rating to the inlet. Maintain the pressure, and close and open the valve under the same pressure load within a period of not less than 6 x (10 cycles per minute). 100 000 cycles shall be completed at room temperature, with additional 1 000 cycles at an ambient temperature of −40 °C (+0 °C, −3 °C) and 1 000 cycles at an ambient temperature of 85 °C (+3 °C, −0 °C). If the manufacturer specifies the temperature range for use, the test temperatures are the minimum and the maximum of the range.

The Class A valve shall comply with 12.3.3 and 12.3.4 upon completion of the 102 000 cycles.

12.3.12 Maximum flow shut-off test

12.3.12.1 General

A valve shall function properly when gas is passing through it at the component pressure rating and the maximum flow rate. Every size in a family of valves shall be tested.

12.3.12.2 Test method

The inlet of the valve under test shall be connected to a system capable of supplying clean test gas at the component pressure rating at −40 °C (+0 °C, −3 °C) and 85 °C (+3 °C, −0 °C) at the manufacturer's specified maximum flow rate. If the manufacturer specifies the temperature range for use, the test temperatures are the minimum and the maximum of the range. The valve shall be maintained at the required test temperature for 1 h prior to and during the test.

With the outlet of the valve open to the atmosphere, test gas shall be allowed to flow through the valve. After 1 min, and with the gas still flowing, the valve shall be capable of completely closing.

After 1 min, with the valve still closed and pressure maintained at the inlet of the valve, measure the leakage at the outlet using an appropriate method.

The leak rate shall be less than 10 cm^3/h (normal) for hydrogen.

12.3.13 Cold gas in warm valve test

This test is applicable to the Class A valves and hose breakaway devices that are used where pre-cooled gas is carried.

Test specified in 5.11 shall be conducted as stated.

13 Marking

13.1 Marking information

The valves shall include the following information as required:

- manufacturer's or agent's name, trademark or symbol;
- model designation (part number);
- rated pressure;

If applicable and with space permitting:

- rated temperature range;
- flow direction;
- serial number;
- pressure for hydrostatic strength test.

For electrically actuated valves, the Ex marking of the valve shall be included in accordance with IEC 60079-0.

NOTE 1 Specific information required for each valve can be found in this document.

NOTE 2 This information can be provided by a suitable identification code on at least one part of the valve when it consists of more than one part.

13.2 Marking method

Marking shall remain legible for the life of the component and shall not be removable without destroying or defacing the marking. Permanent adhesive labels may be used, or markings may be etched, stamped or moulded into the component.

14 Component literature

Manufacturers of valves for gaseous hydrogen fuelling stations shall provide literature for their components. This literature shall include any necessary installation considerations.

Instructions shall include at least the following:

- component pressure rating and/or Pressure Class (H-rating) in accordance with ISO 19880-1;
- material name or code used for the valve body;
- operating temperature limits;
- Cv value;
- names of parts that require periodic replacement and their frequency of replacement.

Instructions shall also include, as appropriate:

- flow direction;
- pressure for hydrostatic strength test;
- requirements for warning labels that might be required as part of the installation;
- installation instructions, including torques;

- installation orientation requirements;
- service procedures, including inspection requirements, replacement frequencies and service life of parts and components;
- recommendations for service access.

In addition, for externally actuated valves, unpowered position of the valve (fail-open or fail-close) shall be included, and for electrically actuated valves, the relevant instructions shall be included in accordance with IEC 60079-0.

Bibliography

Reference documents

[1] ISO 12619-2, *Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components — Part 2: Performance and general test methods*

[2] ISO 14687[1], *Hydrogen fuel — Product specification*

[3] ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

[4] ISO 19880-1[2], *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*

Other relevant documents

[5] ISO 4126-1, *Safety devices for protection against excessive pressure — Part 1: Safety valves*

[6] ISO 4126-9, *Safety devices for protection against excessive pressure — Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices*

[7] ISO 15500-14:2012, *Road vehicles — Compressed natural gas (CNG) fuel system components — Part 14: Excess flow valve*

[8] ISO 19880-5[3], *Gaseous hydrogen — Fuelling stations — Part 5: Hoses and hose assemblies*

[9] ISO 19880-8[4], *Gaseous hydrogen — Fuelling stations — Part 8: Fuel quality control*

[10] CSA HGV3.1-2013, *Fuel system components for compressed hydrogen gas powered vehicles*

[11] ANSI/CSA HGV 4.4-2013, *Breakaway devices for compressed hydrogen dispensing hoses and systems*

[12] ANSI/CSA HGV 4.6-2013, *Manually operated valves for use in gaseous hydrogen vehicle fueling stations*

[13] ANSI/CSA HGV 4.7-2013, *Automatic valves for use in gaseous hydrogen vehicle fueling stations*

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1) Under development.

2) Under development.

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4) Under development.

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Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas
Energy Resources Aotearoa
Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
GNS
Hiringa Energy
HW Richardson Group
HyPotential
Methanex
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PEC
WorkSafe New Zealand − Energy Safety
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New Zealand Standard

Gaseous hydrogen − Fuelling stations

Part 5: Dispenser hoses and hose assemblies

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the requirements for wire- or textile-reinforced hoses and hose assemblies suitable for dispensing hydrogen up to 70 MPa nominal working pressure in the operating temperature range of −40°C to 65°C. It also sets out safety requirements for material, design, manufacture, and testing of gaseous hydrogen hose and hose assemblies for hydrogen fuelling stations.

Hoses and hose assemblies excluded from the scope of this standard are:
(a) Those used as part of a vehicle high pressure on-board fuel storage system;
(b) Those used as part of a vehicle low pressure fuel delivery system; and
(c) Flexible metal hoses.

NOTE –

(1) This document was developed primarily for hoses and hose assemblies for dispensing high-pressure hydrogen from refuelling dispensers to hydrogen vehicles. Requirements for hoses used to deliver hydrogen from a transportable vessel (for example, a trailer) into a station's buffer storage are addressed in ISO 16964:2019 *Gas cylinders − Flexible hoses assemblies − Specification and testing*.

(2) Hose assemblies include the hose with connectors on each end (see Figure 1). Each connector has two basic functional elements that are addressed as described below:

    (a) **Coupling to hose:** This function is defined by requirements and verified (along with the hose itself) by performance-based tests in this document.

    (b) **Fitting for transition and connection to the piping system or equipment:** This function is addressed by reference to appropriate hydrogen equipment standards and piping codes.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 19880-5:2019 *Gaseous hydrogen – Fuelling stations – Part 5: Dispenser hoses and hose assemblies.*

As this standard is reproduced from an international standard, the following applies:
(d) In the source text, 'this International Standard' should read 'this New Zealand standard';
(e) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 19880-5

First edition
2019-11

Gaseous hydrogen — Fuelling stations —

Part 5:
Dispenser hoses and hose assemblies

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 197, *Hydrogen technologies*.

A list of all parts in the ISO 19880 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document promotes the implementation of performance-based testing for components of dispensing systems and fuelling stations that are based on proven engineering principles, research and the combined expertise of gas utilities, fuel providers, manufacturers, users, and others having specialized experience.

The successful commercialization of hydrogen vehicle technologies requires codes and standards pertaining to fuelling stations, vehicle fuel system components, and the global homologation of standards requirements for technologies with the same end use. Essentially this will allow manufacturers to achieve economies of scale by producing one product for use globally.

International harmonization contributes to reducing technical barriers and stimulates related markets. A series of documents that address hydrogen-fuelled vehicles and fuelling stations is being developed. These documents will provide internationally homologized minimum safety performance criteria at the component level, thus providing a foundation to build a safe “fuelling system”.

This document was developed using the standard ANSI/CSA HGV 4.2-2013.

This document was developed based on five pressure classes of wire or textile reinforced hoses and hose assemblies suitable for use with gaseous hydrogen for hydrogen dispensing. This is based on technologies in use at the time of the development of the requirements.

In the future, other types and classes of hoses and hose assemblies will need to be evaluated to determine the suitability of requirements in this document.

This document applies to newly manufactured hoses and hose assemblies for connecting a dispenser to a high pressure fuelling nozzle.

A nozzle vent hose is included in this document; however the pressure rating may be lower than the nozzle rating, based on the nozzle and dispenser design.

For general hydrogen safety information, see ISO/TR 15916.

Gaseous hydrogen — Fuelling stations —

Part 5:
Dispenser hoses and hose assemblies

1 Scope

This document specifies the requirements for wire or textile reinforced hoses and hose assemblies suitable for dispensing hydrogen up to 70 MPa nominal working pressure, in the operating temperature range of −40 °C to 65 °C.

This document contains safety requirements for material, design, manufacture and testing of gaseous hydrogen hose and hose assemblies for hydrogen fuelling stations.

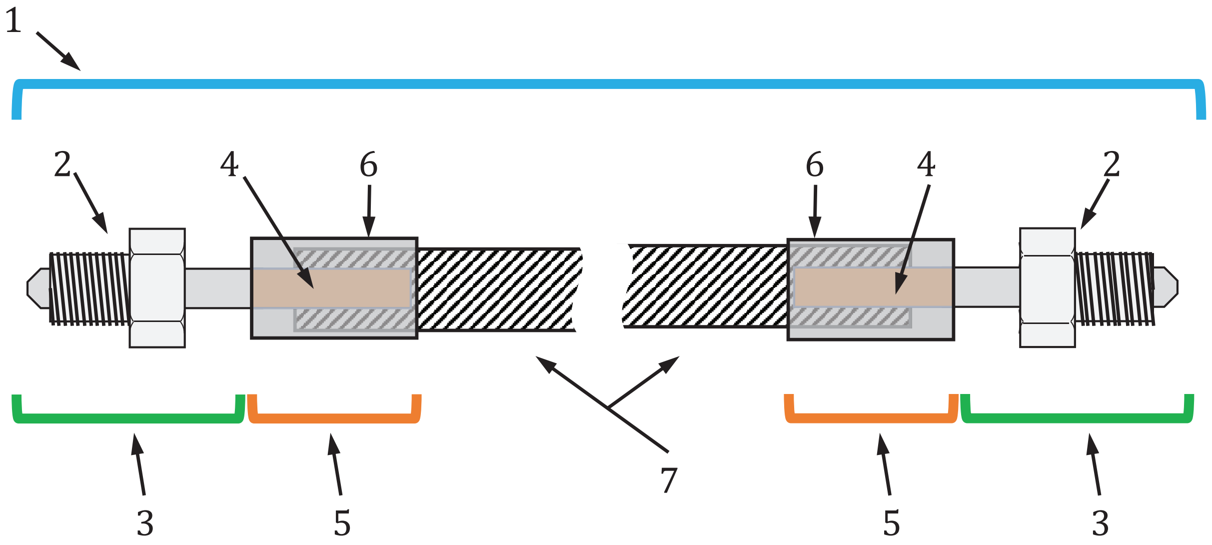
Hoses and hose assemblies excluded from the scope of this document are the following:

1) those used as part of a vehicle high pressure on-board fuel storage system,
2) those used as part of a vehicle low pressure fuel delivery system, and
3) flexible metal hoses.

NOTE 1 This document was developed primarily for hoses and hose assemblies for dispensing high pressure hydrogen from refuelling dispensers to hydrogen vehicles. Requirements for hoses used to deliver hydrogen from a transportable vessel (e.g. trailer) into a buffer storage of a station are addressed in ISO 16964.

NOTE 2 Hose assemblies include the hose with connectors on each end (see Figure 1). Each connector has two basic functional elements that are addressed as described below:

1) Coupling to hose. This function is defined by requirements and verified (along with the hose itself) by performance-based tests in this document.
2) Fitting for transition and connection to the piping system or equipment. This function is addressed by reference to appropriate hydrogen equipment standards and piping codes.



Key

1	hose assembly
2	mechanical joint
3	fitting
4	nipple
5	coupling
6	crimped socket
7	hose

Figure 1 — Hose assembly and fitting

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1402, *Rubber and plastics hoses and hose assemblies — Hydrostatic testing*

ISO 4671, *Rubber and plastics hoses and hose assemblies — Methods of measurement of the dimensions of hoses and the lengths of hose assemblies*

ISO 4080:2009, *Rubber and plastics hoses and hose assemblies — Determination of permeability to gas*

ISO 6802, *Rubber or plastics hoses and hose assemblies — Hydraulic impulse test with flexing*

ISO 6803:2017, *Rubber or plastics hoses and hose assemblies — Hydraulic-pressure impulse test without flexing*

ISO 7326:2016, *Rubber and plastics hoses — Assessment of ozone resistance under static conditions*

ISO 8031:2009, *Rubber and plastics hoses and hose assemblies — Determination of electrical resistance and conductivity*

ISO 8330, *Rubber and plastics hoses and hose assemblies — Vocabulary*

ISO 8331, *Rubber and plastics hoses and hose assemblies — Guidelines for selection, storage, use and maintenance*

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

ISO 15649, *Petroleum and natural gas industries — Piping*

ISO 16964, *Gas cylinders — Flexible hoses assemblies — Specification and testing*

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices*

ISO 19880-1[1], *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*

ISO 30013, *Rubber and plastics hoses — Methods of exposure to laboratory light sources — Determination of changes in colour, appearance and other physical properties*

IEC 60243-1, *Electric strength of insulating materials — Test methods — Part 1: Tests at power frequencies*

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials — Part 3-1: Determination of resistive properties (DC methods) — Volume resistance and volume resistivity — General method*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 8330, ISO 19880-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
connector
matching parts (such as male and female parts) that can be put together to form a "connection" which permits the transfer of fluids, electric power, or control signals

Note 1 to entry: *Fittings* (3.4) are a type of connector used in piping systems.

Note 2 to entry: Examples of connectors commonly used in hydrogen systems are as follows:

a) The fuelling nozzle “connector” mates with the receptacle “connector” on the vehicle to form the connection for transfer of compressed hydrogen between the dispenser and the vehicle, as defined in ISO 17268 for this specific application.

b) The hose assemblies have connectors on each end that allow *coupling* (3.2) to the hoses and connection to the piping system (e.g. hose breakaway device or fuelling nozzle).

c) Control systems often use electrical connectors to allow rapid and secure assembly or replacement.

3.2
coupling
integrated structure of nipple and socket with end portion of a hose crimped together as shown in Figure 1

3.3
dispenser hose
fuelling hose
hose assembly (3.5) used for dispensing gaseous hydrogen to vehicles through a nozzle

Note 1 to entry: See Figure 2.

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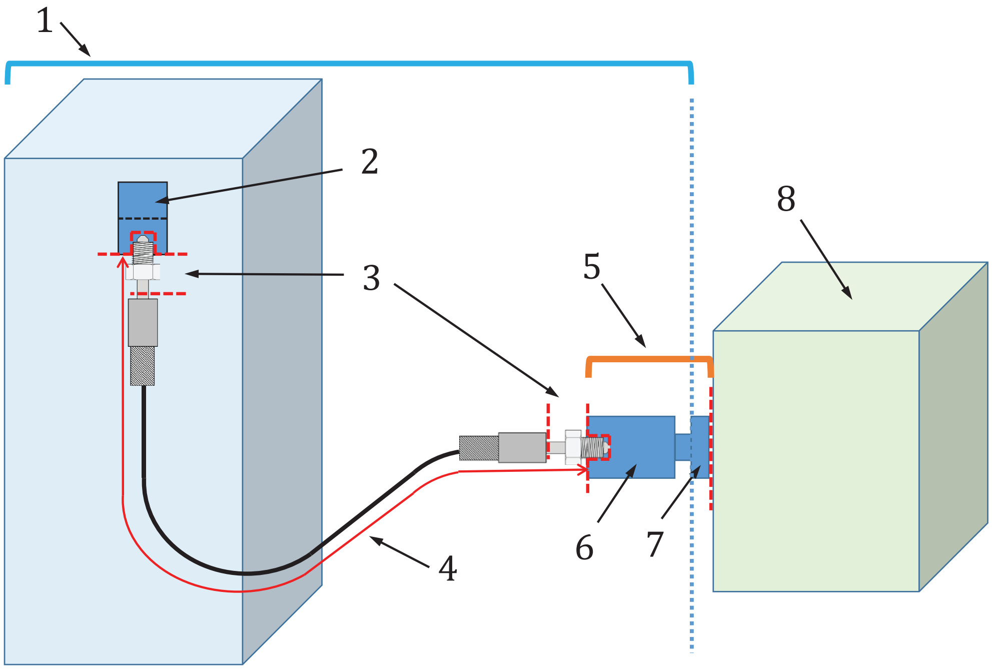
[1] Under preparation.



Key

1	dispenser
2	hose breakaway device (ISO 19880-3)
3	*fitting* (3.4)
4	*hose assembly* (3.5)
5	*connector* (3.1)
6	nozzle (ISO 17268)
7	receptacle on vehicle (ISO 17268)
8	vehicle

Figure 2 — Components connecting a dispenser to a vehicle

3.4
fitting

connector (3.1) used to join any pressure retaining components in the system, and in the case of the *hose assembly* (3.5), device, usually made of metal, attached to the end of a hose to facilitate connection to equipment or other hose shown in Figure 1

Note 1 to entry: Fittings can be used in a finished hose assembly; however requirements for fittings are out of scope of this document.

3.5
hose assembly

assembly which includes the hose and end connections, including any necessary *fittings* (3.4), bend restrictors, and appropriate markings

3.6
nozzle vent hose

hose used to depressurize the fuelling nozzle and vent the hydrogen to an approved location

3.7
minimum bend radius

smallest specified radius to which a hose may be bent in service

Note 1 to entry: The minimum bend radius is shown in Table 3.

3.8
pressure rating

maximum pressure at which it is permissible to operate a component as specified by the manufacturer at the maximum temperature expected during service

3.9
proof pressure

pressure applied during a non-destructive test and held for a specified period of time to prove the integrity of the construction

4 Classification

This clause applies to newly manufactured hoses and hose assemblies for dispenser hoses connecting the dispenser to the fuelling nozzle supply port.

Hoses and couplings shall meet the requirements in this document with end fittings selected by the manufacturer, customer, or testing agency as required to connect to the test equipment. Fittings shall be consistent with the requirements of the appropriate documents in the ISO 19880-series, ISO 17268, or ISO 15649.

The end fitting of the hose assembly may be changed to another type that meets requirements defined above without the need to repeat the performance tests for verification of the hose assembly and its coupling as long as the hose coupling remains unchanged.

Some newly manufactured hoses and hose assemblies include vent lines required by some fuelling nozzles. Nozzle vent hose assemblies shall meet the requirements of ISO 16964 or the requirements in this document and be appropriately rated for operation in the vent system that has been defined based on the nozzle manufacturer instructions and the dispenser design.

Table 1 converts Hydrogen Service Levels (HSL), as defined in ISO 19880-1, to pressure levels.

When using ISO 16964, the hose rating is 125 % of the working pressure which is 10 % lower than the pressure ratings in Table 1.

A hose assembly shall be designated according to the pressure classes defined in Table 1 or by the manufacturer’s stated pressure rating. The information in Table 1 is taken from ISO 19880-1 (and pressure class H11 is added). The pressure rating of the hose assembly shall be equal to or above the dispenser pressure ratings. For further information regarding the relationships between pressure terms, see ISO 19880-1.

Table 1 — Hose assembly pressure levels and minimum pressure ratings

Pressure level (HSL) (MPa)	Pressure class	Maximum allowable working pressure (MAWP) (Minimum component pressure rating for dispenser components) (MPa)
11	H11	15,13
25	H25	34,38
35	H35	48,13
50	H50	68,75
70	H70	96,25

The hoses and hose assemblies shall be designed to operate at temperatures ranging from −40 °C to 65 °C.

5 Materials and construction

5.1 General

The hose and liner shall be constructed with materials that are resistant to corrosion and exposure to hydrogen.

5.2 Lining

The lining shall be of uniform thickness and free from defects. Defects are defined as but are not limited to bubbles, thinning, gouging, or discoloration.

The lining may also consist of multiple material layers.

5.3 Reinforcement

The reinforcement consists of one or more layers of suitable wire or textile material applied by any suitable technique.

5.4 Cover

The cover shall be resistant to abrasion, cracking, crazing, the effects of exposure to ultraviolet light and ozone, be of uniform thickness, and free from defects. Defects may include but are not limited to bubbles, thinning, gouging, or discoloration. All outer covering shall either be of a permeable material or sufficiently perforated to avoid diffused gas build up.

5.5 Static electricity dissipation

5.5.1 General

Static electricity can be generated on the external and interior surface of a hose assembly.

5.5.2 External surface

The hose assembly shall be constructed so as to provide an external, electrically conductive, bonding path between the end couplings to dissipate external static electric charges.

5.5.3 Internal surface

The hose assembly shall be constructed so that the liner provides an adequate internal layer of prevention to avoid dielectric breakdown by static electricity in the fluid during normal use.

6 Dimensions and tolerances

When measured in accordance with ISO 4671, typical diameters and concentricity of hoses are given in Table 2.

Table 2 — Typical diameters and concentricity of hoses

Nominal size	Inside diameter mm		Maximum outside diameter of hose mm	Concentricity (Maximum variation in wall thickness between inside diameter and outside diameter) mm
	minimum	maximum		
6,3	5,9	7,0	25	0,8
8	7,7	8,5	30	1,0
10	9,3	10,1	35	

7 Performance requirements and testing

7.1 General

Performance requirements shall be determined by the following tests and carried out by type tests, routine tests and production acceptance tests.

Type tests are those required to confirm that a particular hose or hose assembly design, manufactured by a particular method from particular materials, meets all the requirements of this document. The tests shall be repeated whenever a change in the method of manufacture or materials used occurs. They shall be performed on all sizes and types except those of the same size and construction.

Routine tests are those required to be carried out on each length of a finished hose or hose assembly prior to dispatch.

Type tests and routine tests shall be carried out as specified in Annex A.

Production acceptance tests are those required to control the quality of the manufacturing. The frequencies specified in Annex B are given as a guide only and determined by the manufacturer or between the manufacturer and the customer or the certifying body.

7.2 Leakage test

7.2.1 General

Leakage tests shall be conducted in accordance with Method A for type tests and Method B for routine tests. Method A is also recommended for production acceptance tests.

7.2.2 Method A

When tested in accordance with ISO 4080:2009, Method 3, with the following conditions, the hourly leakage rate shall be less than 20 ml/h under normal pressure and temperature conditions.

The test can be done at room temperature. The amount shall be converted to 15 °C.

The test piece shall have a free length of 0,5 m between the couplings. Connect the test piece to the hydrogen gas supply with a suitable connector and purge the test assembly with hydrogen gas. Adjust the temperature of the water bath to the specified value.

Insert the test assembly into the transparent tube and immerse it in a water bath so that it is inclined at approximately 20° to the horizontal.

Apply the gas pressure of 1,375 × HSL and maintain it for 10 min. This is the time necessary for releasing trapped air in the reinforcement layer to the outside of the hose through perforated holes. Then, during the next 5 min, collect the gas and measure the amount while maintaining the pressure. This amount is converted to an amount per hour.

7.2.3 Method B

For this test a length of any assembly hose can be used. Hydrogen or helium can be used as test gas. Connect the test piece to the test gas supply with a suitable connector and purge the test assembly with test gas.

Apply the gas pressure of 1,375 × HSL and maintain it for 10 min for the same reason as noted in 7.2.2. Then, still maintaining the pressure, the leakage shall be checked visually for any bubbles from hose body and both coupling ends for 5 min. This check is performed under water by immersing the test piece in a water bath.

Also, a gas leak detector or leak detection fluid may be applied to check leakage in the air.

Leakage can be tested by the permeation test during the first 15 min according to Method A.

The air contained in the reinforcement layer (trapped air), which comes out from perforated holes, can be omitted unless they are abnormal.

7.3 Hydrostatic strength

7.3.1 Proof pressure test

When tested in accordance with ISO 1402, a hose assembly shall withstand a pressure of at least 2,1 × HSL for 5 min without bursting or visible loss of fluid.

As a test fluid, water or a mixture of water and glycol or oil can be used.

This is a non-destructive test.

7.3.2 Ultimate strength

The hose assembly shall be air oven aged for 70 h at 85 °C ± 1 °C.

Following the oven aging, when tested in accordance with ISO 1402, a hose assembly shall withstand without bursting or visible loss of fluid with a pressure of a minimum of 5 times of HSL for 5 min.

Then, continue to pressurize until the hose assembly bursts and measure the pressure.

As a test fluid, water or a mixture of water and glycol or oil can be used.

This is a destructive test.

7.4 Electrical conductivity

When determined in accordance with ISO 8031:2009, 4.8, the bonding resistance of fuelling hose assembly, from end fitting to end fitting, shall be no greater than 100 kΩ, in order to dissipate static electricity.

This test shall be conducted with the hose un-pressurized.

The bonding resistance of the fuelling hose assembly may need to be no greater than 1 kΩ for manufacturing quality control.

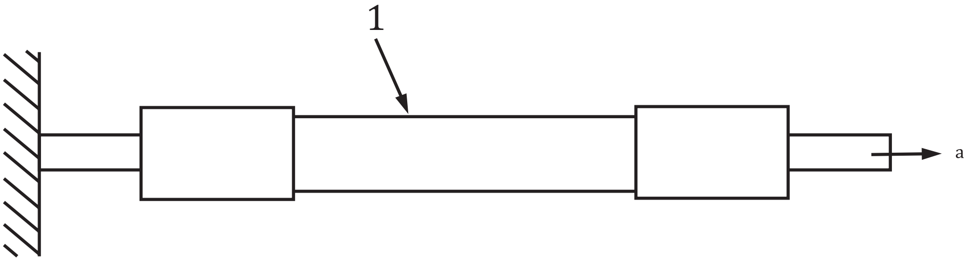
7.5 Tensile test of hose assembly

7.5.1 General

This test is modelling the scenario of the fuelling nozzle being connected to the vehicle while driving away.

This provision applies to a single hose assembly only. For an integrated supply and vent line hose assembly, only the supply portion of the hose assembly shall be tested.

A hose assembly having a free length of 100 mm or longer shall withstand a longitudinal pull force of 3 000 N, as shown Figure 3, without structural damage or leakage after being subjected to accelerated air oven aging. The hose shall comply with 7.3.1 and 7.4 after the tensile test.



Key

1 hose assembly

[a] Direction of force.

Figure 3 — Tensile test of hose assembly

7.5.2 Test method

The hose assembly shall be air oven aged for 70 h at 85 °C ± 1 °C.

Following the oven aging, the hose assembly shall be cooled down to a room temperature of 20 °C ± 10 °C for at least 2 h prior to the conduct of the tensile test. Then the tensile test shall be conducted at room temperature.

The apparatus outlined in ISO 4671 shall be used for this test.

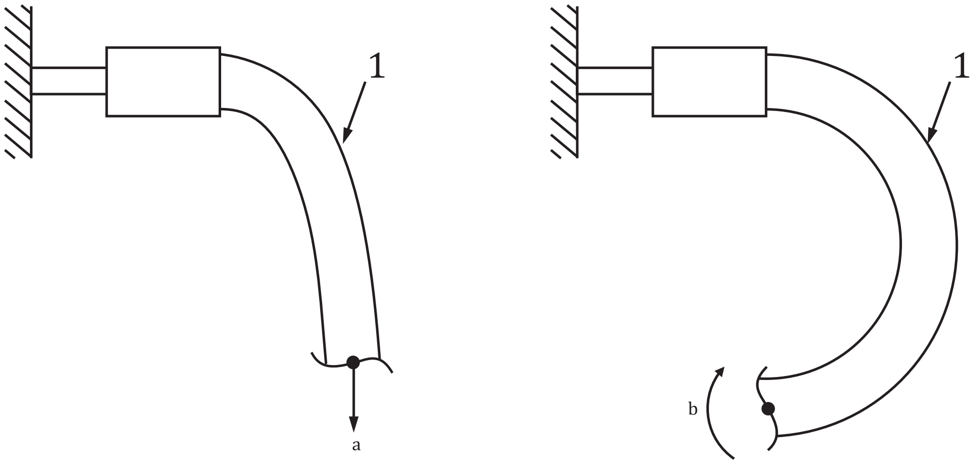
The hose assembly is then to be placed in a tensile testing machine and connected so that the end couplings and hose are subjected to 3 000 N. With the testing machine adjusted for a rate of travel of 0,2 mm/s or slower, the pull force is to be applied until 3 000 N is attained.

At the completion of this test, hose assemblies shall be subjected to and shall comply with 7.3.1 and 7.4.

7.6 Vertical load strength

7.6.1 General

This test models the scenario of a person falling against the hose while the fuelling nozzle is connected to the vehicle receptacle or a loop being generated during handling, as shown Figure 4.



Key

1 hose assembly

a Direction of vertical load.

b Direction of moment.

Figure 4 — Example of abnormal load

7.6.2 Test method

The test piece shall have a free length of 0,5 m between the couplings. This test shall be conducted at 20 ± 10 °C.

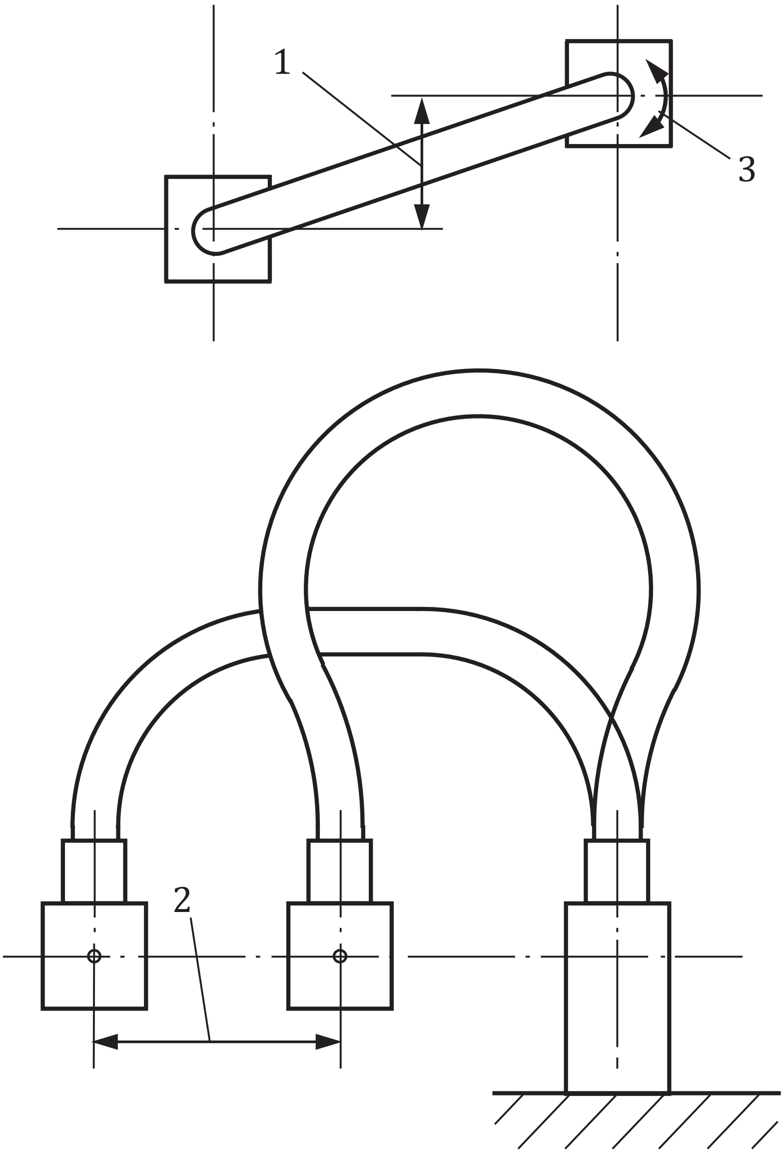
Connect one end of the coupling to the connecter fixed horizontally. Apply the vertical load of 340 N to the other free end and maintain the load for 5 min.

After 5 min, remove the load and perform 7.3.1 and 7.4 for any abnormality.

7.7 Torsion strength

7.7.1 General

This test does not apply to a bonded supply/vent line. When tested in accordance with ISO 6802 with the conditions listed below, a dispenser hose shall withstand 1 000 cycles of horizontally reciprocating movements under atmospheric pressure without damage to the hose or couplings and without leakage in excess of the rate specified in 7.3.1 as shown in Figure 5.



Key

1	offset
2	horizontal reciprocating motion
3	direction of torsion

Figure 5 — Torsion strength

7.7.2 Test method

The test apparatus is a Method 2 horizontally reciprocating manifold.

Offset the sample hose at the distance of four times of outside diameter of hose and mount the test sample at the centre of the stroke making sure there is no twist.

The test shall be conducted under atmospheric pressure and at −40 °C. 1 000 cycles are required.

7.8 Pressure cycle test (Hydraulic-pressure impulse test)

7.8.1 General

This hydraulic test models hot creep conditions at a high temperature.

When tested at impulse pressure equal to 1,25 × HSL, the hose shall withstand a minimum of 100 000 impulse cycles without leakage or failure.

7.8.2 Apparatus

The apparatus for this test shall be in accordance with ISO 6803:2017, Clause 4.

7.8.3 Test fluid

As a fluid for this test, water, mixture of water and glycol or oil (i.e. from grade ISO VG 32 to ISO VG 100 in ISO 3448) can be used. Circulate the fluid at a rate sufficient to maintain a uniform fluid temperature within the test pieces. Other fluids may be used as agreed upon between the customer and the manufacturer.

7.8.4 Test temperature

The test fluid shall be circulated through the test piece at 65 °C ± 3 °C.

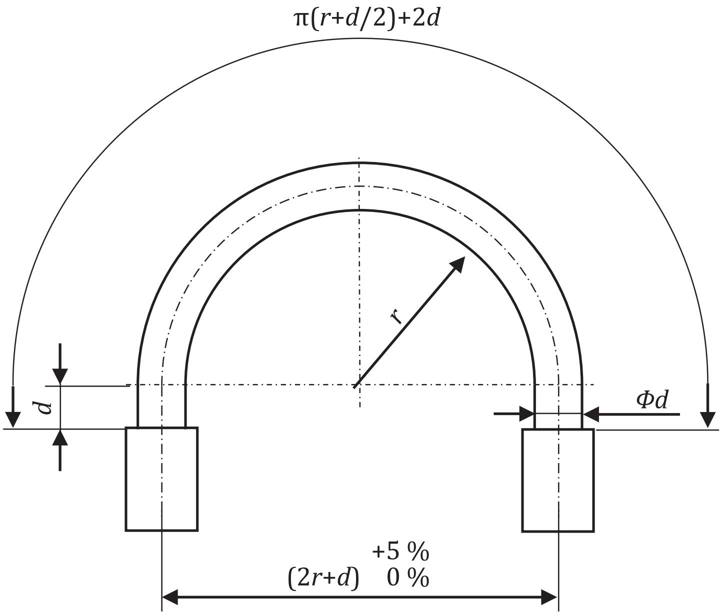
7.8.5 Test piece

Test pieces shall be complete hose assemblies with suitable end couplings attached. Unless otherwise specified, test four unaged hose assemblies with end couplings which have been attached for not more than 30 days.

Calculate the necessary free length of the hose in the test piece as shown in Figure 6.

For values of d less than 25,4 mm, use d = 25,4 mm for the $+2d$ term in the expression for the hose free length, so that the hose between the coupling shell and the start of the bend radius is straight.

The actual free hose length shall agree with the calculated free hose length to within $^{+1}_{0}$ % or $^{+8}_{0}$ mm, whichever is greater.



Key

r	minimum bend radius
d	hose outside diameter

Figure 6 — Test piece for pressure cycle test

7.8.6 Procedure

Connect the test pieces to the apparatus. The test pieces shall be installed in accordance with Figure 6. Test pieces of hose shall be bent through 180°.

Bring the test fluid to the test temperature and then apply a pulsating pressure equal to 100 % of 1,25 × HSL internally to the hose assemblies at a uniform rate between 0,1 Hz and 0,4 Hz. Record the pulse rate used. The pressure cycle shall fall within the shaded area of Figure 7.

The pressurization shall be stopped and the impulse test unit shall be allowed to cool down the temperature of the test fluid to room temperature of 30 °C ± 10 °C at every 30 000 cycles of impulse cycles.

Accelerated cool down procedures, i.e. fans, heat exchangers, etc., may be used to speed up the cooling process.

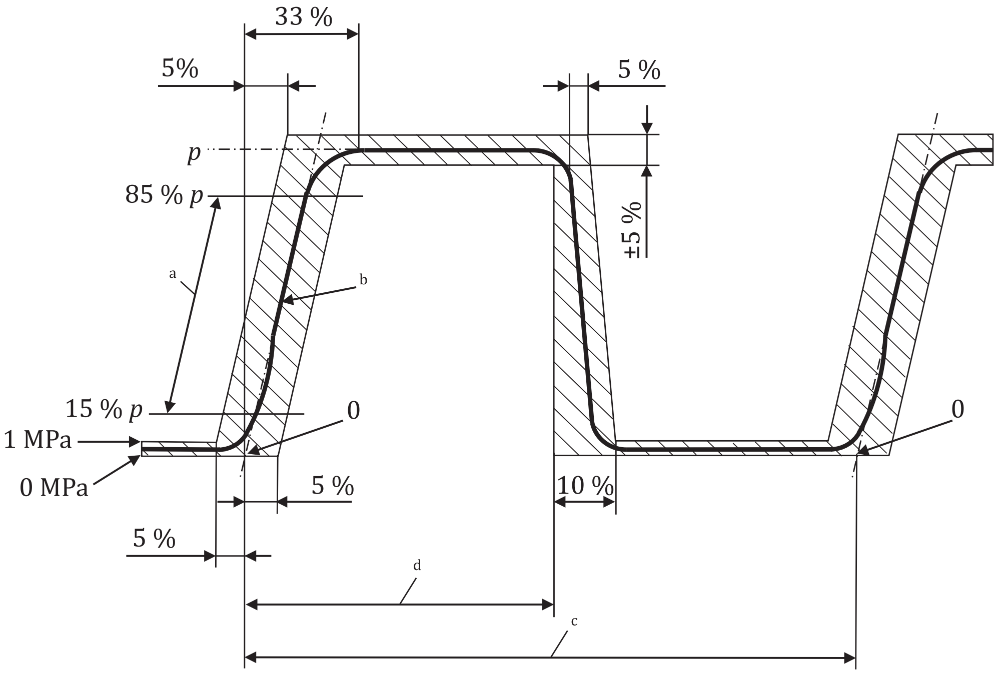
At every cool down, check test assemblies to ensure they are clean and dry. With fluid heater turned off, resume the test and observe and note leakage for 1 000 impulse cycles.

After cool down, raise the fluid temperature to the specified temperature and restart the impulse cycle until next cool down. Run the test until the hose fails or the number of required cycles is performed.

If a test is stopped before completion of the minimum number of cycles and then restarted, leakage may occur at the hose/coupling junction upon restarting the test and until the test temperature is reached. Leakage less than class 4 as defined in ISO/TR 11340 does not constitute a failure of the hose assembly. Any leakage should be reported in accordance with the classification in ISO/TR 11340.

There shall be no leakage or other malfunction of the test piece before reaching the specified number of cycles.

This test shall be considered a destructive test and the test piece shall be destroyed.



Key

p	test pressure
a	Rate of rise to be determined between these points (50 MPa/s to 100 MPa/s).
b	Secant pressure rise.
c	One pulse cycle (0,1 Hz to 0,4 Hz).
d	45 % to 55 % of the cycle.

Figure 7 — Pressure pulse wave

7.9 Hydrogen impulse test

This pneumatic test models cold fracture conditions at a low temperature.

Guidance on the hydrogen impulse test is provided in Annex C.

When a hydrogen impulse test is performed, passing criteria require that no blistering shall be observed. Verification as to whether blistering is observed shall be documented.

7.10 Corrosion test

7.10.1 General

When tested in accordance with ISO 9227 with the conditions listed below, couplings and other metal parts shall not show any evidence of corrosion or other deterioration.

Minor corrosion is allowed on areas where there is mechanical deformation of the plating or coating caused by crimping, flaring, bending, and other post-plate metal forming operations.

At the completion of this test, hose assemblies shall be subjected to and shall comply with 7.3.1.

7.10.2 Test conditions

Test specimen: Hose assembly.

Test method: Acetic Acid Salt Spray (AASS) or Neutral Salt Spray (NSS).

Temperature: 35 °C ± 2 °C.

Duration of test: 96 h.

This test shall be applied to each nominal diameter, type, and material of hose coupling submitted for examination under this requirement.

7.11 Minimum bend radius

Use a test piece having a length at least four times the minimum bend radius. Measure the hose outside diameter with callipers in the straight-lay position before bending the hose. Bend the hose through 180° to the minimum bend radius (see Table 3 or the manufacturer's literature if the size is different from Table 3) at 20 °C ± 10 °C and measure the flatness with the callipers. Typical values are shown in Table 3.

When the hose is bent to the minimum bend radius given in Table 3, or the manufacturer's literature if the size is different from Table 3 measured on the inside of the bend, the flatness shall not exceed 10 % of the original outside diameter.

Table 3 — Typical minimum bend radius

Nominal size	Minimum bend radius (mm)				
	H11	H25	H35	H50	H70
6,3	150	150	150	200	200
8	200	200	200	250	250
10	200	200	200	300	300

7.12 Hose permeation

7.12.1 General

The manufacturer may choose either Test Method A or Test Method B.

When tested in accordance with the following test methods, the hourly permeation rate shall be less than 500 ml/m under normal pressure and temperature conditions. After the test, inspect the exterior of the hose for any blistering or swellings. This outside inspection is to verify hose cover perforation.

7.12.2 Test Method A

The hose assembly shall be tested in accordance with ISO 4080:2009, Method 3 with the exceptional conditions listed below.

The test piece shall have a free length of 0,5 m between the couplings. Connect the test piece to the hydrogen gas supply with a suitable connector and purge the test assembly with hydrogen gas.

Adjust the temperature of the water at 23 °C ± 2 °C.

Insert the test assembly into the transparent tube and immerse it in the water bath so that it is inclined at approximately 20° to the horizontal.

Apply the hydrogen gas pressure of 1,25 × HSL and maintain it for 24 h before measuring the permeability to gas. Following preconditioning, while still maintaining the specified pressure, collect the gas for 6 h or record the time to collect between 450 ml and 500 ml of gas.

Repeat the measurement a further two times. Calculate the permeability to gas expressed in millilitres of gas per meter of hose per hour (ml/m/h). From the three measurements, calculate the average the permeability to gas.

7.12.3 Test Method B

Each sample shall have a suitable hose free length excluding end couplings and shall be assembled with applicable couplings. Plug one end of each sample using an approved plug appropriate for the coupling(s) used on the hose being tested and connect the other end to a regulated hydrogen pressure source using appropriate connectors and adapters. Connect the test piece to the hydrogen gas supply with a suitable connector and purge the test assembly with hydrogen gas.

Place the test piece in a chamber equipped with an inert gas inlet and outlet. After purging the chamber with an inert gas, constant flow rate of inert gas is supplied from the inlet. Pressurize the test piece to 1,25 × HSL using hydrogen and hold the sample at 15 °C for 3 h after the pressure is stabilized. Measure the amount of hydrogen gas contained in the inert gas. The period to determine the permeation rate shall be the last 2 h.

7.13 Ozone resistance

When tested in accordance with ISO 7326:2016, Method 1, a hose outer cover shall show no visible signs of cracking or damage under × 2 magnification after 72 h of exposure with an ozone partial pressure of (100 ± 5) parts per hundred million at a temperature of 40 °C ± 1 °C. The area immediately adjacent to any tooling shall be ignored. Further details can be found in ISO 7326.

7.14 Ultraviolet light and water exposure test

7.14.1 Applicability and verification

This provision applies to a single hose only. In accordance with ISO 30013, after the exposure test with the conditions listed below, all hose samples shall be visually checked and there shall be no signs of crazing or cracking.

7.14.2 Test conditions

Types of test piece: Type 1 (sample of hose with U-shape bend).

Light source: Fluorescent UV lamps Type 1A (UVA-340), Irradiance 0,76 W at 340 nm.

Exposure cycles: Method A: Artificial weathering.

Dry: 8 h at 60 °C.

Condensation: 4 h at 50 °C.

7.14.3 Length of exposure

The test sample shall be cycled continuously under the previously specified cycle pattern for 10 weeks or 1 680 h.

The test sample may be repositioned once per week to obtain uniform exposure to UV radiation, moisture and temperature. Follow the manufacturer’s recommendation for rotation.

7.15 Crush test

7.15.1 General

This provision applies to a single hose assembly only. A dispenser hose assembly shall withstand a force of 8 900 N applied externally without incurring structural damage or leakage.

7.15.2 Test method

The length of the sample hose assembly shall be a minimum of 610 mm. The hose shall be placed against a hard, flat, and smooth metallic surface. A force or weight equivalent to 8 900 N shall be uniformly applied for 15 min to the hose, with the force or weight evenly distributed over 150 mm of the hose length in the approximate centre of the sample. The weight shall then be removed, and the hose shall be subjected to and shall comply with 7.2.1 and 7.4.

If applicable, both hoses of a bonded supply and vent hoses shall be on a horizontal plane when tested. Both hoses shall be in contact with the crushing fixture.

7.16 Abrasion resistance test

When requested by the customer or where regional dispenser designs warrant, dispenser hoses should meet the ISO abrasion resistance test.

7.17 Marking material legibility

7.17.1 General

The legibility of marking materials shall not be adversely affected when marking materials are exposed to heat and moisture as specified in the following test method.

This subclause applies only to markings other than those that are embossed, cast, stamped, or otherwise formed in the part.

7.17.2 Test method

The following tests shall be conducted on two samples. The manufacturer shall have applied the marking materials to the hoses as they would be applied in production.

a) Marking materials shall exhibit no illegible or defaced printing when rubbed with thumb or finger pressure.

b) The marking materials shall then be placed in an oven for a period of 2 weeks with the oven temperature maintained at 85 °C as applicable based on the temperature rating.

Following the oven test, the legibility of the samples shall be checked again as specified in a) above. Samples shall then be immersed in water for a period of 24 h, after which the legibility shall be rechecked as specified in a) above.

Good legibility shall be obtained for all samples under the above specified test conditions.

7.18 Electrical properties of lining material

7.18.1 General

This test shall be applied to the hose lining material, unless the electrical properties are not available from the material manufacturers.

7.18.2 Dielectric breakdown voltage

The dielectric breakdown voltage of the lining material shall be determined in accordance with IEC 60243-1.

7.18.3 Volume resistivity

The volume resistivity of the lining material shall be determined in accordance with IEC 62631-3-1.

7.18.4 Criteria of electric properties of lining materials

The acceptability of the allowable dielectric breakdown voltage and volume resistivity of the lining material shall be determined by the following formula:

$$\log\left(V_{\mathrm{B}} \times t\right) > \frac{1}{2}\log\left(R_{\mathrm{V}}\right) - 6$$

where

V_{B} is the dielectric breakdown voltage (kV/mm) of the liner material;

T is the thickness of the liner tube of the hose in millimetres;

R_{V} is the volume resistivity of the liner material.

NOTE If the material is found to be not acceptable, either the conductivity needs to be enhanced by adjustment to the formulation or a different material needs to be selected.

8 Marking

8.1 General

The marking of hose assemblies is a function of the hose and end fitting design and the hose assembly fabrication. In some cases, the hose assembly, including all components within the assembly, may be manufactured by one manufacturer. In other cases, the hose assembly may be manufactured by a different entity to the manufacturer of the individual components. Where the hose assembly manufacturer is not the manufacturer of each component in the hose assembly, the marking of the components within the hose assembly shall meet the requirements of 8.3 and 8.4.

8.2 Hose assemblies

Hose assemblies shall be marked with at least the following information:

a) the manufacturer’s identification, name, logo, or trademark, e.g. XXX;

b) the number of this document, i.e. ISO 19880-5;

c) the pressure classes; (e.g. H70);

d) Assembly date: the year (last two digits) and then the month of assembly; a slash (/) or a dash (-) can be placed between the year and month.

EXAMPLE XXX/ ISO 19880-5/H70 / 1710.

The maximum working pressure of the assembly is the lowest maximum allowable working pressure of any of its components.

Hose assemblies shall be marked by the following methods:

a) printing or embossing on the hose;

b) engraving on the fitting;

c) stamping on at least one of the couplings;

d) molding in at least one of the couplings;

e) a molded rubber name plate cemented in place;

f) a metal tag or bracket-type marking retained by at least one of the couplings; or

g) printing on a pressure sensitive label of polyester film.

8.3 Hose

Hoses shall be marked with at least the following information, and the marking shall be repeated every 760 mm or less. The letter height shall be a minimum of 15 % of the hose cover outer circumference.

a) the manufacturer's name or identification, e.g. YYY;

b) the number of this document, i.e. ISO 19880-5;

c) the pressure classes; (e.g. H70);

d) the nominal size, e.g. 8;

e) the last two digits of the year and the month of manufacture, e.g. 1710;

f) the manufacturer’s factory identification (MFG internal code); e.g. FAC, if applicable;

g) the certifying body’s name or identification; e.g. NOT, if applicable.

EXAMPLE YYY / ISO 19880-5 / H70 / 8 / 1710 / FAC / NOT.

8.4 Hose end fittings or couplings

Hose end fittings or couplings being permanently marked with the following information is only necessary in the case fittings or couplings are supplied as a single article:

a) the manufacturer’s identification, name, logo, or trademark, e.g. ZZZ;

b) the number of this document, i.e. ISO 19880-5;

c) the pressure classes, e.g. H70;

d) the nominal size, e.g. 8;

EXAMPLE ZZZ/ISO 19880-5/ H70/8

9 Instruction manual

9.1 General

Instructions covering proper selection, installation, inspection, maintenance, safety precautions, and usage shall be provided.

The instructions shall include, as a minimum, statements to the effect that:

a) The hose assembly complies with this document.

b) The manufacturer shall provide appropriate installation instructions.

  1) Safety precautions.

  2) Guidelines for replacement.

9.2 Selection

The hose is suitable only for dispensing of gaseous hydrogen at fuelling stations meeting the requirements of ISO 19880-1.

9.3 Installation

a) 1,375 × HSL shall not be exceeded; the user shall provide overpressure protection to prevent operation of the hose at pressures greater than 1,375 × HSL.

b) The hose assembly shall be of an adequate length for the intended use. Hose assemblies shall not be joined together to achieve the required length.

c) The hose shall not be used for applications where the bend radius is less than the manufacturer's specified minimum bend radius for the hose.

d) The hose shall not be stretched, kinked, twisted, or torqued.

e) The hose assembly shall provide protection for the user from contact damage.

f) The hose shall not be subjected to temperatures outside the temperature limits.

g) The hose assembly shall be removed from service and destroyed in the event of mechanical, chemical, or environmental damages.

9.4 Inspection and maintenance

a) Hose assembly shall be kept in accordance with the conditions specified in ISO 8331 before installation.

b) The hose assembly shall be inspected in accordance with the manufacturer’s instructions. The manufacturer’s instructions shall address such items as:

   1) leakage, in accordance with the applicable installation code;

   WARNING — Open flame testing is prohibited. Leak test solutions may contain halides and will require a potable water rinse after testing.

   2) soft spots, bulges, blisters, kinks, stretching, or discoloration in the hose;

   3) excessive abrasion exposing the hose reinforcement;

   4) cuts or cracks in the hose that expose or damage the reinforcement;

   5) evidence of end connector movement or slippage with respect to the hose;

   6) electrical conductivity.

9.5 Safety precautions and usage

a) The hose assembly shall not be stretched, kinked, twisted, or torqued.

b) Dragging, dropping, contact with sharp objects or edges, and exposure to chemicals shall be avoided.

10 Test report

When requested by the purchaser, the manufacture or supplier shall supply a test report representing the purchased product with each length or batch of hoses containing the following information:

a) a reference to this document with the year of publication (i.e. ISO 19880-5:2019);

b) a full description of the hose assemblies tested;

c) the test items carried out, defined in Clause 7;

e) the test results;

f) the date of the test.

Annex A
(normative)

Type tests and routine tests

Table A.1 gives the tests to be carried out for type testing and routine testing as defined in Clause 7.

Table A.1 — The test items for type test and routine test

Property	Type test			Routine test		
	Hose	Hose assembly	Number of samples	Hose	Hose assembly	Number of samples
Visual examination (inside)	—	—	—	—	—	—
Visual examination (outside)	X	X	minimum 6	X	X	All
Measurement of inside diameter	X	—	minimum 6	X	—	All
Measurement of outside diameter	X	—	minimum 6	X	—	All
Measurement of concentricity	X	—	minimum 6	X	—	All
7.2 Leakage test	—	X	minimum 2	—	X	All
7.3 Hydrostatic strength						
7.3.1 Proof test	—	X	minimum 2	—	X	All
7.3.2 Ultimate strength	—	X	minimum 2	—	—	—
7.4 Electrical conductivity	—	X	minimum 1	—	X	All
7.5 Tensile test of hose assembly	—	X	minimum 2	—	—	—
7.6 Vertical load strength	—	—	minimum 3	—	—	—
7.7 Torsion strength	—	X	minimum 3	—	—	—
7.8 Pressure cycle test (Hydraulic-pressure impulse test)	—	X	minimum 3	—	—	—
7.9 Hydrogen impulse test	—	X	minimum 3	—	—	—
7.10 Corrosion test	—	X	minimum 2	—	—	—
7.11 Minimum bend radius	X	—	minimum 3	—	—	—
7.12 Hose permeation	X	—	minimum 1	—	—	—
7.13 Ozone resistance	X	—	minimum 3	—	—	—
7.14 Ultraviolet light	X	—	4 includes 1 blank	—	—	—
7.15 Crush test	X	—	minimum 2	—	—	—
7.16 Abrasion resistance test	X	—	minimum 3	—	—	—
7.17 Marking material legibility	X	—	minimum 2	—	—	—
7.18 Electrical properties of lining material	X	—	minimum 3	—	—	—

Annex B
(informative)

Production acceptance tests

Table B.1 gives the tests to be carried out for production acceptance tests as defined in Clause 7. It is recommended to carry out these tests for every 3 000 m of hose production.

Table B.1 — The test items for production acceptance tests

Property	Production acceptance tests		
	Hose	**Hose assembly**	**Number of samples**
Visual examination (inside)	—	—	—
Visual examination (outside)	X	X	minimum 6
Measurement of inside diameter	X	—	minimum 3
Measurement of outside diameter	X	—	minimum 3
Measurement of concentricity	X	—	minimum 3
7.2 Leakage test	—	X	minimum 2
7.3 Hydrostatic strength			
7.3.1 Proof test	—	X	minimum 2
7.3.2 Ultimate strength	—	X	minimum 2
7.4 Electrical conductivity	—	—	—
7.5 Tensile test of hose assembly	—	X	minimum 2
7.6 Vertical load strength	—	—	—
7.7 Torsion strength	—	—	—
7.8 Pressure cycle test (Hydraulic-pressure impulse test)	—	X	minimum 3
7.9 Hydrogen impulse test	—	—	—
7.10 Corrosion test	—	—	—
7.11 Minimum bend radius	X	—	—
7.12 Hose permeation	—	—	—
7.13 Ozone resistance	—	—	—
7.14 Ultraviolet light	—	—	—
7.15 Crush test	—	—	—
7.16 Abrasion resistance test	—	—	—
7.17 Marking material legibility	—	—	—
7.18 Electrical properties of lining material	—	—	—

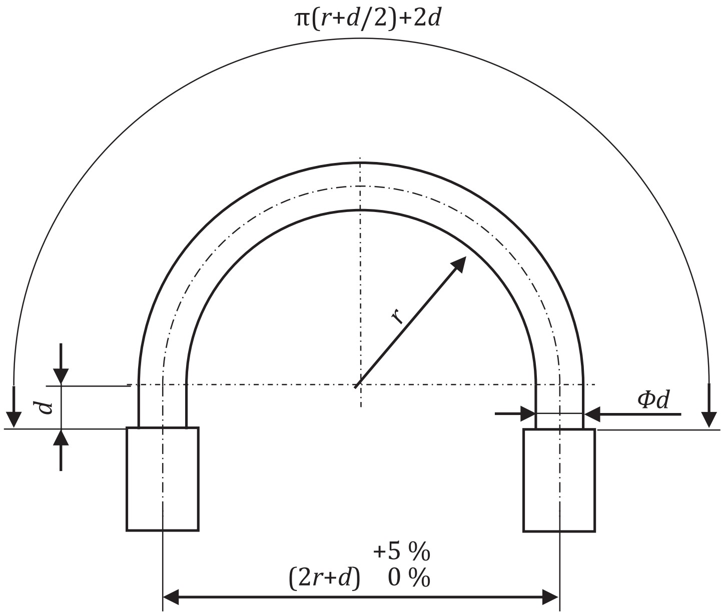
Annex C
(informative)

Hydrogen impulse test

C.1 Test pieces

Test pieces shall be complete hose assemblies with suitable end couplings attached. Test three unaged hose assemblies with end couplings. Calculate the necessary free length of the hose in the test piece as shown in Figure C.1. For values of d less than 25,4 mm, use d = 25,4 mm for the +2d term in the expression for the hose free length, so that the hose between the couplings and the start of the bend radius is straight.

The actual free hose length shall agree with the calculated free hose length to within $^{+1}_{\ 0}\ \%$ or $^{+8}_{\ 0}\ \text{mm}$, whichever is greater.



Key

r	minimum bend radius
d	hose outside diameter

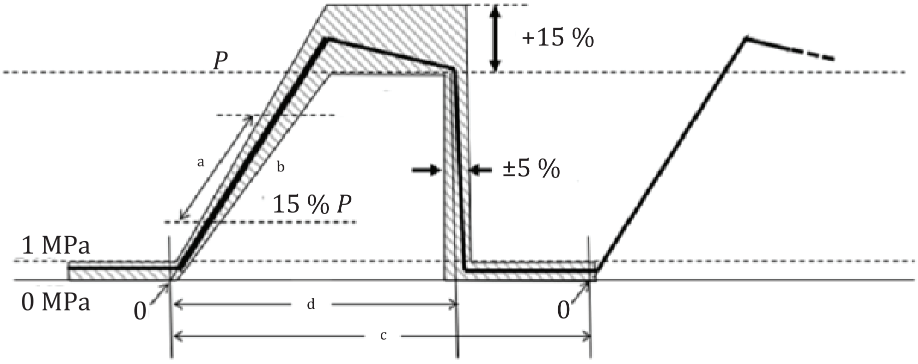
Figure C.1 — Test hose assembly for hydrogen impulse test

C.2 Apparatus

C.2.1 Pressure-application apparatus, capable of applying an internal pulsating pressure to the test hose assemblies at a pressurization rate, (7 % ± 15 %) MPa/s up to 1,25 × HSL using hydrogen gas pressure through the test hose assemblies. Each pressure cycle shall be within the tolerances shown in Figure C.2.

C.2.2 Graphical recorder, digital-storage facility, or **oscilloscope,** capable of measuring the pressure cycle to ensure that the wave form is within the envelope shown in Figure C.2.

C.2.3 If necessary, **test chamber** capable of controlling the ambient temperature of the test hoses to the same temperature of the test gas with a tolerance of ±3 °C.



Key

P	test pressure (1,25 × HSL)
a	Rate of pressure rise to be determined between these points.
b	Secant pressure rise.
c	One pulse cycle (second).
d	Pressurized time, d/c = 0,66 ± 20 %.

The rate of pressure rise to be determined between these points, shall be set to (7 % ± 15 %) MPa/s.

One pulse cycle (second), shall be (1,25 × HSL/a+14) with a tolerance of ±15 %.

The actual rate of pressure rise shall be determined as shown in the figure and shall be within a tolerance of ±15 % of the calculated nominal value.

NOTE The secant pressure rise is the straight line drawn through two points on the pressure rise curve, one point at 15 % of the test pressure and the other at 85 % of the test pressure. Point 0 is the intersection of the secant pressure rise with 0 pressure.

Figure C.2 — Pressure pulse wave form envelope

C.3 Test fluid

Select a hydrogen gas more than 99,9 % in purity as test gas.

C.4 Test procedure

The test gas temperature shall be $-40^{+7,0}_{0}$ °C. The ambient temperature shall be controlled to the same temperature as that of gas with a tolerance of ±3 °C.

It is not required to control the temperature band during a brief decompression stage.

This test should be performed as close as possible to −40°C, based on T40 condition.

Connect the test hose assemblies to the apparatus. The test hose assemblies shall be installed in accordance with Figure C.1, i.e. test pieces of the hose shall be bent through 180°.

Apply the gas pressure of 1,25 × HSL and maintain it for more than 12 h before starting applying pulsating gas pressure.

Bring the test gas to the test temperature and then apply pressure cycles, which shall fall within the shaded area of Figure C.2. Continue the test for the required numbers of cycles or until an assembly fails. Required numbers of cycles shall be determined between the manufacturer and the customer depending on the service life of the hose. If no required numbers of cycles are specified, 10 000 cycles can be used. Record the number of pressure cycles to failure or, if failure did not occur, the number of pressure cycles completed. At the completion of this test, hose assemblies shall be subjected to and shall comply with 7.1, 7.2.1, and 7.5. The test can be interrupted before reaching the target number of cycles and then restarted, as long as the interruption does not affect the test piece or the test conditions. Replacement with tooling for test continuation of other samples is permitted.

This is a destructive test. Hose assemblies which have been subjected to this test should therefore be discarded. The test results obtained are only valid for the combination of hose, coupling type and coupling design that was actually tested.

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Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

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Coregas

Energy Resources Aotearoa

Fabrum

Fonterra Co-operative Group

Gas Appliance Industry

GasNZ

GNS

Hiringa Energy

HW Richardson Group

HyPotential

Methanex

New Zealand Hydrogen Council

PEC

WorkSafe New Zealand − Energy Safety

Z Energy

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New Zealand Standard

Gaseous hydrogen − Fuelling stations

Part 8: Fuel quality control

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the protocol for ensuring the quality of the gaseous hydrogen at hydrogen distribution facilities and hydrogen fuelling stations for proton-exchange membrane (PEM) fuel cells for road vehicles.

In 2021, an amendment (ISO 19880-8:2019/Amd 1:2021) to the ISO standard was published. The amendment's main purpose is to align the standard with Grade D of ISO 14687, *Hydrogen fuel quality − Product specification*. As such, it is part of the suite of New Zealand adoptions and is recommended to be read in conjunction with this version. The New Zealand edition includes the amendment.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 19880-8:2019 *Gaseous hydrogen – Fuelling stations – Part 8: Fuel quality control* and ISO 19880-8:2019/Amd 1:2021 *Gaseous hydrogen – Fuelling stations – Part 8: Fuel quality control*.

As this standard is reproduced from an international standard, the following applies:

(a) In the source text, 'this International Standard' should read 'this New Zealand standard';
(b) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 19880-8

First edition
2019-10

Gaseous hydrogen — Fuelling stations —

Part 8: Fuel quality control

Hydrogène gazeux — Stations de remplissage —

Partie 8: Contrôle qualité du carburant

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee TC 197, *Hydrogen technologies*.

A list of all parts in the ISO 19880 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was developed to specify how the quality of gaseous hydrogen fuel for road vehicles which use PEM fuel cells can be assured. The document discusses hydrogen quality control approaches for routine and non-routine conditions, as well as quality assurance plans. It is based upon best practices and experience from the gaseous fuels and automotive industry. ISO 21087 describes the requirements for analytical methods to measure the level of contaminants found in the gaseous hydrogen fuel.

Gaseous hydrogen — Fuelling stations —

Part 8:
Fuel quality control

1 Scope

This document specifies the protocol for ensuring the quality of the gaseous hydrogen at hydrogen distribution facilities and hydrogen fuelling stations for proton exchange membrane (PEM) fuel cells for road vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 19880-1, *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
authority having jurisdiction
AHJ
organization, office or individual responsible for approving a facility along with an equipment, an installation, or a procedure

3.2
indicator species
one or more *constituents* (3.3) in the gas stream which can signal the presence of other chemical constituents because it has the highest probability of presence in a fuel produced by a given process

3.3
constituent
component (or compound) found within a hydrogen fuel mixture

3.4
contaminant
impurity (3.9) that adversely affects the components within the *fuel cell system* (3.6) or the hydrogen storage system

Note 1 to entry: An adverse effect can be reversible or irreversible.

3.5
filter
equipment to remove undesired *particulates* (3.15) from the hydrogen

3.6
fuel cell system
power system used for the generation of electricity on a *fuel cell vehicle* (3.7), typically containing the following subsystems: fuel cell stack, air processing, fuel processing, thermal management, and water management

3.7
fuel cell vehicle
FCV
vehicle which stores hydrogen on-board and uses a *fuel cell system* (3.6) to generate electricity for propulsion

3.8
fuelling station
facility for the dispensing of compressed hydrogen vehicle fuel, including the supply of hydrogen, and hydrogen compression, storage, and dispensing systems

Note 1 to entry: Fuelling station is often referred to as hydrogen fuelling station or hydrogen filling station.

3.9
impurity
non-hydrogen component in the gas stream

3.10
irreversible damage
irreversible effect
effect, which results in a permanent degradation of the fuel cell power system performance that cannot be restored by practical changes of operational conditions and/or gas composition

3.11
monitoring
act of measuring the *constituents* (3.3) of a hydrogen stream or process controls of a hydrogen production system on a continuous or semi-continuous basis by on-site equipment

3.12
non-routine, adjective
not in accordance with established procedures

3.13
on-site supply
hydrogen fuel supplying system with a hydrogen production system in the same site

3.14
off-site supply
hydrogen fuel supplying system without a hydrogen production system in the same site, receiving hydrogen fuel which is produced out of the site

3.15
particulate
solid or liquid such as oil mist that can be entrained somewhere in the delivery, storage, or transfer of the hydrogen fuel entering a *fuel cell system* (3.6)

3.16
purifier
equipment to remove undesired *constituents* (3.3) from the hydrogen

Note 1 to entry: Hydrogen purifiers may comprise purification vessels, dryers, *filters* (3.5), and separators.

3.17
quality assurance
part of quality management focused on providing confidence that quality requirements will be fulfilled

3.18
quality control
part of quality management focused on fulfilling quality requirements

3.19
quality plan
documentation of quality management

3.20
reversible damage
reversible effect
effect, which results in a non-permanent degradation of the fuel cell power system performance that can be restored by practical changes of operational conditions and/or gas composition

3.21
risk
combination of the probability of occurrence of harm and the *severity* (3.26) of that harm, encompassing both the uncertainty about and severity of the harm

3.22
risk assessment
determination of quantitative or qualitative value of *risk* (3.21) related to a specific situation and a recognized threat also called a hazard

3.23
risk level
assessed magnitude of the *risk* (3.21)

3.24
routine, adjective
in accordance with established procedures

3.25
sampling
act of capturing a measured amount of hydrogen for chemical analysis by external equipment

3.26
severity
measure of the possible consequences for fuel cell cars if filled with H_2 containing higher level of *impurities* (3.9) than the threshold value

4 Abbreviated terms

Abbreviated term	Definition
Halogens	total halogenated compounds
HDS	hydrodesulphurization
PEM	proton exchange membrane
PSA	pressure swing adsorption
SC	severity class
SMR	steam methane reforming
THC	total hydrocarbons
TS	total sulphur compounds
TSA	temperature swing adsorption

5 Hydrogen specifications

The quality requirements of hydrogen fuel dispensed to PEM fuel cells for road vehicles are listed in ISO 14687-2.

6 Quality control approaches

6.1 General

There are two common methods to control the quality of hydrogen at a fuelling station, by spot sampling and continuous monitoring. These methods can be used individually or together to ensure hydrogen quality levels.

6.2 Sampling

Spot sampling at a fuelling station involves capturing a measured amount for chemical analysis. Sampling is used to perform an accurate and comprehensive analysis of impurities which is done externally, typically at a laboratory. Since the sampling process involves drawing a sample of gas, it is typically done on a periodic basis and requires specialized sampling equipment and personnel to operate it. Sampling procedures shall conform to ISO 19880-1. The advantage of spot sampling is that a more detailed laboratory analysis can be conducted on the sample. The disadvantage of spot sampling is that it is not continuous and results in a detail analysis of a single point in time.

6.3 Monitoring

A fuelling station can have real time monitoring of the hydrogen gas stream for one or more impurities on a continuous or semi-continuous basis. A critical impurity can be monitored to ensure it does not exceed a critical level, or monitoring of indicator species are used to alert of potential issues with the hydrogen production or purification process. Monitoring equipment is installed in line with the hydrogen gas stream and shall meet the process requirements of the fuelling station, as well as be calibrated on a periodic basis. Continuous monitoring compliments spot sampling by offsetting the disadvantages.

7 Potential sources of impurities

For a given fuelling station, the contaminants listed in the hydrogen specification referred to in Clause 5 may or may not be potentially present. There are several parts of the supply chain where impurities can be introduced. The potential impurities in each step of the supply chain are described in Annex D.

When a contaminant is classified as potentially present, it shall be taken into account in the quality assurance methodology (risk assessment or prescriptive approach) described in Clause 8.

8 Hydrogen quality assurance methodology

8.1 General

A quality assurance plan for the entire supply chain shall be created to ensure that the hydrogen quality will meet the requirements listed in Clause 5. The methodology used to develop the quality assurance plan can vary but shall include one of the two approaches described in this document. The general description of these two approaches are described in 8.2 and 8.3. Examples of these approaches 1) prescriptive approach and 2) risk assessment for hydrogen quality, are presented in Annexes A, B and C, respectively. The quality assurance plan for the fuelling station shall include the following to ensure hydrogen quality is properly maintained:

- identification of potential impurities;

- — methods to control and remove these impurities;
- — sampling impurities and frequency;
- — monitoring of impurities or process controls;
- — description of solid and liquid particulate filters;
- — cleanliness and maintenance procedures.

It is important to understand that quality should be maintained throughout the complete supply chain of the product (from production source to fuelling station nozzle), such that the impurities that are given in the specification remain below the threshold values.

Each component of the supply chain shall be investigated taking into account the already existing barriers for a given contaminant.

NOTE An effective quality control approach can further ensure the quality of the hydrogen by providing a proactive means to identify and control potential quality issues which can include sampling and monitoring. Additionally, use of quality assurance can improve the decision making if a quality problem arises.

8.2 Prescriptive methodology

The prescriptive approach to hydrogen quality assurance considers potential sources of contaminants and establishes a fixed protocol for analysing and addressing potential contaminants. The prescriptive approach can be applied for the clearly identified supply chain.

The prescriptive quality assurance plan shall be determined taking into account all hydrogen production methods, hydrogen transportation methods and non-routine procedures which exists in the area where the assurance plan is applicable.

NOTE Annex C presents Japanese hydrogen quality guidelines which is an example of a prescriptive quality assurance plan.

8.3 Risk assessment methodology

The risk assessment approach determines the probability to have each impurity above the threshold values of specifications given in Clause 5 and evaluates severity of each impurity for the fuel cell vehicle (see Annex A). As an aid to clearly defining the risk(s) for risk assessment purposes, three fundamental questions are often helpful:

- — What can go wrong: which event can cause the impurities to be above the threshold value?
- — What is the likelihood (probability of occurrence expressed relative to the number of fuelling events) that impurities can be above the threshold value?
- — What are the consequences (severity) for the fuel cell vehicle?

In doing an effective risk assessment, the robustness of the data set is important because it determines the quality of the output. Revealing assumptions and reasonable sources of uncertainty will enhance confidence in this output and/or help identify its limitations. The output of the risk assessment is a qualitative description of a range of risk. To determine the probability of the occurrence that impurities in hydrogen exceed the threshold value, Table 1 defines the occurrence classes.

Table 1 — Occurrence classes for an impurity

Occurrence class	Class name	Description	Occurrence or frequency
0	**Very unlikely (Practically impossible)**	Contaminant above threshold never been observed for this type of source in the industry	Never

Table 1 *(continued)*

Occurrence class	Class name	Description	Occurrence or frequency
1	**Very rare**	Known to occur in the industry for the type of source/Supply chain considered	1 per 1 000 000 fuellings
2	**Rare**	Has occurred more than once/ year in the Industry	1 per 100 000 fuellings
3	**Possible**	Has occurred repeatedly for this type of source at a specific location	1 out of 10 000 fuellings
4	**Frequent**	Occurs on a regular basis	Often

If the occurrence class is unknown, then the risk assessment shall assume the worst case. In addition, the experience of the hydrogen supplier, station manufacturer/installer should be taken into account when performing the risk analysis.

The range of severity classes (level of damage for vehicle) is defined in Table 2.

Table 2 — Severity classes for an impurity

Severity class	FCV performance impact or damage	Impact categories		
		Performance impact	Hardware impact temporary	Hardware impact permanent
0	— No impact	No	No	No
1	— Minor impact — Temporary loss of power — No impact on hardware — Vehicle still operates	Yes	No	No
2	— Reversible damage — Requires specific light maintenance procedure — Vehicle still operates	Yes or No	Yes	No
3	— Reversible damage — Requires specific immediate maintenance procedure — Gradual power loss that does not compromise safety	Yes	Yes	No
4[a]	— Power loss or Vehicle Stop that compromises safety — Irreversible damage	Yes	Yes	No
	— Requires major repair procedure (e.g. stack change)		No	Yes

[a] Any damage, whether permanent or temporary, which compromises safety will be categorized as SC 4, otherwise temporary damage will be categorized as SC 1, 2 or 3.

The final risk is defined by the acceptability table (Table 3) which combines results from Tables 1 and 2:

Table 3 — Combined risk assessment

Probability per one fuelling	**Occurrence**	**Severity**				
		0	**1**	**2**	**3**	**4**
Frequent: Often	**4**	**+**	*	*	*	*
Possible: 10^{-4}	**3**	**+**	**o**	*	*	*
Rare: 10^{-5}	**2**	**+**	**+**	**o**	*	*
Very Rare: 10^{-6}	**1**	**+**	**+**	**+**	**o**	*
Practically Impossible	**0**	**+**	**+**	**+**	**+**	**+**
Key	**+** Acceptable risk area: Existing controls sufficient		**o** Further investigation is needed: existing barriers or control may not be enough		* Unacceptable risk; additional control or barriers required	

NOTE 1 It is possible that contamination of a vehicle at severity class 1 or 2 is not noticeable immediately, thereby making it difficult to identify the source of the contamination.

If a vehicle is found to have hydrogen with contamination that exceeds the specification in Clause 5 and the source is unknown, the procedures in Clause 11 shall be followed.

For each impurity of the specification and for a given fuelling station (including the supply chain of hydrogen), a risk assessment shall be applied to define the global risk.

NOTE 2 Risk control includes decision making to reduce and/or accept risks. The purpose of risk control is to reduce the risk to an acceptable level.

The amount of effort used for risk control should be proportional to the significance of the risk. Decision makers might use different processes, including benefit-cost analysis, for understanding the optimal level of risk control. Risk control can focus on the following questions:

- Is the risk above an acceptable level?
- What can be done to reduce or eliminate risks?
- What is the appropriate balance among benefits, risks and resources?

For each level of risk, a decision shall be taken in order to either refuse the risk and find mitigation or barriers to reduce it, or accept the risk level as it is. Risk reduction focuses on processes for mitigation or avoidance of quality risk when it exceeds an acceptable level ("o" or "*" zone in Table 3). Risk reduction typically includes actions taken to mitigate the severity and/or probability of occurrence. However, this document only deals with the mitigation of probability of occurrence.

8.4 Impact of impurities on fuel cell powertrain

It is necessary to evaluate the possible consequences on a fuel cell car if each impurity exceeds the ISO 14687-2 threshold value. The impact for the car will depend on the concentration of the contaminant. Table 4 shows a summary of the concentration-based impact of the impurities on the fuel cell. The contaminants and their chemical formulas are given in the first two columns of Table 4.

An estimation of the exceeded concentration above the ISO 14687-2 threshold value for each impurity is named "Level 1" and is given in column 5. According to this concentration a severity class is given in column 4 for each impurity. This severity class covers the impact of this impurity above the threshold value up to this limit.

If higher concentrations that exceed Level 1 can be reached, the severity class is given in column 6.

Table 4 — Impact of impurities on fuel cell powertrain

Impurity		ISO 14687-2 threshold value[a] [µmol/mol]	Severity class (from ISO 14687-2 to Level 1)	Level 1 value [µmol/mol]	Severity class (greater than Level 1 threshold)
Total non-H_2 gases		300	1	UD	UD
Total nitrogen and argon	N_2, Ar	100	1[b]	300[a]	4
Oxygen	O_2	5	UD	UD	4[c]
Carbon dioxide	CO_2	2	1	3	4
Carbon monoxide	CO	0,2	2-3[d]	1	4
Methane	CH_4	100	1	300	4
Water	H_2O	5	4	5	4
Total sulphur compounds	H_2S basis	0,004	4	>0,004	4
Ammonia	NH_3	0,1	4	>0,1	4
Total hydrocarbons	CH_4 basis	2	1-4[d]	>2	4
Formaldehyde	CH_2O	0,01	2-3[d]	1	4
Formic acid	HCOOH	0,2	2-3[d]	1	4
Halogens		0,05	4	>0,05	4
Helium	He	300	1	300	4
Maximum particulate concentration (liquid and solid)[e]		1 mg/kg	4	>1 mg/kg	4

Key

UD: Undertermined

[a] The threshold value is according to hydrogen specification of ISO 14687-2.

[b] At the time of publication, the revision of the threshold limit for inert gases (N_2+Ar+He) is undergoing. When the threshold limit is changed from 100 µmol/mol to 300 µmol/mol, severity class for inert gases in a range of 100 µmol/mol to 300 µmol/mol will be 0.

[c] Data is lacking to confirm the Level 1 concentration and severity class for oxygen;, therefore, the most conservative approach of severity class 4 should be taken unless demonstrated otherwise.

[d] A higher value is to be considered for risk assessment approach until more specific data is available.

[e] Particulates are based upon mass density mg/kg.

9 Routine quality control

Routine analysis is performed on a periodic basis once every specified time period or once for each lot or batch. The methodology selected in the hydrogen quality assurance plan determines the type and frequency of the routine analysis. A prescriptive methodology may be used as described in 8.1 or a risk assessment methodology may be used (8.2). Information on the routine analysis for each step of the supply chain is provided in Annex E.

10 Non-routine quality control

The hydrogen quality plan shall identify any non-routine conditions and subsequent required actions. Some common non-routine conditions include the following:

- a new production system is constructed at a production site or a new fuelling station is first commissioned;

- the production system at a production site or fuelling station is modified;
- a routine or non-routine open inspection, repair, catalyst exchange, or the like is performed on a production system at the production site or fuelling station;
- any severe malfunctions of a transportation system of compressed hydrogen, liquid hydrogen, and hydrogen pipeline occur;
- a question concerning quality is raised when, for example, there is a problem with a vehicle because of hydrogen supplied at the production site or fuelling station, and a claim is received from a user directly or indirectly;
- an issue concerning quality emerges when, for example, a voluntary audit raises the possibility that quality control is not administered properly; or
- analysis is deemed necessary for testing, research, or any other purposes.

11 Remedial measures and reporting

If a fuelling station dispenses hydrogen which does not meet the requirements in Clause 5, the fuelling station operator shall immediately prevent any further dispensing until repaired, and notify the station owner/operator as soon as possible, as well as the authorities having jurisdiction. The fuelling station owner/operator shall also review and update quality assurance methodologies to prevent future contamination.

Annex A
(Informative)

Impact of impurities on fuel cell powertrains

A.1 General

This annex gives a brief description of the impact of impurities on the stack, fuel cell components, and the complete fuel cell powertrain. Detailed information can be found in the relevant literature and journal publications. It shall be noted that this annex refers to known impurities and their effects on the fuel cell powertrain at the time of publication. It cannot be excluded that other impurities exist. Furthermore, in most cases only the impact of a single impurity has been investigated and there is still the need for fundamental research regarding the impact of a combination of the different impurities on the fuel cell powertrain.

A.2 Inert gases

The main effect due to the presence of inert gases such as Ar and N_2 is to lower the cell potential due to the dilution effect of the inert species (dilution of the hydrogen gas) and inertial (diffusion) effects. Nevertheless, under consideration of the threshold value current stack designs, fuel cell components and fuel cell powertrains are not adversely affected by inert constituents. High inert gas concentrations will lead to power losses, increased fuel consumption, and loss of efficiency. Furthermore, H_2 starvation caused by high inert gas concentrations may lead to permanent damage of the fuel cell stack or vehicle stop. Inert gases will accumulate in the anode loop and may affect venting and recycle blower control. Further sources report that the presence of N_2 hinders desorption of adsorbed CO from the surface of the anode catalyst. It should also be noted that inert gases can affect the accuracy of mass metering instruments for hydrogen dispensing.

A.3 Oxygen

Oxygen may have a detrimental effect on the fuel cell anode, but the concentration where this effect occurs is not fully known. Higher levels of oxygen may have an impact on metal hydride storage materials.

A.4 Carbon dioxide

The contamination effects of CO_2 depend on the concentration, fuel cell operation conditions, and anode catalyst composition. Firstly, CO_2 dilutes the hydrogen gas and may affect venting and recycle blower control of the fuel cell powertrain. Furthermore, very high concentrations of CO_2 can be catalytically converted via a reverse water gas shift reaction into CO which in consequence poisons the catalyst. In addition, co-occurrence of CO and CO_2 in hydrogen has an accumulated influence on cell performance. CO_2 may adversely affect on-board hydrogen storage systems using metal hydride alloys.

A.5 Carbon monoxide

Carbon monoxide causes severe catalyst poison that adversely affects the performance of the fuel cell powertrain. CO binds strongly to Pt sites, resulting in the reduction of the effective electrochemical surface area available for H_2 adsorption and oxidation. The catalyst poison effect is strongly related to the concentration of CO, the exposure time, the cell operation temperature and anode catalyst types. Although the effects of CO on the fuel cell can be reversed through mitigating strategies, such as material selection of membrane electrode assembly, system design and operation, the life time effects of CO on performance is a strong concern. The lower catalyst loadings needed for cost optimization and longer hydrogen protection times especially lead to more severe poisoning effects. Therefore, CO needs to be kept at very low levels in hydrogen fuel.

A.6 Methane

Methane is one of the very few hydrocarbons that does not contaminate PEM fuel cells. It does not react with the catalyst, so dilution is the major effect that shall be considered with methane gas.

A.7 Water

Water is an issue for hydrogen dispensing systems, in the on-board vehicle tank system or fuel cell components due to the formation of ice. Excess water can exist in a liquid state and can cause corrosion of metallic components. Low quantities could lead to severe impacts on the components. Furthermore, water affects the function of the stack. Water provides a transport mechanism for water-soluble impurities, especially as a solvent for cations like Na^+, K^+, Ca^{2+}, Cs^+ and $NH_4{}^+$ when present as an aerosol. The cations absorb to and block the functional groups of the ionomer thereby reducing the proton conductivity of the membrane. Water is only a concern for the stack in very large quantities. It can lead to water management issues that may limit the current and increase in over-potential. Water should remain gaseous throughout the operating conditions of system. It is believed that water affects the metal hydride life cycle due to exothermic reactions.

A.8 Total sulphur compounds

Sulphur containing compounds are severe catalyst poisons that at even very low levels can cause irreversible degradation of fuel cell performance. The specific sulphur compounds that are addressed are in particular: hydrogen sulphide, sulphur dioxide, carbonyl sulphide, carbon disulphide, methyl mercaptan. Beside these specific compounds further sulphur compounds can exist. The adsorption of the sulphur-containing species to the active sites of the catalyst prevents the hydrogen from adsorbing at the catalyst surface resulting in a significant drop in performance. The reactions of the adsorbed sulphur compounds result in the formation of the very stable platinum sulphide which makes it impossible to recover the fuel cell catalyst from contamination. Lower catalyst loadings are particularly susceptible to catalyst poisoning contaminants.

A.9 Ammonia

Ammonia contamination causes some irreversible fuel cell performance degradation by reducing the proton conductivity of the ionomer. NH_3 migrates into the membrane and reacts with protons to $NH_4{}^+$ which then absorb to and block the functional groups of the ionomer. The level of deterioration depends on both the NH_3 concentration and exposure time. Performance decay is also attributed to the adsorption of ammonia on the catalyst surface blocking the active sites.

A.10 Total hydrocarbons

Different hydrocarbons have different effects on fuel cell performance. The main effect is the adsorption on the catalyst layer, reducing the catalyst surface area and thereby decreasing the cell performance. Another effect is the decomposition into carbon monoxide, which then adsorbs on the catalyst layer. The severity of the effect depends on the type of hydrocarbon. Generally aromatic hydrocarbons adsorb more strongly on the catalyst surface than other hydrocarbons inhibiting access to hydrogen. Acids, aldehydes, etc. degrade performance. Phthalates, squalene, erucamide which could be found in seals and hoses will cause problems on the stack side. CH_4 is considered an inert constituent since its effect on fuel cell performance is to dilute the hydrogen fuel stream (see A.5).

A.11 Formaldehyde

Formaldehyde has a similar effect on fuel cell performance as carbon monoxide. The adsorption process of formaldehyde on the catalyst is the same as for CO followed by an immediate conversion of the CH_2O to CO + H_2. The adsorption of the produced CO on the catalyst layer leads to a reduction of the catalytic surface area which decreases the cell performance. Contamination due to formaldehyde can be recovered by changing the cell voltage and by purging with pure hydrogen. Therefore, formaldehyde can be considered as a reversible contaminant with the same impact on the fuel cell as for CO. Lower catalyst loadings are particularly susceptible to catalyst poisoning contaminants.

A.12 Formic acid

Formic acid has a similar effect on fuel cell performance as carbon monoxide. Under certain operating conditions CO is a possible intermediate during the adsorption process of formic acid and the subsequent reaction of HCOOH to CO_2 + H_2. The adsorption of the intermediate CO product on the catalyst layer leads to a reduction of the catalytic surface area which decreases the cell performance. Contamination due to formic acid can be recovered by changing the cell voltage and by purging with pure hydrogen. Therefore, formic acid can be considered as a reversible contaminant with the same impact on the fuel cell as for CO. Lower catalyst loadings are particularly susceptible to catalyst poisoning contaminants.

A.13 Halogenated compounds

Halogenated compounds adsorb on the catalyst layer, reduce the catalytic surface area, and decrease the cell performance. The performance degradation caused by halogenated compounds is an irreversible effect. The biggest concern is about chlorine in hydrogen from electrolysis of water. Chloride for example promotes the dissolution of Pt by the formation of soluble chloride complexes and subsequent deposition in the fuel cell membrane. Potential sources include chloralkali production processes, refrigerants used in processing, and cleaning agents.

A.14 Helium

The main effect due to the presence of helium is to lower the cell potential due to the dilution effect of the inert species (dilution of the hydrogen gas) and inertial (diffusion) effects. It should be considered that hydrogen sensors show interference with helium. Higher inert gas concentrations may also affect the venting and recycle blower control. Current stack designs are not adversely affected by higher inert gas concentrations. Nevertheless, higher inert gas concentrations will lead to power losses, increased fuel consumption, and loss of fuel cell efficiency.

A.15 Solid and liquid particulates (aerosols)

Aerosols are dispersed solid and/or liquid particles in a gas. These particulates may be introduced in the production, storage, or delivery of hydrogen fuel. A maximum solid and liquid particle concentration is specified to ensure that filters are not clogged and/or solid and liquid particles do not enter the fuel system and affect operation of fuel system components and fuel cell stacks. A maximum particulate size diameter is not specified yet but should be addressed in a fuelling station standard and/or future revision of ISO 14687-2. Particulate sizes should be kept as small as possible.

There are various effects of station operating fluids and solid particulates on the stack, fuel cell components, and the complete fuel cell powertrain. These particulates originate from the operation of hydrogen fuelling stations and show severe impacts. This group of substances comprises cleaning agents, oils, lubricant oils, siloxanes, ionic liquids, decomposition products of ionic liquids, additives, metals, metal oxides, and metal ions. One effect of these substances is the adsorption to the active site of the fuel cell catalyst which prevents the hydrogen from adsorbing at the catalyst surface resulting in significant performance drop. Other effects are the reduction of the proton conductivity of the membrane, impact on storage systems, and interference of H_2 sensors. Generally, the use of operating fluids shall be minimized as far as possible. If the use of operating fluids is mandatory, means shall be provided by the hydrogen fuelling station to hinder these operating fluids from contaminating the vehicle fuel cell powertrain.

The contamination due to aerosols is of extreme importance as illustrated by the following example using SnO_2, the oxide of the tetravalent tin as a model substance. This heavy metal oxide is present in the solid state of matter with a molar mass of $M_{SnO2} = 150{,}69\ g \cdot mol^{-1}$ and a density of $\rho_{SnO2} = 6{,}95\ g \cdot cm^{-3}$ at 20 °C. Under the assumption of a spherical particle shape with a diameter of $d_{particle} = 0{,}1\ \mu m$ and under consideration of the Avogadro Constant $N_A = 6{,}022 \cdot 10^{23}\ mol^{-1}$ the number of SnO_2-molecules n_{SnO2} in the particle can be calculated as follows:

$$n_{SnO_2} = \frac{\pi \cdot d_{particle}{}^3 \cdot \rho_{SnO_2}}{6 \cdot 10^{15} \cdot M_{SnO_2}} \cdot N_A \qquad (A.1)$$

$$n_{SnO_2} = 1{,}45 \cdot 10^7 \qquad (A.2)$$

These 14,5 million SnO_2 molecules can lead to irreversible impacts in microelectronic structures. Therefore it is necessary to filter out any solid and liquid particles close to the fuelling nozzle to prevent any impact on the fuel cell powertrain.

Annex B
(informative)

Example of risk assessment

B.1 Centralized production, pipeline transportation

The different steps for elaborating the quality assurance plan of one fuelling station are illustrated using the following case: one fuelling station delivered by pipeline from an off-site SMR.

The solutions selected in this example to decrease the risk when necessary are given as a possible solution for this specific case. Other solutions may be chosen depending on each fuelling station.

Following the procedure described in Clause 8, the risk assessment is performed on the identification of the probability to have each impurity above the threshold values of specifications and the evaluation of severity for the fuel cell vehicle, assuming some values of impurities above the specification (see Table B.1, Table B.2 and Table B.3). This risk assessment is done for each part of the supply chain: SMR, pipeline distribution and fuelling station itself.

B.2 Steam methane reformation

B.2.1 General

In this process, methane from natural gas and steam react at a high temperature to produce synthesis gas (or syngas). Syngas is a mixture consisting mainly of hydrogen and carbon monoxide.

In order to achieve the reaction between natural gas and steam, catalysts and a high temperature are required. These catalysts are poisoned by any trace of sulphur or chlorinated compounds. It is then necessary to remove all sulphur components from natural gas before the SMR reaction. The purification system, named hydrodesulphurisation is a two steps process: first transformation of all sulphur species in H_2S and then adsorption of H_2S in specific adsorbents. At the outlet of this purification step, the natural gas contains less than 50 nmol/mol of H_2S by design and less than 10 nmol/mol in normal conditions.

After the reforming reaction, the carbon monoxide is further reacted with steam in a water gas shift reaction. It produces carbon dioxide and hydrogen and it increases the hydrogen yield. An additional separation step is mandatory to provide hydrogen with a purity suitable for FCV application.

B.2.2 Purification by pressure swing adsorption

Pressure swing adsorption is a non-cryogenic gas separation process which uses adsorbent technology to purify hydrogen from a gas mixture. PSA principle is based on preferential adsorption of some gaseous components to others on highly porous materials. The PSA ability to trap impurities depends on the affinity between the adsorbent and the gas molecule. Typically a PSA column is filled with multiple adsorbents with very high surface area to volume ratios. Typical adsorbents include silica, alumina, molecular sieves, and activated carbons, which have different relative strength of adsorption depending on the gaseous compounds.

Table B.1 — Probability of occurrence for off-site SMR

Impurity	**Threshold** µmol/mol	**Possible causes For the source studied**	**Typical barriers employed in this process**	**Probability with barriers**
Inert gas N_2	100	Present in natural gas and syngas PSA malfunction	— PSA — Double analysis PSA outlet <100 µmol/mol	3
Inert gas Ar		Only ATR and POx present in O_2 typical 0,6 % in syngas from ATR	— PSA. Not sized to remove Ar. Ar content may be higher if H_2 comes from ATR, POX or feeds with high Ar content	2
O_2	5	Not present in syngas. O_2 is unstable in the condition of reforming and shift reactions. Combines with H_2, CO CH_4	— PSA cannot be used with significant O_2 content for safety reasons	0
CO_2	2	Present in syngas (%)	— PSA adsorption strength of MS, activated carbon, silicagel higher for CO_2 than CO. A CO content lower than 10µmol/mol insures a CO_2 content lower than 2 µmol/mol	0
CO	0,2	Normal operation below threshold. Occasional peaks at µmol/mol level	— Double analysis at the PSA outlet + trip if the CO>1-10 µmol/mol at PSA outlet	4
C H_4	100	Present in syngas at % level	— In most cases CO is sizing the PSA, therefore CO<10 µmol/mol ==> C H_4 < 100 µmol/mol depending on users' specification (Europe pipeline 2 µmol/mol).	2
H_2O	5	Syngas saturated in H_2O	— PSA adsorbed in alumina and MS adsorption strength higher than CO_2. A CO content lower than 10 µmol/mol insures a H_2O content lower than 5 µmol/mol.	0

Table B.1 *(continued)*

Impurity	**Threshold** µmol/mol	**Possible causes For the source studied**	**Typical barriers employed in this process**	**Probability with barriers**
TS	0,004	TS from natural gas	— Desulphuration upstream reformer (typical values: normal < 10 ppb, maximum < 20 ppb, guarantee < 50 ppb,) — Typical dilution factor 2,5 (1mole natural gas produces 2,5 mole H_2) — Pre-reformer catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — Reformer catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — Shift catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — PSA adsorption of H_2S before CO, CO_2, species — H_2S adsorption in pipe and vessels. Strong affinity with steel	0
NH_3	0,1	Traces present in syngas	— PSA adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10µmol/mol insures a NH_3 content lower than 0,1 µmol/mol	0
THC	2	Traces of C2+ after reforming reaction	— PSA C2 C3, C4, C5+adsorbed by activated carbon layer. A CO content lower than 10 µmol/mol insures a THC (C H_4 excluded) content lower than 2 µmol/mol	0
HCHO	0,01	May be present in syngas. essentially liquid	— PSA. Formaldehyde adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 µmol/mol insures a HCHO content lower than 0,1 µmol/mol. To guarantee 0,01 µmol/mol would require more experience of measuring at those levels	1
HCOOH	0,2	May be present in syngas essentially liquid	— PSA. Formic adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 µmol/mol insures a HCOOH content lower than 0,2 µmol/mol	0

Table B.1 *(continued)*

Impurity	Threshold µmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Probability with barriers
Halogens	0,05	Present in natural gas	— Any Cl present in natural gas would be stopped by HDS — Pre-reformer catalyst poisoning by Cl irreversible Cl trapped at this stage. If breakthrough, process condition cannot be achieved — Reformer catalyst poisoning by Cl irreversible. Cl trapped at this stage I break through, process condition cannot be achieved — Shift catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved — PSA adsorption of Cl before CO, CO_2, species	0
He	300	Not present in natural gas in N Europe (<10 µmol/mol). Passes through the whole process. Dilution factor 2,5		0

Table B.2 — Probability of occurrence for pipeline

Impurity	Threshold µmol/mol	Causes possible For the item studied	Typical barriers employed in this process	Probability with barriers
Inert gas N_2	100	Air intake if some areas are at negative pressure From seal gas or purge gas Wrong purging after maintenance	Inlet pressure PSL trip on compressors	1
Inert gas Ar		No potential	1 % Ar in the air. 100 µmol/mol would mean 1 % air in the pipe Never been observed	0
O_2	5	Air intake if some areas are at negative pressure	Inlet pressure PSL trip on compressors	1
CO_2	2	From Air:C O_2 at 400 µmol/mol in the air	2 µmol/mol of C O_2 would mean 0,5 % air in the pipe Never been observed	0
CO	0,2	No potential		0
CH_4	100	No potential		0
H_2O	5	Wrong drying after pressure hydraulic test	H_2 > 40 bar ==> leak from H_2O to H_2 unlikely during operation.	0
TS	0,004	No potential		0
NH_3	0,1	No potential		0
THC	2	No potential		0
HCHO	0,01	No potential		0
HCOOH	0,2	No potential		0
Halogens	0,05	From cleaning material after maintenance		1
He	300	No potential		0

Table B.3 — Probability of occurrence for fuelling station to be source of impurities

Impurity	Threshold µmol/mol	Causes possible For the source studied	Existing barriers	Probability
Inert gas N_2	100	N_2 purging operation, air intake during normal operation or maintenance		3
Inert gas Ar		Air intake during normal operation or maintenance	1 % Ar in the air. 100 µmol/mol would mean 1 % air in the fuelling station Never been observed	0
O_2	5	Air intake during normal operation or maintenance		2
CO_2	2	Air intake during normal operation or maintenance	2 µmol/mol CO_2 would mean 0,5 % air in the fuelling station. Never been observed	0
CO	0,2	No potential at fuelling station level		0
CH_4	100	No potential at fuelling station level		0
H_2O	5	Maintenance, leaks from compressor exchangers, improper pressure vessel drying after periodic inspection, H_2O coming from the vent in case of check valve malfunction, depending on fuelling station/compressor technology		2
TS	0,004	Materials gaskets, valve seats and tubing	Material specifications	1
NH_3	0,1	No potential		0
THC	2	Oil carryover from compressor (depending on compressor technology)		2
HCHO	0,01	No potential		0
HCOOH	0,2	No potential		0
Halogens	0,05	From degreasing material		1
He	300	No potential at fuelling station level	If pure He is not used for maintenance	0

When the study has been conducted for each step within the supply chain (i.e. production, distribution, and fuelling) the highest probability is selected as the compounded probability. Table B.4 gives an example.

To define the severity class of each impurity as it is presented in Table B.4, some assumptions are made concerning the impurity levels above the threshold value. These impurity levels are assumed to be reached for a short period of time.

Table B.4 — Combined risk assessment

ISO specification		Supply chain probability							Residual			
Impurity	**Threshold** µmol/mol	**Production SMR**	**Pipeline distribution**	**Fuelling station**	**Compounded probability**	**Severity**	**Criticality**	**Additional risk reduction measures**	**Severity reduction measures**	**Prob-abili-ty**	**Se-veri-ty**	**Criti-cality**
Inert gas N_2	100	3	1	3	**3**	**1**	**o**	Systematic N_2 analysis after shutdown before resuming operation or specific purging procedure	None	1	1	**+**
Inert gas Ar		2	0	0	**2**	**1**	**+**		None	2	1	**+**
O_2	5	0	1	2	**2**	**0**	**+**		None	2	0	**+**
CO_2	2	0	0	0	**0**	**1**	**+**		None	0	1	**+**
CO	0,2	4	0	0	**4**	**2**	*	CO absorber at fuelling station design margin 100 % + operation procedure for replacement when H_2 quantity purified = 50 % of design capacity.	None	1	2	**+**
CH_4	100	2	0	0	**2**	**1**	**+**		None	2	1	**+**
H_2O	5	0	0	1	**1**	**4**	*	Check H_2O at commissioning and after maintenance involving opening of vessels or piping. Measurement shall be done at appropriate location downstream of the considered vessel or piping	None	0	4	**+**
TS	0,004	0	0	1	**1**	**4**	*	Check TS at commissioning and after maintenance involving parts modification (piping, valves, seals, gaskets). Not required for part replaced by identical component	None	0	4	**+**
NH_3	0,1	0	0	0	**0**	**4**	**+**		None	0	4	**+**
THC	2	0	0	2	**2**	**4**	**+**	Oil/grease cleaning at commissioning and after maintenance. Compressor surveillance depending on compressor technology (coalescing filter) THC analysis or commissioning and after maintenance	None	0	4	**+**

Table B.4 *(continued)*

ISO specification		Supply chain probability			Compounded probability	Severity	Criticality	Additional risk reduction measures	Residual			
Impurity	Threshold µmol/mol	Production SMR	Pipeline distribution	Fuelling station					Severity reduction measures	Probability	Severity	Criticality
HCHO	0,01	1	0	0	**1**	**2**	+		None	1	2	+
HCOOH	0,2	0	0	0	**0**	**2**	+		None	0	2	+
Halogens	0,05	0	0	1	**1**	**4**	*	Halogenated analysis at commissioning (species shall be defined) or after maintenance	None	0	4	+
He	300	0	0	0	**0**	**1**	+		None	0	1	+
Key					+ Acceptable risk area: existing controls sufficient			o Further investigation is needed: existing barriers or control may not be enough	* Unacceptable risk; additional control or barriers required			

Table B.4 is used to define the criticality for each impurity.

When the result is light grey or "+", the H_2 quality is under control and the risk of having an issue with the vehicle using this hydrogen is considered acceptable. No additional barrier is necessary and this impurity has no reason to be controlled at the fuelling station nozzle.

When the result is medium grey or "o", which is the case for N_2, the conclusion is to further investigate the means to decrease the occurrence probability. For instance, in addition to the existing analysis at SMR plant, measure N_2 at the commissioning of the fuelling station and after each maintenance where some parts of the system are open to air or apply a specific purge procedure which guarantees reaching a value within the specification.

When the result is dark grey or "*", it is necessary to reduce the probability of occurrence or to decrease the severity to bring back the risk at an acceptable limit. Additional barriers shall be added. These barriers are studied case by case.

For CO the conclusion in this example of risk assessment may be:

- to add a purifier with proper capacity of purification and to define a strict procedure for the purifier replacement, or
- to add a continuous analysis and shutoff valve at the inlet of the fuelling station (at pipeline connection).

For H_2O the conclusion is to measure H_2O at the commissioning of the fuelling station and after each maintenance open vessels or piping or replace one of them. This analysis could be done at low pressure to have more sensitivity.

For THC, depending of the compressor type, add a coalescing filter and proper maintenance procedure. Measure THC after commissioning or maintenance operation involving cleaning/degreasing.

For Halogens, make an analysis at commissioning on a list of predefined components.

In conclusion,

- for commissioning: measure N_2, H_2O, THC, TS , and Halogens;
- after maintenance: measure N_2, H_2O, THC.

The analysis of other impurities is not mandatory if there is an analysis of CO and N_2 at the production site.

B.3 Alkaline electrolysis

Table B.5 shows the probability of occurrence of different contaminants for hydrogen produced by alkaline electrolysis.

Table B.5 — Probability of occurrence for alkaline electrolysis

Impurity	Threshold µmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Probability
Inert gas N_2	100	Insufficient purging after shutdown	Electrolyser process control	3
Inert gas Ar		Insufficient purging after shutdown	If N_2 below 1 %, Ar < 100 µmol/mol	1
O_2	5	Insufficient purging after shutdown (does not apply to all systems) O_2 permeation through the membrane	Process control Deoxo O_2 sensor	2
CO_2	2			0
CO	0,2			0
$C H_4$	100			0
H_2O	5	H_2 from electrolyser is saturated.	Dryer plus water sensor downstream of electrolyser	2
TS	0,004			0
NH_3	0,1			0
THC (excluding CH_4)	2			0
HCHO	0,01			0
HCOOH	0,2			0
Halogens	0,05	Cl from water?	Any trace of halogenated compounds would be trapped in the dryer which has a stronger adsorption capacity for Cl than for H_2O	0
He	300			0

Annex C
(informative)

Example of Japanese hydrogen quality guidelines

C.1 General

This annex is a condensed version of the Japanese quality control guidelines developed in Japan and is intended to be an example of a prescriptive approach to hydrogen quality assurance.

C.2 Approaches to administration of Japanese quality control guidelines

The approach to conducting a quality analysis of the contaminants listed in ISO 14687-2 is to first consider the potential sources of contaminants, and, second, establish a protocol for analysing potential contaminants.

- Potential sources of contaminants:
  - sampling procedures;
  - characteristics of hydrogen production method(s);
  - characteristics of hydrogen transport method(s);
  - non-routine procedure (for example maintenance, major production system change).
- Analysis of possible contaminants:
  - possible quantification.

C.3 Hydrogen production methods, hydrogen purification methods and hydrogen transportation methods

C.3.1 Hydrogen production methods

Potential sources of contaminants are evaluated for the following hydrogen production methods:

- steam reforming (off-site/on-site);
- partial oxidation (off-site);
- autothermal reforming (off-site);
- water gas shift reaction (WGSR);
- catalytic reforming (off-site);
- coke-oven gas (COG) (off-site);
- steam cracking for ethylene by-product (off-site);
- chloralkali process (off-site);
- electrolysis of H_2O (on-site/off-site).

C.3.2 Hydrogen purification methods

Potential sources of contaminants are evaluated for the following hydrogen purification methods:

- adsorption;
- membrane separation;
- solvent absorption;
- cryogenic separation;
- methanation;
- selective CO oxidation.

C.3.3 Hydrogen transportation methods

Potential sources of contaminants are evaluated for the following hydrogen transportation methods:

- transportation of hydrogen in compressed state;
- transportation of hydrogen in liquid form;
- pipeline transportation;
- transportation by storage materials.

C.4 Constituents requiring analysis (potential sources of contaminants)

C.4.1 General

An analysis shall be conducted on constituents that may contaminate hydrogen regardless of which hydrogen production method is used, as well as those constituents that may contaminate hydrogen due to the unique nature of a given hydrogen production method (see Table C.1 and Table C.2).

C.4.2 All hydrogen production methods

Table C.1 — Constituents requiring an analysis for all production methods

Name of constituent	Hydrogen production method to be analysed	Approach
N_2	All hydrogen production methods	Perform an analysis on all production methods since there is a risk of contamination through the equipment in case of hydrogen sampling
O_2	All hydrogen production methods	Perform an analysis on all production methods since there is a risk of contamination through the equipment in case of hydrogen sampling
H_2O	All hydrogen production methods	Perform an analysis on all production methods since there is a risk of contamination through the equipment in case of hydrogen sampling
Ar	All hydrogen production methods	Perform an analysis on all production methods since there is a risk of contamination through the equipment in case of hydrogen sampling. The ISO standard specifies the limit as a total combined value of N_2 and Ar.

C.4.3 Specific hydrogen production methods

Table C.2 — Constituents requiring an analysis for specific production methods

Name of constituent	Hydrogen production method to be analysed	Approach
He	All hydrogen production methods using natural gas as feedstock	An analysis is necessary since natural gas contains up to 300 µmol/mol of He Exclude a hydrogen production method if He has been removed from the natural gas used for the method
NH_3	NH_3 production process generating excess hydrogen Biogas reforming Coal gasification generating hydrogen by-product NH_3 hydride method	
Halogens	Chloralkali process producing excess hydrogen* Biogas production from plastic waste generating hydrogen Coke oven gas Water electrolysis**	*Excludes ion exchange membrane method **Limited to cases where tap water is used as feedstock and the performance of H_2O purification system cannot be warranted
TS	Steam reforming* Catalytic reforming Partial oxidation Autothermal reforming Coal gasification generating hydrogen by-product Production methods using TS as odorant	*Since TS are found in the form of H_2S, analysis of H_2S, not total sulphur content, is sufficient
THC	Production methods in which fossil fuels are present, such as steam reforming, catalytic reforming, partial oxidation, autothermal reforming, and coal gasification generating hydrogen by-product	
CO	Steam reforming* Catalytic reforming Partial oxidation Autothermal reforming Coal gasification generating hydrogen by-product	
HCHO	Hydrogen production methods using city gas or petroleum as fuel other than steam reforming	Rationale for excluding steam reforming methods using city gas or petroleum: it has been verified that the thermo-equilibrium concentration of HCHO in steam reforming is significantly lower than the ISO limit
HCOOH	Hydrogen production methods using city gas or petroleum as fuel other than steam reforming	Rationale for excluding steam reforming methods using city gas or petroleum: it has been verified that the thermo-equilibrium concentration of HCOOH in steam reforming is significantly lower than the ISO limit

C.5 Constituents that do not require analysis

Listed below in Table C.3 are constituents for which there is no scientific basis for conducting a routine analysis, and the rationale for this conclusion, such as when there is no risk of contamination in any hydrogen production method (a framework shall be provided to conduct a non-routine analysis, however).

Table C.3 — Constituents that do not require an analysis

Substance	Rationale
Hydrogen	While it is clear that hydrogen is the main component, there is no method for directly determining its quantity to a required degree of accuracy. If the proportion of hydrogen is to be calculated by division, it would be necessary to determine the quantity of all contaminants.
All non-hydrogen gases	There is no method for directly determining their quantity. If the proportion of non-hydrogen gases is to be calculated by summation, a qualitative determination of all contaminants would be required.
Particulates	If a filter is installed in the flow path, contamination is highly unlikely. Generally speaking, particulates found at demonstration fuelling station have been lower than the standard upper limit by two digits. Particulates should be controlled as indicated in C.9

C.6 Administration of quality control

C.6.1 Frequency of routine analysis

C.6.1.1 Routine analysis at a centralized production and distribution facility

As a general rule, the product quality of a plant is consistent regardless of the size of its production system, as long as the input and the operating conditions are consistent. If there are no changes in the input and the operating conditions over a long period of time, only one quality analysis shall be needed per operation period. On the other hand, if there are changes in the input and the operating conditions, a quality analysis shall be needed for each condition.

When the input and the operating conditions have not changed and if it can be assured that the possibility of contamination is eliminated by the good operation and control of the distribution facility by, for example, continuously monitoring the indicator species before shipping, the test frequency may be reduced to as low as once per year.

C.6.1.2 Routine analysis at fuelling station

C.6.1.2.1 Off-site fuelling station

Hydrogen received by an off-site fuelling station is subject to a routine analysis for the chemical constituents that have not been covered by the centralized hydrogen production and distribution facility and for those that may infiltrate the gas after it is accepted by the fuelling station. For individual contaminant species that may enter after fuelling station acceptance, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of infiltration is deemed eliminated by having a good operation and control program at the fuelling station, such as a purge procedure.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fuelling nozzle to the extent that no changes occur to the quality of hydrogen.

C.6.1.2.2 On-site fuelling station

When a hydrogen generator (such as reformer or H_2O electrolysis apparatus) is operated in the daily start and shut mode, the quality of the hydrogen gas produced fluctuates on a daily basis. Such operation therefore calls for one analysis per day. However, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of infiltration is deemed eliminated by the good operation and control of the fuelling station, such as when accumulators are filled after the indicator species is continuously monitored for quality control on a daily basis following the start-up of the generator.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fuelling nozzle to the extent that no changes occur to the quality of hydrogen.

C.6.2 Frequency of non-routine analysis

After the conditions described in Clause 10, a quality analysis of all cases is needed.

C.7 Administration of analysis and monitoring records

C.7.1 Forms for analysis and monitoring records and reports

Each operator is to design and administer forms for records of analyses at its centralized production and distribution facilities, records of sampling and analyses at fuelling station, and records of monitoring.

C.7.2 Safekeeping and recording

Centralized production or distribution facilities and fuelling station are to safekeep their own records of analyses at the facility, of samples collected at the fuelling station, and of monitoring in an appropriate manner.

The records shall be kept for a period of ten years. Such records may be kept at the department (or headquarters) that oversees the operation other than the applicable facilities or fuelling station.

C.8 Routine analysis work

Table C.4 provides the routine analysis work defined on the basis of the attitudes stated in C.4, C.5 and C.6.1. The table gives the analytical species and the minimum analysis frequencies classified by hydrogen dispensing sites and hydrogen production, purification and transportation methods.

C.9 Non-routine analysis work

Table C.5 provides the non-routine analysis work defined on the basis of the attitudes stated in C.4, C.5 and C.6.2. The table gives the analytical species classified by hydrogen dispensing sites and hydrogen production, purification, and transportation methods.

C.10 Approaches to particulates requirements

According to ISO 14687-2, the requirements of particulates are no more than 1 mg/kg in concentration. The hydrogen shall be sampled from a dispenser nozzle of the fuelling station under conditions that are as close to the actual fuelling conditions as possible. The weight of the particulates collected in a filter is measured.

However, past analyses of particulates collected by filters at the fuelling station have demonstrated that particulates occur intermittently, and not always consistently, from such sources as pieces of sealing tapes for threaded parts, particles found in new equipment, and friction from movable parts. Therefore, it is questionable whether the concentration of the samples collected by the method described above can be considered representative of a given period of time. For this reason, filters shall be installed at fuelling station to remove particulates in lieu of conducting a routine analysis of particulate concentration levels.

It is appropriate to install filters with an aperture of no more than 5 µm (nominal) downstream of dispenser components. Filters should be as close as possible to the nozzle or hose breakaway device. Filters shall be mesh-type because of the filter robustness.

Table C.4 — Routine analysis work

Category: Distribution				
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Threshold** (μmol/mol)	**Reduced frequency**
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	TS[a]	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2+Ar	100	Annual[b,c]
		H_2O	5	Annual[b]
		O_2	5	Annual[b,c]
Electrolysis of Na Cl for hydrogen, purification, and distribution	Downstream of the purifier	Halogens	0,05	Annual[b]
		N_2+Ar	100	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]
Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		Halogens	0,05	Annual[b]
		N_2+Ar	100	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]
		NH_3	0,1	Annual[b]
		HCHO	0,01	Annual[b]
		HCOOH	0,2	Annual[b]
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2+Ar	100	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]

Table C.4 *(continued)*

Category: Fuelling station				
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Threshold** (µmol/mol)	**Reduced frequency**
With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor		Annual[b]
		N_2+Ar	100	Annual[b, c]
		H_2O	5	Annual[b,d]
		O_2	5	Annual[b,c]
With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)		Annual[b,e]
	End of nozzle	Those not analysed by the distributor		Annual[b]
		N_2+Ar	100	Annual[b,c]
		H_2O	5	Annual[b,d]
		O_2	5	Annual[b,c]
With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0,2	Continuous and Annual[b,f]
	End of nozzle	TS[a]	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2+Ar	100	Annual[b,c]
		H_2O	5	Annual[b,d]
		O_2	5	Annual[b,c]
With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	N_2+Ar	100	Annual[b]
		H_2O	5	Continuous and Annual[b,f]
		O_2	5	Continuous and Annual[b,f]
	End of nozzle	Halogens	0,05	Annual[b]
		N_2+Ar	100	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]

Table C.5 — Non-routine analysis work

Category: Distribution			
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Standard value** (µmol/mol)
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, or partial oxidation or ATR, followed by refinement	Downstream of the purifier	TS[5]	0,004
		THC as C1	2
		CO	0,2
		N_2+Ar	100
		H_2O	5
		O_2	5
Hydrogen production using brine electrolysis, followed by purification	Downstream of the purifier	Halogens	0,05
		N_2+Ar	100
		H_2O	5
		O_2	5
Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0,004
		THC as C1	2
		CO	0,2
		Halogens	0,05
		N_2+Ar	100
		H_2O	5
		O_2	5
		NH_3	0,1
		HCHO	0,01
		HCOOH	0,2
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0,004
		THC as C1	2
		CO	0,2
		N_2+Ar	100
		H_2O	5
		O_2	5

Table C.5 *(continued)*

Category: Fuelling station			
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Standard value** (µmol/mol)
With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor	
		N_2+Ar	100
		H_2O	5
		O_2	5
With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)	
	End of nozzle	Those not analysed by the distributor	
		N_2+Ar	100
		H_2O	5
		O_2	5
With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0,2
	End of nozzle	TS1)	0,004
		THC as C1	2
		CO	0,2
		N_2+Ar	100
		H_2O	5
		O_2	5
With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	H_2O	5
		O_2	5
	End of nozzle	Halogens	0,05
		N_2+Ar	100
		H_2O	5
		O_2	5

Annex D
(informative)

Typical hydrogen fuelling station supply chain

D.1 General

This annex describes the potential impurities in each step of the supply chain. An example of a typical fuelling station supply chain is given in Figure D.1.

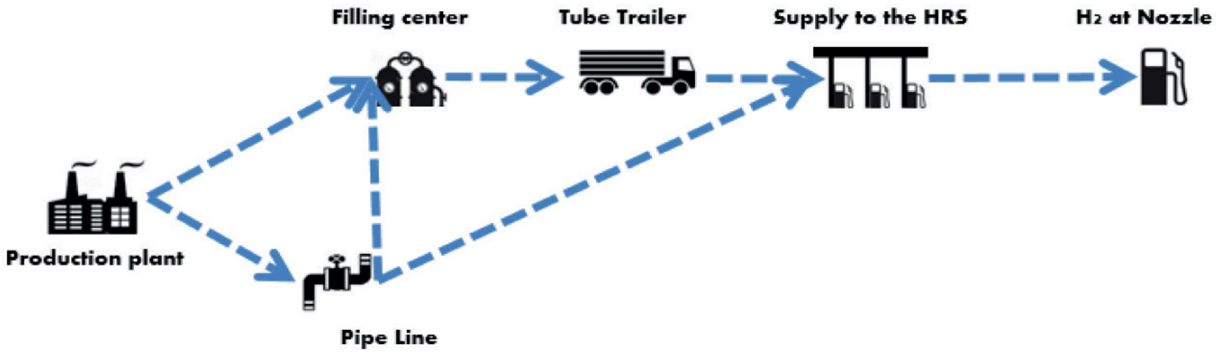

Figure D.1 — Example of a typical fuelling station supply chain

D.2 Production

D.2.1 General

The contaminants that may be introduced at production depend on the production technology and on the barriers and control implemented. Only gaseous impurities are considered in each production method subclause below. Particulates are considered separately in D.4. For Tables D.1 to D.6, the following definitions are used for the "possibility of impurity over threshold":

- Possible: The impurities have been observed during non-routine operation or fault conditions.
- Improbable: The impurities have not been observed during non-routine operation nor fault conditions.

D.2.2 Reforming

Reforming is the most common H_2 production method today. It uses various types of feedstocks, such as, natural gas, biogas, naphtha, methanol, and NH_3 (see Table D.1). The feedstock is usually converted into a synthetic gas (Syngas), and shift reacted to produce more H_2 and CO_2, then purified. The most common purification way is by pressure swing adsorption (PSA).

The contaminants potentially present in the hydrogen are dependent on the process technology and on the purification. It should be investigated on a case by case basis for each production source.

Annex B on centralized steam methane reforming (SMR) of natural gas with PSA purification gives an example on how to investigate the potential contaminants related to a very widely-used H_2 production route. Table D 1 is the result:

Table D.1 — Impurities potentially present in H_2 produced by SMR

Possibility of impurity over threshold	Gaseous impurities
Possible	N_2, CH_4, CO, He
Improbable	Ar, O_2, CO_2, H_2O, TS, NH_3, THC (except methane), HCOOH, Halogens, HCHO

D.2.3 Alkaline electrolysis

Alkaline electrolysis has been used for more than a century to produce H_2 from H_2O using electricity. The hydrogen produced at the anode is usually purified from the remaining O_2 through a catalytic reactor and then dried through a temperature swing adsorption (TSA). Table D.2 investigates the potential sources of contaminations. Such contaminants are mainly coming from the H_2O and the air.

Table D.2 — Impurities potentially present in H_2 produced by alkaline electrolysis

Possibility of impurity over threshold	Gaseous impurities
Possible	O_2, H_2O
Improbable	CO_2, CO, CH_4, He, N_2, Ar, TS, NH_3, THC, HCHO, HCOOH, Halogens

NOTE As per the rationale in ISO 14687-2 (see B.2), the presence of water soluble contaminants such as K+ and Na+, which could be present as an aerosol, can be controlled by process control of the level of water contamination precluding the presence of water in liquid form.

D.2.4 Proton exchange membrane electrolysis

PEM electrolysis is the electrolysis of H_2O in a cell equipped with a solid polymer electrolyte that is responsible for the conduction of protons, separation of product gases, and electrical insulation of the electrodes. Table D.3 investigates the potential sources of contaminants. Such contaminations are mainly coming from the H_2O and the air.

Table D.3 — Impurities potentially present in H_2 produced by PEM electrolysis

Possibility of impurity over threshold	Gaseous impurities
Possible	O_2, H_2O,
Improbable	CO_2, CO, CH_4, Ar, TS, N_2, NH_3, THC, HCHO, HCOOH, Halogens

D.2.5 By-products

Hydrogen may be obtained through purification of H_2 rich effluent by-product of chemical/petrochemical industry. Given the large variety of potential feeds to be purified and processes involved, a specific dedicated analysis should be carried out for each source to identify the potential contaminants and associated probabilities.

D.2.6 New production methods

There are a number of new production methods under investigation such as photoelectrolysis, algae, bacterial, etc. Each of them should be the object of a dedicated evaluation if the produced H_2 is used for the supply of a fuelling station.

D.3 Transportation

D.3.1 General

This clause relates to additional contaminants that may be introduced in the H_2 during transportation.

D.3.2 Pipeline

When transported in pipelines, H_2 is usually at relatively high pressure (>40 bar). Contamination can be due to intentional and unintentional causes (see Table D.4). An example of an intentional cause would be the "odorization" of the fuel. An example of an unintentional cause would be condensate.

During maintenance, the potential sources of contamination are:

- N_2 if insufficiently purged after maintenance;
- H_2O if insufficiently dried after maintenance.

Normal criteria for N_2 purging after maintenance is O_2 below 2 %. This is what is required for safety reasons before allowing to fill the system with H_2. If H_2 purging is done to reach 100 µmol/mol N_2 before putting into operation, the O_2 levels will be less than 2 µmol/mol. If improper purging occurs, and the O_2 levels exceed 5 µmol/mol, then the N_2 levels will be greater than 250 µmol/mol. This implies that the probabilities to exceed threshold due to poor purging are in the same order of magnitude for both O_2 and N_2.

Table D.4 — Impurities potentially introduced during Pipeline Transportation

Possibility of Impurity over threshold	Gaseous Impurities
Possible	N_2,O_2
Improbable	**CO_2, CO, CH_4, He, H_2O, TS, NH_3, THC, HCHO, HCOOH, Halogens**

D.3.3 Filling center and tube trailer

Filling center may be attached to a production site or to a pipeline network. They are used to fill gaseous pressurized tube trailers (see Table D.5). Contamination during normal operation is "Improbable".

During maintenance, the potential sources of contamination are:

- O_2 or N_2 if insufficiently purged after maintenance;
- H_2O if insufficiently dried after maintenance;
- if cutting oils are used during the process, contamination from sulphur, hydrocarbons, or halogenates is possible.

Normal criteria for N_2 purging after maintenance is O_2 below 2 %. This is what is required for safety reasons before allowing the system to fill with H_2.

Starting with a system containing N_2 with less than 2 % O_2, if H_2 purging is done to reach 100 µmol/mol N_2 before putting into operation, the O_2 levels will be less than 2 µmol/mol. If improper purging occurs, and the O_2 levels exceed 5 µmol/mol, then the N_2 levels will be greater than 250 µmol/mol. This implies that the probabilities to exceed the threshold due to poor purging are in the same order of magnitude for both O_2 and N_2.

Tube trailers may be filled at different sources. The risk of contamination due to the residual H_2 contained in a tube trailer coming from a different location is relevant at the considered fuelling station. This should be taken into account if necessary in the risk analysis.

Table D.5 — Impurities potentially introduced during centralized distribution and tube trailer transportation

Possibility of impurity over threshold	Gaseous impurities
Possible	N_2, O_2
Improbable	CO_2, CO, CH_4, He, H_2O, TS, NH_3, THC, HCHO, HCOOH, Halogens

D.4 Hydrogen fuelling station

Contamination during normal operation should be assessed with consideration of the technology used on a case by case basis (see Table D.6). During maintenance, the potential sources of contamination are:

— N_2, O_2, He (if used) if insufficiently purged after maintenance of fuelling station;

— H_2O if insufficiently dried after maintenance of the fuelling station or after shutdown of the precooling system where water can form ice upon restart;

— if oils or lubricants are used during the process, contamination from sulphur, hydrocarbons, or halogenates is possible.

Table D.6 — Impurities potentially introduced at fuelling station

Possibility of impurity over threshold	Gaseous impurities
Possible	N_2, O_2, He, THC, H_2O,
Improbable	TS, Halogens

D.5 Particulates

Particulates may enter the hydrogen at each level of the supply chain. By default, they should be considered as "possible" for each of them, except if specific design measures (filtering) permit to demonstrate the opposite. Particulates can include solid or liquid materials and can occur due to improper cleaning (metal burrs, cleaning fluid, etc.), abrasion, condensation, etc., especially in the fuelling station. Use of cutting oils during the process could lead to contamination particulates (construction debris if insufficiently cleaned after maintenance). The filter requirements are specified in ISO 19880-1.

Annex E
(informative)

Routine hydrogen quality analysis

E.1 Off-site production

The risk to have contaminants over the threshold depends on the production technology. Usually, contaminants which are critical for a given process are monitored on line either directly (analysers) or indirectly through the monitoring of process parameters which are directly related to the contaminant considered.

For each contaminant, the routine quality control should be defined depending on the process considered, the existing online monitoring, and the actual risk of contamination.

E.2 Transportation

E.2.1 Storage and transportation of compressed hydrogen

When hydrogen produced at a centralized production site is transported by compressing and filling it into transport cylinders, there is minimal risk that its components are altered by chemical reactions. However, one cannot rule out the possibility of contamination by residual or condensed contaminants that are present in the cylinders in the first place. This could occur with (for example) new cylinders or following an inspection. The quality assurance plan will take this into account and ensure the quality of delivered compressed gas hydrogen for all feedstocks by (for example) a routine analysis.

E.2.2 Storage and transportation of liquid hydrogen

When hydrogen is produced in a liquid state, any contaminant present in the gas before liquefaction will be trapped as solid deposit in the liquefaction process and not appear in the product gas (except He).

E.2.3 Pipeline transport

When hydrogen is transported via pipelines from a production facility, it is clear that, in general, there is no risk of contamination as demonstrated by the example of city gas transport. Therefore, in principle, no additional routine analyses are required within the pipelines.

E.3 Hydrogen fuelling station

E.3.1 Delivered hydrogen

Quality control for delivered hydrogen will be carried out following a quality assurance plan developed specifically for the supply chain of the hydrogen.

For individual contaminant species that may enter after delivery to the fuelling station, the frequency of analysis may be reduced, provided that the possibility of infiltration is deemed eliminated by having a good operation and control program at the fuelling station, such as a purge procedure.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fuelling nozzle to the extent that no changes occur to the quality of hydrogen. (See 6.1).

E.3.2 On-site hydrogen generation

On-site generation should require on-site quality control, whether by monitoring of specific analytes that can act as an indicator species for those contaminants considered to have potential to be present based on the type of on-site generation, or by other process control methodologies.

An example could be the monitoring of the differential pressure across an electrolyser membrane, or of the temperature of the hydrogen following a de-oxo catalyst system where this can be demonstrated to be adequate process control for the oxygen concentration within the hydrogen. If it is confirmed that the concentration of the indicator species of a given production method is less than its specified limit, other impurities are deemed to have met the standard requirements. For example, in the case of SMR and PSA production and purification, CO could serve as the indicator species.

E.3.3 Hydrogen fuelling station contaminants

Contaminants may be introduced at the fuelling station during installation, operation, and maintenance. The hydrogen quality control plan should include steps to mitigate these potential contaminants. The analysis immediately following installation or maintenance may be different than the analysis for routine operations. Both should be based upon the hydrogen quality control plan. A routine analysis of the potential contaminants generated by the fuelling station shall be performed, but may be reduced based upon the hydrogen quality control plan.

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Gaseous hydrogen — Fuelling stations —

Part 8:
Fuel quality control

AMENDMENT 1: Alignment with Grade D of ISO 14687

Hydrogène gazeux — Stations de remplissage —

Partie 8: Contrôle qualité du carburant

AMENDEMENT 1: Alignement avec le Grade D de l'ISO 14687

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Gaseous hydrogen — Fuelling stations —

Part 8:
Fuel quality control

AMENDMENT 1: Alignment with Grade D of ISO 14687

Clause 5, first paragraph

Replace the paragraph with the following:

> The quality requirements of hydrogen fuel dispensed to PEM fuel cells for road vehicles are listed in Grade D of ISO 14687.

8.4, first paragraph

Replace the paragraph with the following:

> It is necessary to evaluate the possible consequences on a fuel cell vehicle if any impurity exceeds the threshold value of ISO 14687 Grade D.

8.4, second paragraph

Replace the paragraph with the following:

> An estimation of the concentration above the ISO 14687 Grade D threshold values at which the severity increases (if applicable) is named “Level 1” and is given in column 5 for each impurity where the “severity class” is not already 4.

Table 4

Replace Table 4 with the following table:

Table 4 — Impact of impurities on fuel cell powertrain

Impurity		ISO 14687 Grade D threshold value[a] [µmol/mol]	Severity class (from ISO 14687 Grade D threshold value to Level 1)	Level 1 value [µmol/mol]	Severity class (greater than Level 1 threshold)
Total non-H_2 gases		300	UD [b]	UD [b]	4
Helium	He	300	UD [b]	UD [b]	4
Nitrogen	N_2	300	UD [b]	UD [b]	4
Argon	Ar	300	UD [b]	UD [b]	4
Oxygen	O_2	5	UD [c]	UD [c]	4
Carbon dioxide	CO_2	2	1	3	4
Carbon monoxide	CO	0,2	2-3[d]	1	4
Methane	CH_4	100	1	300	4
Water	H_2O	5	4	N/A	4
Total sulphur compounds	H_2S basis	0,004	4	N/A	4
Ammonia	NH_3	0,1	4	N/A	4
Total hydrocarbons except methane	CH_4 basis	2	1-4[d]	N/A	4
Formaldehyde	HCHO	0,2	2-3[d]	1	4
Formic acid	HCOOH	0,2	2-3[d]	1	4
Halogens		0,05	4	N/A	4
Maximum particulate concentration (liquid and solid) [e]		1 mg/kg	4	N/A	4

Key

UD: undetermined

N/A: not applicable

[a] The threshold value is according to hydrogen specification of Grade D of ISO 14687.

[b] The severity class (from ISO 14687 Grade D threshold value to Level 1) and Level 1 value for this impurity is undetermined because no specific study has been conducted yet in alignment with the new threshold value. It needs to be covered in the next edition of this document.

[c] The severity class (from ISO 14687 Grade D threshold value to Level 1) and Level 1 value for oxygen are undetermined because data are lacking to confirm those values. It needs to be covered in the next edition of this document.

[d] A higher value is to be considered for risk assessment approach until more specific data is available.

[e] Particulates are based upon mass density mg/kg.

A.15 first paragraph

Replace “ISO 14687-2” with “Grade D of ISO 14687” in the second last sentence.

Table B.1

Replace Table B.1 with the following table:

Table B.1 — Probability of occurrence for off-site SMR

Impurity	Threshold µmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Probability with barriers
Inert gas N_2	300	Present in natural gas and syngas PSA malfunction	— PSA — Double analysis PSA outlet <100 µmol/mol	UD [a]
Inert gas Ar	300	Only ATR and POx present in O_2 typical 0,6 % in syngas from ATR	— PSA. Not sized to remove Ar. Ar content may be higher if H_2 comes from ATR, POX or feeds with high Ar content	UD [a]
O_2	5	Not present in syngas. O_2 is unstable in the condition of reforming and shift reactions. Combines with H_2, CO, and CH_4	— PSA cannot be used with significant O_2 content for safety reasons	0
CO_2	2	Present in syngas (%)	— PSA adsorption strength of MS, activated carbon, silicagel higher for CO_2 than CO. A CO content lower than 10µmol/mol insures a CO_2 content lower than 2 µmol/mol	0
CO	0,2	Normal operation below threshold. Occasional peaks at µmol/mol level	— Double analysis at the PSA outlet + trip if the CO>1-10 µmol/mol at PSA outlet	4
CH_4	100	Present in syngas at % level	— In most cases CO is sizing the PSA, therefore CO<10 µmol/mol ==> C H_4 < 100 µmol/mol depending on users' specification (Europe pipeline 2 µmol/mol).	2
H_2O	5	Syngas saturated in H_2O	— PSA adsorbed in alumina and MS adsorption strength higher than CO_2. A CO content lower than 10 µmol/mol insures a H_2O content lower than 5 µmol/mol.	0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet.

Table B.1 *(continued)*

Impurity	Threshold µmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Probability with barriers
TS	0,004	TS from natural gas	— Desulphuration upstream reformer (typical values: normal < 10 ppb, maximum < 20 ppb, guarantee < 50 ppb) — Typical dilution factor 2,5 (1 mole natural gas produces 2,5 mole H_2) — Pre-reformer catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — Reformer catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — Shift catalyst poisoning by sulphur is irreversible. Sulphur trapped at this stage. In case of breakthrough, process condition cannot be achieved — PSA adsorption of H_2S before CO, CO_2, species — H_2S adsorption in pipe and vessels. Strong affinity with steel	0
NH_3	0,1	Traces present in syngas	— PSA adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10µmol/mol insures a NH_3 content lower than 0,1 µmol/mol	0
THC	2	Traces of C2+ after reforming reaction	— PSA C2 C3, C4, C5+adsorbed by activated carbon layer. A CO content lower than 10 µmol/mol insures a THC ($C H_4$ excluded) content lower than 2 µmol/mol	0
HCHO	0,2	May be present in syngas. essentially liquid	— PSA. Formaldehyde adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 µmol/mol insures a HCHO content lower than 0,1 µmol/mol. To guarantee 0,01 µmol/mol would require more experience of measuring at those levels	UD [a]
HCOOH	0,2	May be present in syngas essentially liquid	— PSA. Formic adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 µmol/mol insures a HCOOH content lower than 0,2 µmol/mol	0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet.

Table B.1 *(continued)*

Impurity	Threshold µmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Probability with barriers
Halogens	0,05	Present in natural gas	— Any Cl present in natural gas would be stopped by HDS — Pre-reformer catalyst poisoning by Cl irreversible Cl trapped at this stage. If breakthrough, process condition cannot be achieved — Reformer catalyst poisoning by Cl irreversible. Cl trapped at this stage I break through, process condition cannot be achieved — Shift catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved — PSA adsorption of Cl before CO, CO_2, species	0
He	300	Not present in natural gas in N Europe (<10 µmol/mol). Passes through the whole process. Dilution factor 2,5		0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet.

Table B.2

Replace Table B.2 with the following table:

Table B.2 — Probability of occurrence for pipeline

Impurity	Threshold µmol/mol	Causes possible For the item studied	Typical barriers employed in this process	Probability with barriers
Inert gas N_2	300	Air intake if some areas are at negative pressure From seal gas or purge gas Wrong purging after maintenance	Inlet pressure PSL trip on compressors	UD [a]
Inert gas Ar	300	No potential	1 % Ar in the air. 100 µmol/mol would mean 1 % air in the pipe Never been observed	UD [a]
O_2	5	Air intake if some areas are at negative pressure	Inlet pressure PSL trip on compressors	1
CO_2	2	From Air: CO_2 at 400 µmol/mol in the air	2 µmol/mol of C O_2 would mean 0,5 % air in the pipe Never been observed	0
CO	0,2	No potential		0
CH_4	100	No potential		0
H_2O	5	Wrong drying after pressure hydraulic test	H_2 > 40 bar ==> leak from H_2O to H_2 unlikely during operation.	0
TS	0,004	No potential		0
NH_3	0,1	No potential		0
THC	2	No potential		0
HCHO	0,2	No potential		UD [a]
HCOOH	0,2	No potential		0
Halogens	0,05	From cleaning material after maintenance		1
He	300	No potential		0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet. It needs to be covered in the next edition of this document.

Table B.3

Replace Table B.3 with the following table:

Table B.3 — Probability of occurrence for fuelling station to be source of impurities

Impurity	**Threshold** µmol/mol	**Causes possible For the source studied**	**Existing barriers**	**Probability**
Inert gas N_2	300	N_2 purging operation, air intake during normal operation or maintenance		UD [a]
Inert gas Ar	300	Air intake during normal operation or maintenance	1 % Ar in the air. 100 µmol/mol would mean 1 % air in the fuelling station Never been observed	UD [a]
O_2	5	Air intake during normal operation or maintenance		2
CO_2	2	Air intake during normal operation or maintenance	2 µmol/mol CO_2 would mean 0,5 % air in the fuelling station. Never been observed	0
CO	0,2	No potential at fuelling station level		0
CH_4	100	No potential at fuelling station level		0
H_2O	5	Maintenance, leaks from compressor exchangers, improper pressure vessel drying after periodic inspection, H_2O coming from the vent in case of check valve malfunction, depending on fuelling station/compressor technology		2
TS	0,004	Materials gaskets, valve seats and tubing	Material specifications	1
NH_3	0,1	No potential		0
THC	2	Oil carryover from compressor (depending on compressor technology)		2
HCHO	0,2	No potential		UD [a]
HCOOH	0,2	No potential		0
Halogens	0,05	From degreasing material		1
He	300	No potential at fuelling station level	If pure He is not used for maintenance	0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet. It will be covered in the next edition of this document.

Table B.4

Replace Table B.4 with the following table:

Table B.4 — Combined risk assessment

ISO specification		Supply chain probability							Residual			
Impurity	**Threshold** µmol/mol	**Production SMR**	**Pipeline distribution**	**Fuelling station**	**Compounded probability**	**Severity**	**Criticality**	**Additional risk reduction measures**	**Severity reduction measures**	**Probability**	**Severity**	**Criticality**
Inert gas N_2	300	UD [a]	UD [a]	UD [a]	**UD** [a]	**UD** [a]	**UD** [a]	Systematic N_2 analysis after shutdown before resuming operation or specific purging procedure	None	UD [a]	UD [a]	**UD** [a]
Inert gas Ar	300	UD [a]	UD [a]	UD [a]	**UD** [a]	**UD** [a]	**UD** [a]		None	UD [a]	UD [a]	**UD** [a]
O_2	5	0	1	2	**2**	**UD** [b]	**UD** [b]		None	2	**UD** [b]	**UD** [b]
CO_2	2	0	0	0	**0**	**1**	**+**		None	0	1	**+**
CO	0,2	4	0	0	**4**	**2**	*	CO absorber at fuelling station design margin 100 % + operation procedure for replacement when H_2 quantity purified = 50 % of design capacity.	None	1	2	**+**
CH_4	100	2	0	0	**2**	**1**	**+**		None	2	1	**+**
H_2O	5	0	0	1	**1**	**4**	*	Check H_2O at commissioning and after maintenance involving opening of vessels or piping. Measurement shall be done at appropriate location downstream of the considered vessel or piping	None	0	4	**+**
TS	0,004	0	0	1	**1**	**4**	*	Check TS at commissioning and after maintenance involving parts modification (piping, valves, seals, gaskets). Not required for part replaced by identical component	None	0	4	**+**
NH_3	0,1	0	0	0	**0**	**4**	**+**		None	0	4	**+**

Key

UD: undetermined

[a] The probability of occurrence, the severity and the criticality for this impurity are undetermined because no specific study has been conducted yet. It needs to be covered in the next edition of this document.

[b] The severity and the criticality for oxygen are undetermined because data are lacking to confirm those values.

Table B.4 *(continued)*

ISO specification		Supply chain probability							Residual			
Impurity	**Threshold** µmol/mol	**Production SMR**	**Pipeline distribution**	**Fuelling station**	**Compounded probability**	**Severity**	**Criticality**	**Additional risk reduction measures**	**Severity reduction measures**	**Probability**	**Severity**	**Criticality**
THC	2	0	0	2	**2**	**4**	**+**	Oil/grease cleaning at commissioning and after maintenance. Compressor surveillance depending on compressor technology (coalescing filter) THC analysis or commissioning and after maintenance	None	0	4	**+**
HCHO	0,2	UD [a]	UD [a]	UD [a]	UD [a]	UD [a]	UD [a]		None	UD [a]	UD [a]	**UD** [a]
HCOOH	0,2	0	0	0	**0**	**2**	**+**		None	0	2	**+**
Halogens	0,05	0	0	1	**1**	**4**	*	Halogenated analysis at commissioning (species shall be defined) or after maintenance	None	0	4	**+**
He	300	0	0	0	**0**	**4**	**+**		None	0	4	+
Key				+ Acceptable risk area: existing controls sufficient			o Further investigation is needed: existing barriers or control may not be enough		* Unacceptable risk; additional control or barriers required			

Key

UD: undetermined

[a] The probability of occurrence, the severity and the criticality for this impurity are undetermined because no specific study has been conducted yet. It needs to be covered in the next edition of this document.

[b] The severity and the criticality for oxygen are undetermined because data are lacking to confirm those values.

Table B.5

Replace Table B.5 with the following table:

Table B.5 — Probability of occurrence for alkaline electrolysis

Impurity	**Threshold** μmol/mol	**Possible causes For the source studied**	**Typical barriers employed in this process**	**Probability**
Inert gas N_2	300	Insufficient purging after shutdown	Electrolyser process control	UD [a]
Inert gas Ar	300	Insufficient purging after shutdown	If N_2 below 1 %, Ar < 100 μmol/mol	UD [a]
O_2	5	Insufficient purging after shutdown (does not apply to all systems) O_2 permeation through the membrane	Process control Deoxo O_2 sensor	2
CO_2	2			0
CO	0,2			0
$C H_4$	100			0
H_2O	5	H_2 from electrolyser is saturated.	Dryer plus water sensor downstream of electrolyser	2
TS	0,004			0
NH_3	0,1			0
THC (excluding CH_4)	2			0
HCHO	0,2			UD [a]
HCOOH	0,2			0
Halogens	0,05	Cl from water?	Any trace of halogenated compounds would be trapped in the dryer which has a stronger adsorption capacity for Cl than for H_2O	0
He	300			0

Key

UD: undetermined

[a] The probability of occurrence for this impurity is undetermined because no specific study has been conducted yet in alignment with the new threshold value. It needs to be covered in the next edition of this document.

C.2 first paragraph

Replace “ISO 14687-2” with “Grade D of ISO 14687”.

C.10 first paragraph

Replace “ISO 14687-2” with “Grade D of ISO 14687”.

Table C.4

Replace Table C.4 with the following table:

Table C.4 — Routine analysis work

Category: Distribution				
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Threshold** (µmol/mol)	**Reduced frequency**
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	TS[a]	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2	300	Annual[b, c]
		Ar	300	Annual[b, c]
		H_2O	5	Annual[b]
		O_2	5	Annual[b, c]
Electrolysis of NaCl for hydrogen, purification, and distribution	Downstream of the purifier	Halogens	0,05	Annual[b]
		N_2	300	Annual[b]
		Ar	300	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]
Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		Halogens	0,05	Annual[b]
		N_2	300	Annual[b]
		Ar	300	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]
		NH_3	0,1	Annual[b]
		HCHO	0,2	Annual[b]
		HCOOH	0,2	Annual[b]
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2	300	Annual[b]
		Ar	300	Annual[b]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]

[a] Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis.

[b] The minimum frequency of the analysis is premised on the combination of continuous analysis of the indicator species (CO for hydrocarbon cracking and O_2/H_2O for water electrolysis) and proper operation controls to make sure no mixing of impurities will occur. If that premise is not satisfied, the analysis shall be carried out once a day.

[c] If a container or piping maintenance has not been opened to air or purged since the last hydrogen analysis, it is not necessary for analysis

[d] If the 5 ppm (dew point of -66 °C or less) are satisfied by routine management, there is no need for analysis.

[e] If the hydrogen on a pipeline contains odorant, the odorant shall be analysed with minimum frequency of once a year.

[f] The batch analysis once a year is needed even if a continuous analysis is performed.

Table C.4 *(continued)*

Category: Fuelling station				
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Threshold (µmol/mol)**	**Reduced frequency**
With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor		Annual[b]
		N_2	300	Annual[b, c]
		Ar	300	Annual[b, c]
		H_2O	5	Annual[b, d]
		O_2	5	Annual[b, c]
With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)		Annual[b, e]
	End of nozzle	Those not analysed by the distributor		Annual[b]
		N_2	300	Annual[b, c]
		Ar	300	Annual[b, c]
		H_2O	5	Annual[b, d]
		O_2	5	Annual[b, c]
With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0,2	Continuous and Annual[b, f]
	End of nozzle	TS[a]	0,004	Annual[b]
		THC as C1	2	Annual[b]
		CO	0,2	Annual[b]
		N_2	300	Annual[b, c]
		Ar	300	Annual[b, c]
		H_2O	5	Annual[b, d]
		O_2	5	Annual[b, c]
With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	N_2	300	Annual[b, c]
		Ar	300	Annual[b, c]
		H_2O	5	Continuous and Annual[b, f]
		O_2	5	Continuous and Annual[b, f]
	End of nozzle	Halogens	0,05	Annual[b]
		N_2	300	Annual[b]
		Ar	300	Annual[b, c]
		H_2O	5	Annual[b]
		O_2	5	Annual[b]

[a] Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis.

[b] The minimum frequency of the analysis is premised on the combination of continuous analysis of the indicator species (CO for hydrocarbon cracking and O_2/H_2O for water electrolysis) and proper operation controls to make sure no mixing of impurities will occur. If that premise is not satisfied, the analysis shall be carried out once a day.

[c] If a container or piping maintenance has not been opened to air or purged since the last hydrogen analysis, it is not necessary for analysis

[d] If the 5 ppm (dew point of -66 °C or less) are satisfied by routine management, there is no need for analysis.

[e] If the hydrogen on a pipeline contains odorant, the odorant shall be analysed with minimum frequency of once a year.

[f] The batch analysis once a year is needed even if a continuous analysis is performed.

Table C.5

Replace Table C.5 with the following table:

Table C.5 — Non-routine analysis work

Category: Distribution			
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Standard value** (µmol/mol)
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, or partial oxidation or ATR, followed by refinement	Downstream of the purifier	TS[a]	0,004
		THC as C1	2
		CO	0,2
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
Hydrogen production using brine electrolysis, followed by purification	Downstream of the purifier	Halogens	0,05
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0,004
		THC as C1	2
		CO	0,2
		Halogens	0,05
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
		NH_3	0,1
		HCHO	0,2
		HCOOH	0,2
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0,004
		THC as C1	2
		CO	0,2
		N_2	300
		Ar	300
		H_2O	5
		O_2	5

[a] Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis.

Table C.5 *(continued)*

Category: Fuelling station			
Facility type	**Sampling/ Monitoring point**	**Contaminant**	**Standard value** (μmol/mol)
With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor	
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)	
	End of nozzle	Those not analysed by the distributor	
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0,2
	End of nozzle	TS[a]	0,004
		THC as C1	2
		CO	0,2
		N_2	300
		Ar	300
		H_2O	5
		O_2	5
With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	H_2O	5
		O_2	5
	End of nozzle	Halogens	0,05
		N_2	300
		Ar	300
		H_2O	5
		O_2	5

[a] Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis.

D.2.3, NOTE

Replace “As per the rationale in ISO 14687-2 (see B.2)” with “As per the rationale for water (see A.7)”.

Bibliography

Replace the reference to ISO 14687-2 with:

[1] ISO 14687, *Hydrogen fuel — Product specification*

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New Zealand Standard

Public consultation draft

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Committee representation

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New Zealand Standard

Gaseous hydrogen − Land vehicle fuel containers

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the material, design, manufacture, marking, and testing of serially produced, refillable containers intended only for the storage of compressed hydrogen gas for land vehicle operation.

These containers:
(a) Are permanently attached to the vehicle; and
(b) Have up to 1 000 litres' water capacity; and
(c) Have a nominal working pressure that does not exceed 70 MPa.

The scope of this document is limited to fuel containers containing fuel-cell-grade hydrogen according to ISO 14687 *Hydrogen fuel quality − Product specification* for fuel cell land vehicles, and Grade A or better hydrogen as per ISO 14687 for internal combustion engine land vehicles.

This document also contains requirements for hydrogen fuel containers acceptable for use aboard light-duty vehicles, heavy-duty vehicles, and powered industrial trucks, such as forklifts and other material handling vehicles.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 19881:2018 *Gaseous hydrogen – Land vehicle fuel containers.*

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INTERNATIONAL
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Gaseous hydrogen — Land vehicle fuel containers

Hydrogène gazeux — Réservoirs de carburant pour véhicules terrestres

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Contents

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee TC 197, *Hydrogen technologies*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to promote the implementation of hydrogen powered land vehicles through the creation of performance based testing requirements for compressed hydrogen fuel containers. The successful commercialization of hydrogen land vehicle technologies requires standards pertaining to fueling stations, vehicle fuel system components and the global homologation of standards requirements for technologies with the same end use. This will allow manufacturers to achieve economies of scale in production through the ability to manufacture one product for global use.

This document is based on the CSA Standard ANSI/HGV 2-2014.

Gaseous hydrogen — Land vehicle fuel containers

1 Scope

This document contains requirements for the material, design, manufacture, marking and testing of serially produced, refillable containers intended only for the storage of compressed hydrogen gas for land vehicle operation. These containers

a) are permanently attached to the vehicle,

b) have a capacity of up to 1 000 l water capacity, and

c) have a nominal working pressure that does not exceed 70 MPa.

The scope of this document is limited to fuel containers containing fuel cell grade hydrogen according to ISO 14687 for fuel cell land vehicles and Grade A or better hydrogen as per ISO 14687 for internal combustion engine land vehicles. This document also contains requirements for hydrogen fuel containers acceptable for use on-board light duty vehicles, heavy duty vehicles and industrial powered trucks such as forklifts and other material handling vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 306, *Plastics — Thermoplastic Materials — Determination of Vicat Softening Temperature (VST)*

ISO 7866:2012, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

ISO 9809-1:2010, *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 9809-2:2010, *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 11439:2013, *Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles*

ISO 19078:2013, *Gas cylinders — Inspection of the cylinder installation, and requalification of high pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles*

ISO 19882, *Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D2344/D2344M-00, *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*

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

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

ASTM D4138, *Standard Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive, Cross Sectioning Means*

ASTM D4814, *Standard Specification for Automotive Spark-Ignition Engine Fuel*

ASTM D7091, *Standard Practice for Nondestructive Measurement of Fry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals*

ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM G154-12, *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*

CGA C-1-2009, *Methods for Pressure Testing Compressed Gas Cylinders*

CGA C-6.4, *Methods for External Visual Inspection of Natural Gas Vehicle (NGV) and Hydrogen Gas Vehicle (HGV) Fuel Containers and Their Installations*

SAE J2579:2013, *Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles*

SAE J2601, *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*

UN GTR No. 13, *UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

3.1
autofrettage
pressure application procedure, used in manufacturing composite containers with metal *liners* (3.14), which strains the *liner* (3.14) past its yield point sufficiently to cause permanent plastic deformation that results in the *liner* (3.14) having residual compressive stresses and the fibers having residual tensile stresses at zero internal pressure

3.2
burst pressure
highest pressure reached in a container during a burst test

3.3
composite
filament and resin system

3.4
container category
unique class of containers that are intended for a specific usage

3.4.1
Category A
class of containers that are intended to be used in light duty and heavy duty land vehicle applications, regardless of the potential for further qualification to the UN GTR No. 13 for hydrogen and fuel cell vehicles

3.4.2
Category B
class of *Type 4* (3.5.4) containers of 70 MPa nominal working pressure that are intended to be further qualified in accordance with the UN GTR No. 13 for hydrogen and fuel cell vehicles with a gross vehicle mass of 4 536 kg or less

3.4.3
Category C
class of containers that are intended to be used on hydrogen powered industrial trucks

3.5 Container type

3.5.1
Type 1
metal container

3.5.2
Type 2
container which contains a metal *liner* (3.14) reinforced with a resin impregnated continuous filament (hoop-wrapped)

Note 1 to entry: See 3.11.

3.5.3
Type 3
container which contains a metal *liner* (3.14) reinforced with a resin impregnated continuous filament (fully-wrapped)

Note 1 to entry: See 3.10.

3.5.4
Type 4
container which contains a resin impregnated continuous filament with a nonmetallic *liner* (3.14) (all composite)

Note 1 to entry: See 3.3.

3.6
design family
group of containers consisting of one fully qualified design and variations on that design that comply with Table 6

3.7
destroyed
in a state of alteration which makes a container physically unusable for its purpose

3.8
dry hydrogen
hydrogen which meets or exceeds the quality level in ISO 14687

3.9
fold
place where two material flows meet in such a manner as to create a sharp visual groove

3.10
full-wrapped
reinforced by a *composite* (3.3) material applied over the entire *liner* (3.14) including the domes

3.11
hoop-wrapped
reinforced by a *composite* (3.3) material applied in a substantially circumferential pattern over the cylindrical portion of the *liner* (3.14) so that the filament does not transmit any significant stresses in a direction parallel to the container longitudinal axis

3.12
leakage
release of contents through a defect or crack

3.13
leak test gas
gas for testing leaks that consists of *dry hydrogen* (3.8), dry helium or blends that contain these gases at a detectable level

Note 1 to entry: Use leak test gas in 9.3.

3.14
liner
inner gas tight container or gas container to which the overwrap is applied

3.15
maximum fueling pressure
MFP
maximum pressure applied to a compressed system during fueling

Note 1 to entry: The maximum fueling pressure is 125 % of the *nominal working pressure* (3.18).

3.16
minimum required burst pressure
minimum *burst pressure* (3.2) that is to be met during a burst test and which is needed to demonstrate the required *stress ratio* (3.26)

3.17
normal cubic centimeter
Ncc
dry gas that occupies a volume of 1 cm^3 at a temperature of 273,15 K (0 °C) and an absolute pressure of 101,325 kPa (1 atm)

3.18
nominal working pressure
container pressure, as specified by the container manufacturer, at a uniform gas temperature of 15 °C and full gas content

3.19
permanently attached
intended to remain fixed to a particular vehicle for the lifetime of the container or vehicle, whichever comes first

3.20
permeation
diffusion of the gaseous contents to the atmosphere at a molecular level, by means of pores or molecular gaps

3.21 Pressures

3.21.1
autofrettage pressure
pressure to which a container is taken with the intent of yielding the *liner* (3.14) or inner surface of the container

Note 1 to entry: The autofrettage operation is considered to be part of the manufacturing operation and is conducted prior to proof testing.

3.21.2
fill pressure
pressure attained at the actual time of filling

Note 1 to entry: Fill pressure varies according to the gas temperature in the container, which is dependent on the filling parameters and the ambient conditions. The maximum fill pressure should not exceed 125 % of the *nominal working pressure* (3.18).

3.21.3
hydrostatic pressure
pressure to which a container is taken during acceptance testing

Note 1 to entry: See 17.3.5.

3.22
pressure relief device
PRD
device that, when activated under specified performance conditions, is used to vent the container contents

3.23
rejectable damage
damage as outlined in ISO 19078 or CGA C-6.4 and in agreement with the container manufacturer's recommendations

3.24
rupture
sudden and unstable damage propagation in the structural components of the container resulting in loss of contents

3.25
settled temperature
uniform gas temperature after any change in the temperature caused by filling has dissipated

3.26
stress ratio
minimum ultimate strength of the fiber, as determined in pressure container burst tests, divided by the stress in the fiber at the *nominal working pressure* (3.18)

4 Service conditions

4.1 General

4.1.1 Standard service conditions

The standard service conditions specified herein are provided as a basis for the design, manufacture, inspection, testing and approval of containers that are to be mounted permanently on vehicles and used to store compressed hydrogen for use as a fuel on-board the vehicles. Containers are intended to be installed on vehicles in accordance with SAE J2578, SAE J2579, IEC 62282-4-101, UN GTR No. 13, or other equivalent standards.

4.1.2 Category

Category A, Category B and Category C containers are intended to provide a sufficient level of safety for the intended application, but test methods and records are different.

4.1.3 Service life

The service life for the containers shall be specified by the container manufacturer. The specified life shall not be less than 10 years or greater than 25 years as defined in 4.3.

4.1.4 Periodic in-service inspections

Any requirements and procedures for periodic re-qualification by inspection or testing during the service life shall be specified by the container or vehicle manufacturer on the basis of use under the service conditions specified herein. For containers that require periodic re-qualification by inspection or testing, the container label shall identify this requirement according to Clause 15. Guidance on periodic inspection is included in Annex A.

4.2 Pressures

4.2.1 Nominal working pressures

This document applies to containers that have a nominal working pressure, as specified by the container manufacturer, of 25 MPa, 35 MPa, 50 MPa or 70 MPa at 15 °C, hereinafter referred to in this document as the following:

a) “H25” — 25 MPa;

b) “H35” — 35 MPa;

c) “H50” — 50 MPa;

d) “H70” — 70 MPa.

4.2.2 Maximum pressures

Containers are designed to be filled to a pressure not exceeding any of the following conditions:

a) A pressure that would settle to the nominal working pressure at a settled temperature of 15 °C. The fill pressure shall be temperature compensated to prevent pressures from exceeding the maximum pressures that are defined.

b) Normally up to 125 % of the nominal working pressure immediately after filling, regardless of the gas temperature, and infrequently up to 150 % under dispenser fault conditions.

4.3 Maximum number of filling cycles

Containers are designed to be filled to pressures not exceeding the requirements of 4.2.2, as follows:

a) Category A:

For a maximum of 750 times the service life of the container in years for a minimum of 10 years and a maximum of 25 years.

b) Category B:

For a maximum of 5 500, 7 500, or 11 000 for a 15 year service life.

c) Category C:

For a maximum of 1 125 times the service life of the container in years for a minimum of 10 years and a maximum of 25 years.

NOTE 1 Refer to D.3, D.4, and D.5 for the rationale on container fill cycles.

NOTE 2 Containers are expected to be removed from service when the service life used in the design qualification has expired, consistent with the labelling requirements in Clause 15.

4.4 Temperature range

4.4.1 Settled gas temperatures

Settled temperature of the gas in containers may vary from −40 °C to 85 °C.

4.4.2 Container temperatures

The temperature of the container materials may vary from −40 °C to 85 °C.

4.4.3 Transient gas temperatures

Transient gas temperatures (temperatures that would be insufficient to change the bulk temperature of the liner material) during filling and discharge may vary beyond the limits described in 4.4.1. Containers qualified to meet this document shall be capable of being filled safely utilizing SAE J2601 fueling protocol or an equivalent fueling protocol.

4.4.4 Test temperatures

Unless otherwise specified, all tests shall be conducted at an ambient temperature of 20 °C ± 5 °C.

4.5 Gas composition

Containers made according to this document are designed to be used with hydrogen fuel complying with ISO 14687 or SAE J2719. Containers made according to this document can also be used for hydrogen road vehicles with hydrogen fuel (Type I Grade A) complying with ISO 14687.

4.6 External surfaces

Container external surfaces shall be designed to be resistant to environmental conditions outlined in 17.3.3.

4.7 Installation requirements

The container manufacturer shall provide information to the vehicle manufacturer or system integrator as necessary to support proper installation in the vehicle.

The vehicle manufacturer or system integrator shall be responsible for the protection of the container, container valves, pressure relief devices and connections as required.

If this protection is mounted to the container, the design and method of attachment shall be approved by the container manufacturer. Factors to be considered include the ability of the container to support the transferred impact loads and the effect of local stiffening on container stresses and fatigue life.

Containers shall be protected from accidental cargo spillage and from mechanical damage. This document contains no requirements for container integrity in a vehicle collision. Container locations and mountings should be designed to provide adequate impact protection to prevent container failure in a collision.

5 Compliance

Compliance shall be required in all details, without exception. If there is evidence of a fault in carrying out a test or an error in measurement, another test shall be performed. If the results of this test are satisfactory, the results of the prior test shall not be a basis for rejection.

6 Material qualification tests and requirements

6.1 General

All structural materials shall be traceable to their original manufacturer's certified test reports. The materials shall be of uniform quality. Materials not in compliance with the original manufacturer's design specifications are not authorized.

Table 1 summarizes specific material tests that are required herein subsequently.

Table 1 — Material tests

Material tests	Clause	Material type	Container type			
			1	2	3	4
Impact test	6.3.2	Steel	•	•	•	•
Tensile test	6.3.3	Metals	•	•	•	•
Sustained load cracking test	6.3.4	Aluminum	•	•	•	•
Corrosion test	6.3.5	Aluminum	•	•	•	•
Ultraviolet resistance test	6.4	External coatings	•	•	•	•
Shear strength test	6.6	Resins		•	•	•
Glass transition temperature test	6.6	Resins		•	•	•
Tensile test	6.7	Nonmetallic liners				•
Softening temperature test	6.7	Nonmetallic liners				•
Tensile test	9.3	Nonmetallic liner welds				•

6.2 Material requirements

Materials normally in contact with hydrogen shall be determined to be acceptable in hydrogen service, with the consideration of hydrogen embrittlement and hydrogen accelerated fatigue. The performance tests cannot guarantee that all cases and conditions of hydrogen service will be validated, so it is still incumbent on the container manufacturer to carefully screen materials of construction for their intended use. The materials and design shall be such that there will be no significant change in the functioning of the container, deformation or mechanical change in the container, and no harmful corrosion, deformation or deterioration of the materials when subject to the service conditions provided in Clause 4.

NOTE Material performance data and/or acceptance criteria in hydrogen environments can be found in the ISO 11114 series, the Sandia National Laboratory Technical Reference for Hydrogen Compatibility of Materials or ANSI/AIAA G-095, ANSI/CSA CHMC 1, ASME B31.12, and SAE J2579:2013, Appendix B.

Nonmetallic materials normally in contact with hydrogen shall be verified to be acceptable in hydrogen service. Consideration shall be given to the fact that hydrogen diffuses through these materials more easily than through metals; therefore, the suitability of materials shall be verified. Nonmetallic materials shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of service conditions and lifetime as specified by the container manufacturer. Materials shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation. The chemical and physical properties necessary for operational safety shall not be significantly affected within the scheduled lifetime of the equipment unless a replacement is foreseen; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, aging resistance, the effects of temperature variations, the effects arising when materials are put together (for example, galvanic corrosion), the effects of ultraviolet radiation and the degradation effects of hydrogen on the mechanical performance of a material.

6.3 Metal containers and metal liners

6.3.1 Material properties

Steels shall be aluminum killed and produced to predominantly fine grain practice. The container manufacturer shall demonstrate that exposure to high-pressure hydrogen under the service conditions provided in Clause 4 does not cause any harmful corrosion, deformation, or deterioration of the material. The chemical composition of all steels shall be declared and defined at least by

a) carbon, manganese, aluminum and silicon content in all cases, and

b) nickel, chromium, molybdenum, boron, vanadium or any other elements that are deliberately added.

Aluminum alloys shall be quoted in line with the Aluminum Association practice for a given alloy system. The impurity limit for bismuth in any aluminum alloy shall not exceed 0,003 %. Aluminum alloys 6351 and 6082 shall not be used.

6.3.2 Impact test for steel

The impact properties of the steel in the finished container or liner shall be determined in general accordance with ISO 148-1 or ASTM E23. The impact test pieces shall be taken from the wall of the container in the transverse direction. The notch plane orientation shall be in the C-L direction (i.e., perpendicular to the circumference and along the length). Test pieces with a width of less than 5 mm shall be taken from the longitudinal direction. If the wall thickness does not permit a final test piece width of 10 mm, the width shall be as near as practicable to the nominal thickness of the container wall. All impact tests shall be conducted at −40 °C. Impact values shall not be less than that indicated as follows:

Width of the test piece	(mm)	5,0 ≤ width < 7,5	7,5 ≤ width < 10,0
Impact strength	(J/cm^2)	35	40

a) Impact values for test pieces of width less than 5 mm shall be based on special studies of particular materials and particular specimens.

b) Required average results of three specimens.

c) Not more than one specimen shall break at less than the average value required and no single specimen shall break at less than 80 % of the average value.

6.3.3 Tensile tests for metals

Tensile strength methods shall be according to the Test Methods of ASTM E8/E8M, and shall meet the requirements of the designs. Alternatively, tensile tests shall be carried out in accordance with ISO 9809-1 for steels, and ISO 7866 for aluminum.

6.3.4 Sustained load cracking (SLC) test for aluminum alloys

The resistance to SLC shall be determined in accordance with ISO 7866:2012, Annex B and shall meet the requirements therein.

6.3.5 Corrosion tests for aluminum alloys

Corrosion tests for aluminum alloys shall be carried out in accordance with ISO 7866:2012, Annex A and shall meet the requirements therein.

6.4 Ultraviolet resistance of external coatings

Protective coatings required to meet 17.3.3 shall be evaluated for resistance to ultraviolet effects using a minimum 1 000 h exposure using a UVA 340 lamp in accordance with ASTM G154. Evidence of blistering, cracking, chalking or softening shall be a cause for rejection.

6.5 Fibers

Structural reinforcing filament material types shall be glass fiber, aramid fiber, carbon fiber or mixtures or hybrids thereof. If carbon fiber reinforcement is used, the design shall incorporate means to prevent galvanic corrosion of metallic components of the fuel container.

6.6 Resins

The material for impregnation may be thermosetting or thermoplastic resin. Examples of suitable matrix materials are epoxy, modified epoxy, polyester and vinylester thermosetting plastics, and polyethylene and polyamide thermoplastic material. Resin system materials shall be tested on a sample test panel, representative of the composite overwrap, in accordance with ASTM D2344. Following a 24 h water boil, the composite shall have a minimum shear strength of 13,8 MPa.

Resin system materials shall have a glass transition temperature (Tg) of at least 20 °C above the maximum container temperature (i.e ≥105 °C). The glass transition temperature of resin materials shall be determined in accordance with ASTM D3418.

NOTE There is safe container operation experience at Tg at least 20 °C above the maximum container temperature. At temperatures less than this value, viscous flow phenomena can have an effect, resulting in stress concentration and damage accumulation in the laminate.

6.7 Nonmetallic liners (Type 4)

The nonmetallic liner material shall be compatible with the service conditions specified in Clause 4.

The liner melt temperature shall be sufficiently high to allow gas release only through pressure relief devices during fire tests. See 17.3.8 for further details.

The tensile yield strength and ultimate elongation shall be determined in accordance with ASTM D638. Tensile or impact testing shall be conducted on samples of the nonmetallic liner material to demonstrate that the material fails in a ductile, rather than brittle, mode at temperatures down to −50 °C.

The softening temperature shall be sufficiently high to meet the service conditions specified in Clause 4. The container manufacturer shall establish the suitable value for the softening temperature and the testing shall be in accordance with the method described in ISO 306 or using an equivalent method.

6.8 Bosses for Type 4 containers

Materials shall be compatible with the liner and intended environment and shall meet the requirements of 6.2, 6.3.1, 6.3.2, 6.3.3, 6.3.4, and 6.3.5 as applicable.

7 Wall thickness

7.1 Type 1 containers

The minimum wall thickness shall be sufficient to comply with all applicable qualification tests within this document.

7.2 Liners for Type 2, Type 3, and Type 4 containers

Minimum thickness of the liner shall be such that the required qualification test requirements of this document are met.

For Type 2 designs, the unreinforced metal liner shall have a minimum burst pressure of 125 % of the nominal working pressure.

7.3 Composite reinforcement for Type 2, Type 3, and Type 4 containers

7.3.1 Stress analysis

The stress analysis is applicable to Category A and C containers only.

Stresses in the liner and composite reinforcement shall be computed using suitable analysis techniques to adequately predict the stresses and strains in both the liner and the composite overwrap at the following pressures: autofrettage (Type 2 and 3 only) pressure, zero gauge pressure (after autofrettage for Type 2 and Type 3), nominal working pressure, hydrostatic test pressure, and minimum burst pressure.

NOTE The analysis of Type 4 cylinders is relatively straightforward because the composite stresses are linear with pressure. The analysis of Type 2 and Type 3 cylinders is more complicated because of the non-linear behaviour of the metal liner, specifically as it is subjected to the autofrettage pressure. It is critical that stress ratio requirements are met to ensure high reliability in regards to stress rupture (see ISO/TR 13086-1 for additional information). Stress ratios are not an issue with Type 1 containers, as they do not have composite reinforcement.

A thick liner, in combination with a high autofrettage pressure, can result in sufficient pre-stress on the composite such that the fiber is loaded in excess of the allowed stress ratio.

Type 2 designs are not likely to experience an excessive pre-stress condition if the liner burst pressure does not exceed 150 % of the nominal working pressure, and the autofrettage pressure does not exceed 165 % of the nominal working pressure.

Type 3 designs are not likely to experience an excessive pre-stress condition if the liner burst pressure does not exceed 30 % of the nominal working pressure, and the autofrettage pressure does not exceed 165 % of the nominal working pressure.

It is important to accurately calculate stresses in order to ensure stress ratio requirements are met, particularly when the liner thickness or autofrettage pressure exceeds the values noted above.

7.3.2 Stress ratios

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 following composite reinforcement stress ratio values shown below:

Material	Type 2	Type 3	Type 4
E-Glass	2,65	3,5	3,5
S-Glass	2,65	3,5	3,5
Aramid	2,25	3,0	3,0
Carbon	2,25	2,25	2,25

NOTE For guidance on the calculation of stress ratio values, see ISO/TR 13086-1.

7.3.3 Modified stress ratio test

At the option of the container manufacturer, or for designs in which the required minimum container burst pressure is not sufficient to cause tensile failure in the fiber, a modified burst test procedure may be used to verify that the fiber stress ratio at the nominal working pressure is achieved. The stress ratio requirements (2,65) for E-glass and S-glass, reinforced Type 2 containers, may be demonstrated by meeting a minimum hold time at a specified pressure during the burst tests conducted under 12.5 or 17.3.5. Acceptable alternative combinations of hold times and pressures are as follows:

a) 1 min at 250 % of the nominal working pressure;

b) 1 h at 225 % of the nominal working pressure.

As an alternative, the strength of the fiber may be verified by the testing of containers, with the composite thickness reduced by no more than 50 %, to cause failure initiation in the composite.

7.3.4 Hybrid designs

Hybrid construction (using more than one type of reinforcing fiber) shall be permitted. The strength of the individual types of fibers used in a hybrid construction may be verified by the testing of containers reinforced with a single type of fiber. In a hybrid construction, the applicable stress ratio requirements shall be met in one of the following ways:

a) if load sharing between the various fiber reinforcing materials is considered a fundamental part of the design, each fiber shall meet the stated stress ratio requirements;

b) if load sharing between fibers is not considered as a fundamental part of the design, one of the reinforcing fibers shall be capable of meeting the stress ratio requirements even if all other fiber reinforcing materials are removed, such as in the case of a non-load sharing protective layer.

7.4 External loads on containers

Containers with greater than 450 l water capacity and all containers employing integral mounts or valve protection shall consider the external loads imposed on the container as a function of the service conditions and mounting provisions. This includes bending and torsional stresses.

8 Threaded openings

All threads shall comply with a recognized international or national standard.

Threads shall be clean cut, even and to gauge.

Tapered threads are only permitted on steel containers, steel liners and steel bosses.

9 Manufacture

9.1 General

Manufacturing processes shall be the same as those used to produce the containers subjected to design qualification tests and shall be specified by the container manufacturer in sufficient detail to produce consistent product. No defect shall be acceptable that is likely to cause failure within the lifetime of the container.

9.2 Metal containers and metal liners

Surfaces shall have dirt and scale removed, as necessary, to afford proper inspection. A reasonably smooth and uniform surface finish shall be required. No interior folding shall be permitted. Smooth gathering of the material, in the neck or dome area in which there are no sharp rooted folds, shall be acceptable. If not originally free from such defects, the liner or container surface may be machined or otherwise treated to eliminate these defects provided the required minimum wall thickness is maintained. The liner or container end contour shall be concave to pressure.

9.3 Nonmetallic liners

Nonmetallic liners shall be free of contaminants as necessary to afford proper inspection. Interior folds, laps or sharp surface indentations are not permitted. If not originally free from such defects, the liner surface may be reworked to eliminate these defects providing the liner then meets all design requirements. Welded construction of nonmetallic liners shall be permissible.

Liner weld processes, particularly time, temperature and joining force, shall be monitored during the welding process and controlled within the parameters established by the container manufacturer. Tensile tests of liner weld specimens shall be conducted on samples manufactured at the extreme limits of the process within which the container manufacturer controls the weld process.

Tensile testing of liner weld specimens shall be conducted during qualification of the weld process at −40 °C, at an ambient temperature and at 85 °C.

Tensile specimens shall fail either outside the weld joint or with a ductile failure, if the failure is within the weld.

9.4 Composite containers with metallic liners

The container shall be fabricated from a metal liner overwrapped with resin impregnated continuous filament windings or using an equivalent method. The winding pattern shall be in the “hoop” direction for “hoop-wrapped” containers or in the “helical or in-plane” and “hoop” directions for “full-wrapped” containers. The windings shall be applied under controlled tension to develop the design composite thickness. After the winding is complete, composites using thermoset resins shall be cured by a controlled temperature process that does not compromise the performance of the liner.

9.5 Composite containers with nonmetallic liners

Type 4 composite containers shall be fabricated from a nonmetallic liner overwrapped with resin impregnated continuous filament windings or using an equivalent method. The winding shall be applied under controlled tension to develop the design composite thickness. After the winding is complete, composites using thermoset resins shall be cured by a controlled process that does not compromise the performance of the liner.

Composite containers with nonmetallic liners shall be designed as such that if, when pressurized, the liner is susceptible to creep and flow, no leakage will occur during the prescribed lifetime.

The softening temperature for the liner may be exceeded during processing if the qualification testing verifies that the completed container passes all required tests.

9.6 Brazing

Brazing for any purpose whatsoever shall not be permitted.

9.7 Welding

Welded construction of metal containers, liners, and bosses shall not be permitted.

9.8 End closing by forming

The ends of aluminum containers or liners shall not be closed by a forming process. The base ends of steel containers or liners which have been closed by forming, except those containers or liners designed in accordance with ISO 9809-1, shall be inspected using non-destructive examination (NDE). Metal shall not be added in the process of closure at the end. Each container or liner shall be examined before end forming operations for thickness and surface finish.

9.9 Mounting and protection

If mounting provisions and/or valve protecting shrouds are required, they shall be permitted to be manufactured as part of the container, provided they are not detrimental to the performance of the container. If manufactured as part of the container, structural integrity shall be demonstrated by compliance with qualification tests specified in Table 3 or Table 4, as applicable.

9.10 Batch definitions

9.10.1 The batch definitions shall be as follows:

a) Metal liners and containers only. A “batch” shall be a group of metal liners or containers successively produced having the same design, specified material of construction, process of manufacture, process of heat treatment, equipment of manufacture, equipment of heat treatment and conditions of time, temperature and atmosphere during heat treatment as the batch acceptance sample, with the only variation being the length up to ±50 %.

b) Nonmetal liners only. A “batch” shall be a group of nonmetal liners successively produced having the same design, specified material of construction, process of manufacture and equipment of manufacture as the batch acceptance sample, with the only variation being the length up to ±50 %.

c) Composite container only. A “batch” shall be a group of containers successively produced from liners having the same design, specified materials of construction, process of manufacture and autofrettage process as the batch acceptance sample, with the only variation, applicable to Type 2 containers only, being the length up to ±50 %.

9.10.2 The batch size shall be determined and managed under the container manufacturer’s quality control system.

9.11 Design qualification tests

Prior to initialling the in service usage of any specific container design, qualification tests as prescribed in Clause 17, shall meet all applicable requirements.

10 Production tests and examinations

10.1 General

Production examinations and tests shall be carried out by the following means on all containers produced in a batch:

a) verification through non-destructive examination that flaws in metal containers and liners do not exceed the container manufacturer's specified limits;

NOTE Guidance for the determination of the container manufacturer's specified limits can be found in Annex B.

b) verification through visual or non-destructive examination that nonmetallic liners are free of flaws exceeding the container manufacturer's specified limits (see 9.3 for types of flaws);

c) verification that the critical dimensions and parameters specified by the manufacturer of the completed container and of any liner and overwrapping are within design tolerances. Statistical sampling of critical dimensions shall be acceptable provided that the process is demonstrated capable of maintaining a process capability index (Cpk) of 1,33 or more;

d) verification of the compliance with specified surface finish with special attention to deep drawn surfaces and folds or laps in the neck or dome area of forged or spun end closures or openings;

e) verification of the coating quality (if required);

f) verification of markings;

g) verification of strength (heat treatment) of metal containers liners and bosses. For Type 1 containers and Type 2 liners, a hardness test or equivalent shall be required.

A summary of critical production inspection requirements to be performed on every container is provided in Table 2.

Any container not meeting the specifications in Table 2 shall be rejected.

Table 2 — Production verification requirements (See 10.1)

Production verification requirement(s):	Provision	Container type			
		1	2	3	4
Dimensions	10.1 (c)	X	X	X	X
Flaws	10.1 (a) and (b)	X	X	X	X
Strength (heat treatment) of metal containers, metal liners and metal bosses	10.1 (g)	X	X	X	X
Hydrostatic test	10.2	X	X	X	X
Leak test	10.3	[a]	[a]	[a]	X
Coatings (where required)	10.1(e)	X	X	X	X
Surface finish	10.1(d)	X	X	X	X
End closing by forming (Steel)	9.8	X	X	X	
Markings	10.1(f)	X	X	X	X

[a] Leak tests shall be conducted on those container types that are closed by forming.

10.2 Hydrostatic test

Each finished container shall be hydrostatically tested to at least 150 % of the nominal working pressure. Measuring systems for pressure and expansion shall meet the accuracy and periodic calibration requirements of CGA C-1-2009, or ISO 11439:2013, A.11. Pressure shall be maintained for

30 s and sufficiently longer to produce complete expansion. If the test pressure cannot be maintained due to failure of the test apparatus, it shall be permissible to repeat the test at a pressure increased by 0,69 MPa minimum.

The container manufacturer shall define the appropriate limit of elastic and permanent volumetric expansion for the test pressure used. The container manufacturer shall record all actual test results. Any containers not meeting the defined rejection limit shall be destroyed.

10.3 Leak test

All containers shall be leak-tested using the procedures in items (a) and (b) or an acceptable alternative method. Containers with multiple sealing connections shall be leak-tested at each connection. Permeation through the wall shall not be considered to be leakage.

a) Containers shall be thoroughly dried and then pressurized to the nominal working pressure with a detectable gas or gas mixture.

b) Containers shall be placed in an enclosure to permit the detection of any leaks.

Any gas detected beyond the allowable permeation rate shall be a cause for rejection.

Extreme care should be taken not to create explosive mixtures of gases within the container or test area (enclosure) when using combustible gases. Precautions should be taken in consideration of the potential for the release of combustible gases.

11 Batch tests

11.1 General

Batch testing shall be conducted on finished containers or liners that are representative of the normal production and are complete with identification marks. The test containers and liners, as appropriate, shall be randomly selected from each batch. If more containers are subjected to the tests than are required by this document, all results shall be documented.

When the test results fail to meet the requirements, the container or liner batch shall be rejected. One retest of a rejected batch may be authorized if the test result identifies the presence of a defect in the container or liner and the batch is 100 % inspected to remove defective containers or liners from the batch. A second sample shall then be permitted to be selected from the batch and tested. The batch shall be considered acceptable if the second sample meets the batch criteria.

11.2 Batch material tests

The container or liner shall meet the requirements of the design when subjected to the following tests:

a) Dimensions checked against the design.

b) For metal containers and liners, tensile test two specimens in accordance with the appropriate method specified in 6.3.3.

c) For steel containers and liners, three impact tests in accordance with the method specified in 6.3.2.

11.3 Coated containers

When a protective coating is a part of the design, the following tests shall be performed (in order) on a finished container or a representative test panel from each coating batch:

a) Coating thickness tests shall be in accordance with the following appropriate test method:

    1) ASTM D7091;

   2) ASTM D4138.

b) Containers that do not meet the container manufacturer's specified coating thickness requirement may be recoated after appropriate surface preparation without prior re-stripping.

c) The coating adhesion test in accordance with ASTM D3359 shall provide a minimum rating of 4 when measured using either test method a) or b), as appropriate.

Repair of tested surfaces shall be permitted to a container manufacturer's approved procedure.

Where the coating fails to meet the requirements, the batch shall be 100 % inspected to remove similarly defective containers. The coating on all defective containers may be stripped, using a method that does not affect the integrity of composite wrapped containers, and re-coated. The coating batch test shall then be repeated.

11.4 Burst test

11.4.1 Batch burst test

One container selected from each batch shall be hydrostatically pressurized to burst in accordance with the test procedure described in 17.3.5.2. Rupture may occur in any region of the container. The burst pressure shall meet or exceed the minimum required burst pressure; otherwise, the batch shall be rejected.

The container used for the cycle test in 11.5 may be used for the burst test. If the burst pressure of the cycled container is less than the minimum required burst pressure, an additional burst test shall be conducted on another container selected from the batch. The burst pressure on the additional container shall meet or exceed the minimum required burst pressure; otherwise, the batch shall be rejected.

11.4.2 Periodic burst test

11.4.2.1 The requirement in 11.4.1 to burst a container from each batch may be replaced by periodic burst testing. For the first five sequential batches of a design family (i.e., similar materials, processes and stress levels, but allowing different sizes) one container from each batch shall be burst-tested in accordance with the requirements of 11.4.1. If the container from any batch fails to meet the minimum required burst pressure, the batch shall be rejected.

11.4.2.2 If five sequential batches pass the burst test, subsequent burst tests are only required on every tenth batch manufactured. If more than three months have passed since the last batch of containers was burst-tested, a container from the next batch of containers manufactured shall be burst-tested.

11.4.2.3 If a container fails to meet the minimum burst test requirement, the batch shall be rejected and a sample from every batch manufactured since the previous periodic burst test shall be tested. Any failure to meet the minimum burst test requirement shall also cause rejection of the corresponding batch. A representative container from each of the next ten batches shall be burst-tested.

11.5 Cycle test

11.5.1 Batch cycle test

One container selected from each batch shall be pressure cycle tested in accordance with the following.

11.5.2 Periodic pressure cycling test

11.5.2.1 The container shall be pressure cycle tested in accordance with the following procedure:

a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol.

b) Cycle the pressure in the container between 2 MPa ± 1 MPa and 125 % of the nominal working pressure for a total number of cycles equivalent to 750 times the service life of the container in years for Category A containers, or to 5 500, 7 500, or 11 000 cycles as appropriate for Category B containers, or to 1 125 times the service life of the container in years for Category C containers. The maximum pressurization rate shall be 2,75 MPa per second.

c) Leakage may occur in any region of the container. The number of cycles attained before failure shall meet or exceed the number specified above; otherwise, the batch shall be rejected.

11.5.2.2 The first five sequential batches of a design family shall be tested to a total number of cycles equivalent to 750 times the service life of the container in years for Category A containers, or to 5 500, 7 500, or 11 000 cycles as appropriate for Category B containers, or to 1 125 times the service life of the container in years for Category C containers, not to exceed 10 cycles per minute. If the container from any batch fails to meet this requirement, the batch shall be rejected.

11.5.2.3 If five sequential batches pass the cycling test, subsequent pressure cycling tests shall only be required on every tenth batch manufactured. If more than three months have passed since the last batch of containers was cycle tested, a container from the next batch of containers manufactured shall be cycle tested.

11.5.2.4 If a container fails to meet the cycle requirement, the batch shall be rejected and a representative container from each of the next 10 batches shall be cycle tested.

12 Rejected containers and liners

12.1 Physical test

In the event of failure to meet the physical test requirements, retesting or reheat treatment and retesting shall be authorized as follows to the satisfaction of the Inspector.

a) If there is evidence of a fault in carrying out a test or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored.

b) If the test has been carried out in a satisfactory manner, the cause of test failure shall be identified.

    1) If the failure is considered to be due to the heat treatment applied, the manufacturer may subject all the cylinders implicated by the failure to a further heat treatment, e.g. if the failure is in a test representing the prototype or batch cylinders. A test failure shall require reheat treatment of all the represented cylinders prior to retesting. One additional heat treatment shall be allowed for aluminum and two additional heat treatments are allowed for steel. Additional heat treatments require the validation by material properties testing (6.3.2 and 6.3.3) for steels.

       This reheat treatment shall consist of either re-tempering or a complete reheat treatment.

       Whenever cylinders are reheat treated, the minimum guaranteed wall thickness shall be maintained.

       Only the relevant prototype or batch tests needed to prove the acceptability of the new batch shall be performed again. If one or more tests prove even partially unsatisfactory, all cylinders of the batch shall be rejected.

    2) If the failure is due to a cause other than the heat treatment applied, all cylinders with imperfections shall be either rejected or repaired such that the repaired cylinders pass the test(s) required for the repair. They shall then be re-instated as part of the original batch.

12.2 Leak test

Containers with leaks not meeting the requirements of 10.3 shall not be placed in service.

12.3 Hydrostatic test

Rejected containers not meeting the requirements of 10.2 shall not be placed in service.

12.4 Cycle test

Containers from rejected batches (see 11.5) shall not be placed in service.

12.5 Burst test

Containers from rejected batches (see 11.4) shall not be placed in service.

13 Pressure relief devices

Containers shall be protected from rupture in a fire situation. This protection shall be provided by a pressure relief device(s) complying with ISO 19882. The effectiveness of the pressure relief devices shall be demonstrated in accordance with 17.3.8.

Installation standards may permit alternative configurations if they can be demonstrated to provide adequate levels of safety. A vehicle manufacturer may specify additional PRD locations for specific vehicle installations to optimize safety considerations.

14 Records of manufacture

The container manufacturer shall record appropriate information on the materials, manufacturing processes and test results for the fuel containers. These records shall be clear, legible and in general accordance with the forms in Annex C.

The Inspector shall furnish completed test reports to the container manufacturer.

The Inspector's record shall be retained by the container manufacturer and the Inspector for a minimum of the service life of the container plus five years from the original test date on the containers.

15 Marking and dispatch

15.1 Markings

15.1.1 General

On each container, the container manufacturer shall provide clear permanent markings. Markings may be included on either a single label or divided among multiple labels. All labels should be located such that they are not obscured by mounting brackets. Label position should be agreed with the vehicle manufacturer to assist reading when installed in the vehicle. Duplicate labels are allowed.

15.1.2 Marking information

Each container meeting the requirements of this document shall be marked as follows:

a) Mandatory information:

   1) name and contact information of the container manufacturer;

   2) date of manufacture;

   3) date of removal from service;
   4) number of cycles used in the test program (Category B containers only);
   5) ISO 19881:xxxx-Hyyz (where “xxxx” denotes the year of the standard according to which the container is designed, “yy” denotes the nominal working pressure designation identified in 4.2.1, and “z” denotes the A, B or C designation identified in 4.3);
   6) MFP xx.x (where “xx.x” denotes the maximum fueling pressure);
   7) container manufacturer's part number and serial number;
   8) the statement “For Use Only with the Container Manufacturer's Approved Pressure Relief Devices and Valves”;
   9) the statement “Container Service Life Ends after Use in a Single Vehicle — Container Transfer between Vehicles Is Prohibited”;
   10) the statement “Mounting Shall Be in Accordance with the Container Manufacturer’s Instructions.”

b) Non-mandatory information can be added but it shall be presented in such a form so as not to be confused with the mandatory information. All non-mandatory information shall follow or be separate from the mandatory information sequence.

The markings shall be placed in the listed sequence but the specific arrangement may be varied to match the space available.

15.2 Dispatch inspection

Prior to dispatch from the container manufacturer, every container shall be internally clean and dry and every container shall be inspected as required by the container manufacturer. Containers not immediately closed by the fitting of a valve, and safety devices if applicable, shall be closed using a method that prevents condensation and entry of fluids and protects threads.

16 Quality assurance

Tests and examinations performed to demonstrate compliance shall be conducted using instruments calibrated before being put into service and thereafter according to an established programme.

17 Design qualification tests

17.1 General

Qualification testing shall be conducted on finished containers that are representative of the normal production (including a protective coating if part of the design, unless otherwise specified) and complete with identification marks.

17.2 Test requirements

Containers representative of each design and design change shall successfully meet the requirements of a Category A, Category B, or Category C design qualification test.

Category A design qualification requirements are prescribed in Table 3, using procedures found in 17.3.

Category B design qualification requirements are prescribed in Table 4, using procedures found in 17.3 and 17.5.

Category C design qualification requirements are prescribed in Table 3, using procedures found in 17.3 and with the conditions and limitations found in 17.6.

The container pressure during cycle testing shall be monitored by a transducer located after the container, i.e., the container shall be located between the pressure source and the transducer. Alternatively, it shall be demonstrated to the satisfaction of the Inspector or demonstrated by the test agency that the pressure measured at the maximum cycle pressure is the “true” pressure, i.e., there is no pressure drop between the container and the pressure transducer. This may be achieved by incorporating a 1 s hold in the cycle at the maximum pressure and the minimum pressure. The pressure cycle rate during cycle testing shall not exceed the rate at which the pressure verification was performed.

If not otherwise specified, the pressure cycling rate shall be at the discretion of the container manufacturer but shall not exceed 10 cycles per minute.

Caution shall be taken to confirm that the specified test temperature and test pressure are maintained. Unless stated otherwise, the tests specified herein shall be conducted with the following tolerances on specified temperatures and pressures:

a) −40 °C (0,−5) °C;

b) +85 °C (0,−5) °C ;

c) $P_{\max}$ +2,0 MPa.

Temperatures and pressures may be exceeded if specified by the manufacturer.

Composite reinforcement on containers subjected to qualification tests shall be fully cured. Completeness of the cure shall be verified on all units used in qualification tests.

Table 3 — Test requirements for Category A and C containers (See 9.9 and 17.2.)

Clause	Test name	Type 1	Type 2	Type 3	Type 4
17.3.2	Ambient cycling test	•	•	•	•
17.3.3	Environmental test		•	•	•
17.3.4	Extreme temperature cycling test		•	•	•
17.3.5	Hydrostatic burst test	•	•	•	•
17.3.6	Flaw tolerance test	•	•	•	•
17.3.7	Drop test		•	•	•
17.3.8	Fire test	•	•	•	•
17.3.9	Accelerated stress rupture test		•	•	•
17.3.10	High strain rate impact test	•	•	•	•
17.3.11	Permeation test				•
17.3.12	Boss torque test				•
17.3.13	Hydrogen gas cycling test	•	•	•	•
17.3.14	Leak before break test	•	•		

Table 4 — Test requirements for Category B containers (See 9.9 and 17.2.)

Clause	Test name
17.5.2	Ambient cycling test (per 17.3.2)
17.5.3	Hydrostatic burst test (per 17.3.5)
17.5.4	Container test for performance durability
17.3.8	Fire test
17.5.5	Container test for expected on-road performance

17.3 Category A, B and C: design qualification tests

17.3.1 Test requirements

Category A and C containers shall be subjected to the tests specified in 17.3. Category B containers shall be subjected to the tests specified in 17.3, as applicable.

17.3.2 Ambient cycling test

17.3.2.1 Sampling

Three finished containers shall be subjected to the ambient pressure cycle test.

17.3.2.2 Procedure

Pressure cycling shall be performed in accordance with the following procedure:

a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol.

b) Cycle the pressure in the container between 2 MPa ± 1 MPa and 125 % of the nominal working pressure at a rate not greater than 10 cycles per minute for the following number of cycles:

   1) Category A containers: Number of cycles equivalent to 1 500 times the service life of the container in years.

   2) Category B containers: Number of cycles equivalent to 11 000, 15 000 or 22 000 cycles for a 15-year service life.

   3) Category C containers: Number of cycles equivalent to 2 250 times the service life of the container in years.

17.3.2.3 Acceptable results

a) Category A containers shall not leak before reaching a number of cycles equivalent to 750 times and shall not rupture before reaching 1 500 times the service life of the container in years.

b) Category B containers shall not leak before reaching a number of cycles equivalent to 5 500, 7 500 or 11 000 cycles and shall not rupture before reaching 11 000, 15 000 or 22 000 cycles for a 15-year service life.

c) Category C containers shall not leak before reaching a number of cycles equivalent to 1 125 times, and shall not rupture before reaching 2 250 times the service life of the container in years.

d) For Types 2, 3, and 4 containers, the fibers in the overwrap are not allowed to fail.

NOTE It is acceptable for the pressurizing fluid to rise above the ambient temperature as long as the temperature of the test chamber and the fluid do not exceed the maximum specified temperature of the container.

17.3.3 Environmental test

17.3.3.1 Sampling

One finished container including coating, if part of the design, shall be subjected to the environmental test.

17.3.3.2 Procedure

17.3.3.2.1 General

The environmental test shall be performed in accordance with the following procedure.

The upper section of the container shall be divided into five distinct areas and marked for pendulum impact preconditioning and fluid exposure (see Figure 1). The areas shall be nominally 10 cm in diameter. While convenient for testing, the areas need not be oriented along a single line, but shall not overlap.

Although preconditioning and other fluid exposure is performed on the cylindrical section of the container, all of the container, including the domed sections, shall be as resistant to the exposure environments as the exposed areas.

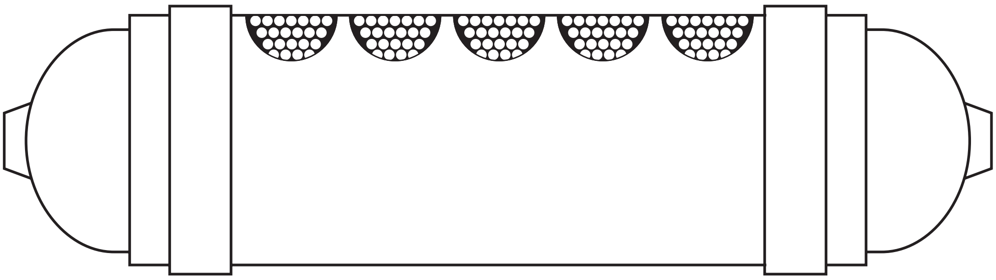


Figure 1 — Container orientation and layout of exposure areas (See 17.3.3.2.1 and 17.3.3.2.2)

17.3.3.2.2 Pendulum impact preconditioning

The impact body shall be of steel and have the shape of a pyramid with equilateral triangle faces at a 45° angle and a square base, the summit and the edges being rounded to a radius of 3 mm. The center of percussion of the pendulum shall coincide with the center of gravity of the pyramid. The total mass of the pendulum referred to its center of percussion shall be 15 kg. The energy of the pendulum at the moment of impact shall be not less than 30 Nm and as close to that value as possible.

During pendulum impact, the container shall be held in position by the end bosses or by the intended mounting brackets. Each of the five areas identified in Figure 1 shall be preconditioned by the impact of the pendulum body summit at the center of the area. The container shall be unpressurized during preconditioning.

17.3.3.2.3 Environmental fluids for exposure

Each marked area shall be exposed to one of the five solutions. The five solutions are

a) sulfuric acid – 190 ml/l in water,

b) sodium hydroxide – 25 % solution by weight in water,

c) methanol/gasoline – 5 %/95 % concentration of M5 fuel meeting the requirements of ASTM D4814,

d) ammonium nitrate – 28 % by weight in water, and

e) windshield washer fluid (500 ml/l methanol in water).

When exposed, the test sample is oriented with the exposure area uppermost. A pad of glass wool approximately 0,5 mm thick and between 90 mm and 100 mm in diameter shall be placed on the exposure area. Apply an amount of the test fluid to the glass wool sufficient to wet the pad evenly across its surface and through its thickness immediately prior to the start of pressure cycling. Reapply the test fluid as needed to maintain the pad saturation.

17.3.3.2.4 Pressure cycle and pressure hold

Containers shall be hydraulically pressure cycled between 2 MPa ± 1 MPa and 125 % of the nominal working pressure for a total of 3 000 cycles. The maximum pressurization rate shall be 2,75 MPa per second. After pressure cycling, containers shall be pressurized to 125 % of the nominal working pressure and held at that pressure a minimum of 24 h and until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids totals a minimum of 48 h.

17.3.3.2.5 Acceptable results

Following the above test sequence, the residual burst strength of the container shall be no less than 180 % of the nominal working pressure when tested in accordance with the hydrostatic burst test in 17.3.5.

17.3.4 Extreme temperature cycling test

17.3.4.1 Sampling

One finished container shall be subjected to the extreme temperature cycling test.

17.3.4.2 Procedure

The extreme temperature cycle test shall be performed in accordance with the following procedure:

a) Stabilize the container at 85 °C or higher.

b) Hydraulically pressure cycle between 2 MPa ± 1 MPa and 125 % of the nominal working pressure for 4 000 cycles for Category A containers and 4 500 cycles for Category C containers. The temperature limits specified in a) shall be met on the container skin and in the working fluid in the container throughout the cycling.

c) Stabilize the container at ambient conditions.

d) Stabilize the container at −40 °C or lower.

e) Hydraulically pressure cycle between 2 MPa ± 1 MPa and 80 % of the nominal working pressure for 4 000 cycles for Category A containers and 4 500 cycles for Category C containers. The temperature limits specified in d) shall be met on the container skin and in the working fluid in the container throughout the cycling.

The cycling rate shall not exceed 10 cycles per minute.

17.3.4.3 Acceptable results

Following pressure cycling at extreme temperatures, the container shall not leak or rupture and the residual burst strength of the container shall be no less than 180 % of the nominal working pressure when tested in accordance with the hydrostatic burst test in 17.3.5.

17.3.5 Hydrostatic burst test

17.3.5.1 Sampling

Three finished containers shall be subjected to the hydrostatic burst test.

17.3.5.2 Procedure

The hydrostatic burst test shall be performed in accordance with the following procedure:

The rate of pressurization shall not exceed 1,4 MPa per second at pressures in excess of 150 % of the nominal working pressure. If the rate of pressurization at pressures in excess of 150 % of the nominal working pressure exceeds 0,35 MPa per second, either the container shall be placed schematically between the pressure source and the pressure measurement device or there shall be a 5 s hold at the minimum required burst pressure.

17.3.5.3 Acceptable results

The actual burst pressure shall be recorded.

The minimum required burst pressure shall be at least 225 % of the nominal working pressure and in no case less than the value necessary to meet the burst/nominal working pressure ratio requirement of 7.1, for Type 1 containers or the stress ratio requirement of 7.3.2, when analysed in accordance with the requirements of 7.3.1.

17.3.6 Flaw tolerance test

17.3.6.1 Sampling

One finished container shall be subjected to the flaw tolerance test.

17.3.6.2 Procedure

The flaw tolerance test shall be performed in accordance with the following procedure:

For Type 1 containers:

a) One uncoated container shall have two saw cuts in the longitudinal direction cut into the container sidewall. One flaw shall be minimum 25 mm long and minimum 0,42 mm deep and the other flaw shall be minimum 200 mm long and minimum 0,25 mm deep.

b) The flawed container shall then be pressure cycled, from 2 MPa ± 1 MPa and 125 % of the nominal working pressure for a number of cycles equivalent to 750 times the service life of the container in years for Category A containers, or to 1 125 times the service life of the container in years for Category C containers.

For Types 2, 3, and 4 containers:

c) One uncoated container shall have two flaws in the longitudinal direction cut into the composite sidewall. One flaw shall be minimum 25 mm long and minimum 1,25 mm deep and the other flaw shall be minimum 200 mm long and minimum 0,75 mm deep.

d) The flawed container shall then be pressure cycled, from 2 MPa ± 1 MPa and 125 % of the nominal working pressure for a number of cycles equivalent to 750 times the service life of the container in years for Category A containers, or to 1 125 times the service life of the container in years for Category C containers.

17.3.6.3 Acceptable results

The container shall not leak or rupture within the first 3 000 cycles, but may fail by leakage up to the maximum number of cycles. All containers that complete this test shall be destroyed.

17.3.7 Drop test

17.3.7.1 Sampling

One or more finished containers shall be subjected to the drop test.

17.3.7.2 Procedure

For Types 2, 3, and 4 containers only:

a) One or more finished containers shall be drop tested at the ambient temperature without internal pressurization or attached valves. The surface onto which the containers are dropped shall be a smooth, horizontal concrete pad or flooring. One container shall be dropped in a horizontal position with the lowest point of the container no less than 1,83 m above the surface onto which it is dropped. One container shall be dropped vertically on each end at a sufficient height above the floor or pad so that the potential energy is 488 J, but in no case shall the height of the lower end be greater than 1,83 m. One container shall be dropped at a 45° angle onto a dome from a height such that the center of gravity is at 1,83 m; however, if the lower end is closer to the ground than 0,6 m, the drop angle shall be changed to maintain a minimum height of 0,6 m and a center of gravity of 1,83 m. The container(s) shall be allowed to bounce on the concrete pad or flooring after the initial impact. No attempt shall be made to prevent this secondary impacting, but the container may be prevented from toppling during the vertical drop test.

b) Following the drop impact, the container(s) shall be pressure cycled, 2 MPa ± 1 MPa to 125 % of the nominal working pressure for a number of cycles equivalent to 750 times the service life of the container in years for Category A containers, or to 1 125 times the service life of the container in years for Category C containers.

c) For Category B containers the orientation of the container being dropped [per the requirement of 17.3.7.2 a)] is determined as follows:

    1) One or more additional container(s) shall be dropped in each of the orientations described. The drop orientations may be executed with a single container or as many as four containers may be used to accomplish the four drop orientations.

    2) If more than one container is used to execute all three drop specifications, those containers shall undergo pressure cycling according to 17.3.2 until either leakage or 22 000 cycles without leakage have occurred. Leakage shall not occur within the number of cycles (5 500, 7 500 or 11 000).

    3) The container used for further testing shall be identified as follows:

        i) If a single container was subjected to all four drop orientations, the container being dropped shall undergo further testing as specified;

        ii) If more than one container is used to execute the four drop orientations and if all containers reach 22 000 cycles without leakage, the orientation of the container being dropped is the 45° orientation, and that the container shall then undergo further testing as specified;

        iii) If more than one container is used to execute the four drop orientations and if any container does not reach 22 000 cycles without leakage, the new container shall be subjected to the drop orientation(s) that resulted in the lowest number of cycles to leakage and then undergo further testing as specified.

17.3.7.3 Acceptable results

The container(s) shall not leak or rupture within the first 3 000 cycles, but may fail by leakage up to the maximum number of cycles. All containers that complete this test shall be destroyed.

17.3.8 Fire test

17.3.8.1 Sampling

One finished container shall be subjected to the fire test.

17.3.8.2 Procedure

17.3.8.2.1 General

The fire test shall be performed in accordance with the following procedure.

The fire test shall be designed to demonstrate that finished containers complete with the pressure relief devices specified in the design along with additional relevant features including the venting system (such as the vent line and vent line covering) and any shielding affixed directly to the container (such as thermal wraps and/or coverings/barriers over the pressure relief device) will prevent the rupture of the container when tested under the specified fire conditions. The specified fire conditions include both localized and engulfing fire threats.

Extreme caution shall be exercised during fire testing. Container rupture can occur.

17.3.8.2.2 Container set-up

The localized fire exposure area shall be the area on the container farthest from the pressure relief device(s). If the container is not cylindrically symmetrical, it shall be oriented over the fire source in a worst-case configuration. The container shall only include thermal shielding or other mitigation devices affixed directly to the container that are used in all vehicle applications. Venting system(s) (such as the vent line and vent line covering) and/or coverings/barriers over the pressure relief device(s) shall be included in the test if they are anticipated for use in any application. If a container is tested without representative components, retesting of that container shall be required if a vehicle application specifies the use of these types of components.

If a specific vehicle installation configuration is specified and the qualification of the system is limited to that specific vehicle installation configuration, the test setup may also include other vehicle components in addition to the hydrogen storage system. These vehicle components (such as shielding or barriers, which are permanently attached to the vehicle's structure by means of welding or bolts and not affixed to the storage system) shall be included in the test setup in the vehicle-installed configuration relative to the hydrogen storage system. This localized fire test shall be conducted on the worst-case localized fire exposure areas based on the four fire orientations: fires originating from the direction of the passenger compartment, cargo/luggage compartment, wheel wells or ground-pooled gasoline.

Containers shall be pressurized with hydrogen to the nominal working pressure (±1 MPa), pressure compensated for the ambient test temperature, such that the proper mass of gas is contained, and placed horizontally with the container bottom approximately 100 mm above the fire source. The fire source shall initiate within a 250 mm ± 50 mm longitudinal expanse positioned under the localized exposure area of the container. The width of the fire source shall encompass the entire diameter of the container.

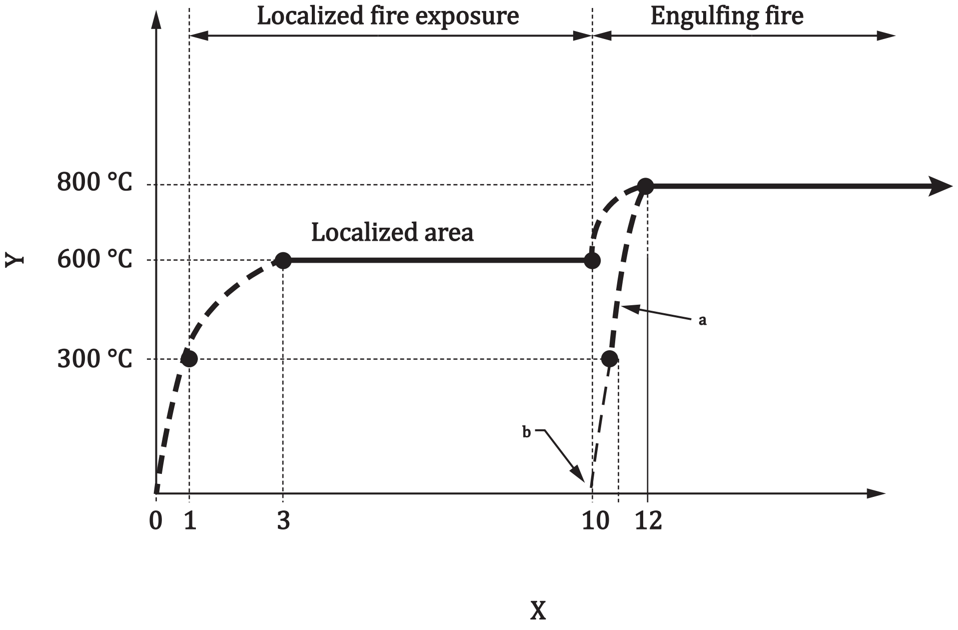
17.3.8.2.3 Fire source

The fire source shall consist of LPG burners configured to produce a uniform minimum temperature on the container defined as a moving 1 min average per thermocouple with minimum 5 thermocouples covering the length of the container up to 1,65 m maximum (at least 2 thermocouples within the localized fire area, and at least 3 thermocouples equally spaced and no more than 50 cm apart in the remaining area) located 25 mm ± 10 mm from the outside surface of the container along its longitudinal axis. At the option of the container manufacturer or Inspector or testing facility, additional thermocouples may be located at pressure relief device sensing points or any other locations for optional diagnostic purposes.

Wind shields shall be utilized to allow uniform heating.

17.3.8.2.4 Test requirements

The test temperature profile for the localized fire test is shown in Figure 2 and detailed thermal requirements are provided in Table 5. The temperature at the thermocouples in the localized fire area shall be increased continuously to at least 300 °C within 1 min of ignition, to at least 600 °C within 3 min of ignition, and a rolling average temperature of at least 600 °C shall be maintained for the next 7 min. Then, within the next 2 min interval, the temperature at the thermocouples in the fire source shall be increased to at least 800 °C and the fire source shall be extended to produce a rolling average temperature of at least 800 °C along the entire length and width of the container (engulfing fire). Note that the temperature outside the region of the initial fire source is not specified during the initial 10 min from the time of ignition.



Key

X	minutes
Y	Minimum temperature
a	Engulfing region outside the localized area (burner ramp rate).
b	Ignite the main burner.

Figure 2 — Minimum temperature during the fire test (See 17.3.8.2.4)

Table 5 — Fire test procedure description (See 17.3.8.2.4)

	Localized fire region	Time period	Engulfing fire region (outside the localized fire region)
Action	Ignite burners	0 to 1 min	No burner operation
Minimum temperature	Not specified		Not specified
Maximum temperature	Less than 900 °C		Not specified
Action	Increase the temperature and stabilize the fire for the start of localized fire exposure	1 to 3 min	No burner operation
Minimum temperature	Greater than 300 °C		Not specified
Maximum temperature	Less than 900 °C		Not specified
Action	Localized fire exposure continues	3 to 10 min	No burner operation
Minimum temperature	1 min rolling average greater than 600 °C		Not specified

Table 5 *(continued)*

	Localized fire region	Time period	Engulfing fire region (outside the localized fire region)
Maximum temperature	1 min rolling average less than 900 °C		Not specified
Action	Increase the temperature	10 to 11 min	Main burner ignited at 10 min
Minimum temperature	1 min rolling average greater than 600 °C		Not specified
Maximum temperature	1 min rolling average less than 1 100 °C		Less than 1 100 °C
Action	Increase the temperature and stabilize the fire for the start of engulfing fire exposure	11 to 12 min	Increase the temperature and stabilize the fire for the start of engulfing fire exposure
Minimum temperature	1 min rolling average greater than 600 °C		Greater than 300 °C
Maximum temperature	1 min rolling average less than 1 100 °C		Less than 1 100 °C
Action	Engulfing fire exposure continues 1 min rolling average	12 mins - end of test	Engulfing fire exposure continues 1 min rolling average
Minimum temperature	Greater than 800 °C		Greater than 800 °C
Maximum temperature	1 min rolling average less than 1 100 °C		1 min rolling average less than 1 100 °C

17.3.8.3 Acceptable results

The container shall be held at the temperature (engulfing fire condition) until the hydrogen vents through the pressure relief device(s) and the test shall continue until the pressure falls to less than 1 MPa. The venting shall be continuous (without interruption) and the container shall not rupture. An additional release through leakage [not including release through the pressure relief device(s)] that results in a flame with a length greater than 0,5 m beyond the perimeter of the applied flame shall not occur.

The arrangement of the fire shall be recorded in sufficient detail to confirm the rate of heat input to the container is reproducible. The results shall include the elapsed time from the ignition of the fire to the start of venting through the pressure relief device(s) and the maximum pressure and time of evacuation until a pressure of less than 1 MPa is reached. Thermocouple temperatures and container pressure shall be recorded at intervals of every 10 s or less during the test. Any failure to maintain specified temperature requirements during a test invalidates the result.

17.3.9 Accelerated stress rupture test

17.3.9.1 Sampling

One finished Type 2, 3 or 4 container shall be subjected to the accelerated stress rupture test.

17.3.9.2 Procedure

The accelerated stress rupture test shall be performed in accordance with the following procedure.

The container shall be hydrostatically pressurized to 125 % of the nominal working pressure (±1 MPa) while at a temperature of 85 °C. The container shall be held at this pressure and temperature for 1 000 h.

At the completion of the test the container shall be burst.

17.3.9.3 Acceptable results

The container shall exceed 75 % of the minimum burst pressure when tested in accordance with the hydrostatic burst test in 17.3.5.

The residual burst strength of the container shall be no less than 180 % of the nominal working pressure when tested in accordance with the hydrostatic burst test in 17.3.5.

17.3.10 High strain rate impact test

17.3.10.1 Sampling

One finished container shall be subjected to the high strain rate impact test.

17.3.10.2 Procedure

A container shall be pressurized to the nominal working pressure (±1 MPa) with nitrogen, helium or hydrogen and be impacted by either:

a) a 7,62 mm diameter armor-piercing projectile (specified as 7,62 mm × 51 mm NATO, armor piercing bullet) with a nominal velocity of 850 m/s. The bullet shall be fired from a distance of no more than 45 m, or

b) a steel projectile having a minimum hardness of 870 Hv, with a diameter between 6,08 mm and 7,62 mm, having a mass of between 3,8 g and 9,75 g, a conical shape with a nose angle of 45°, a nominal velocity of 850 m/s and impacting with a minimum energy of 3 300 J.

The projectile shall impact the sidewall of the container at a 90° angle but shall not be required to pass through the sidewall of the container.

17.3.10.3 Acceptable results

The container shall not rupture.

17.3.11 Permeation test

17.3.11.1 Sampling

This test shall only be required on Type 4 containers.

One finished container shall be subjected to the permeation test.

17.3.11.2 Procedure

The permeation test shall be performed in accordance with the following procedure.

Containers may be located in enclosed spaces for extended periods of time.

One container shall be filled with hydrogen to the nominal working pressure (±1 MPa), placed in an enclosed sealed container at 15 °C ± 5 °C. The test shall continue until the measured permeation reaches a steady state based on at least 3 consecutive readings separated by at least 12 h being within ±10 % of the previous reading.

17.3.11.3 Acceptable results

The steady state permeation rate for hydrogen gas shall be less than 6,0 Ncc of hydrogen per hour per liter water capacity.

NOTE For the purposes of this document, the combination of permeation and leakage, if below the allowable permeation rate according to 17.3.11, constitutes compliance with the permeation requirements, and if above the allowable permeation rate according to 17.3.11, constitutes lack of compliance with the permeation requirements.

17.3.12 Boss torque test

17.3.12.1 Sampling

This test shall only be required on Type 4 containers.

One finished container shall be subjected to the boss torque test.

17.3.12.2 Procedure

One container shall be preconditioned with the boss subjected to twice the installation torque specified for the fittings. The container shall then be subjected to 10.3.

17.3.12.3 Acceptable results

Any gas detected beyond the allowable permeation rate shall be a cause for rejection.

17.3.13 Hydrogen gas cycling test

17.3.13.1 Sampling

One finished container shall be subjected to the hydrogen gas cycling test.

17.3.13.2 Procedure

The hydrogen gas cycling test shall be performed in accordance with the following procedure.

The container shall be pressure cycled using hydrogen from 2 MPa ± 1 MPa to 125 % of the nominal working pressure for 1 000 cycles. The end boss at the valve end (the end where the fill/discharge occurs) may be grounded. Each cycle shall consist of filling and venting of the container. The fill rate shall not exceed 60 g/s and the maximum allowable gas temperature shall not be exceeded. The defueling rate shall be specified by the container manufacturer.

The first 500 cycles shall be conducted at the ambient temperature, followed by a static hold at 115 % of the nominal working pressure (±1 MPa) at 55 °C for a minimum of 30 h. The second 500 cycles shall be conducted with the container at an ambient temperature of −30 °C (250 cycles) and at 50 °C (250 cycles).

Subscale specimens may be used for this test with diameters reduced by as much as 20 % and lengths reduced by as much as 50 %.

17.3.13.3 Acceptable results

Following the completion of the test, the container shall meet the requirements of the leak test in 11.3. Type 4 containers shall then be sectioned and the liner and liner/end boss interface inspected for evidence of any deterioration, such as fatigue cracking, disbonding of plastic, deterioration of seals or damage from electrostatic discharge.

17.3.14 Leak before break test

17.3.14.1 Sampling

One finished container shall be subjected to the leak before break test.

17.3.14.2 Procedure

The leak before break test shall be performed in accordance with the following procedure.

This test only applies to Type 1 and Type 2 containers.

The containers shall be pressure cycled between not more than 2 MPa ± 1 MPa and 150 % of the nominal working pressure at a rate not to exceed 10 cycles per minute in accordance with 17.3.2.

17.3.14.3 Acceptable results

All containers shall either fail by leakage or exceed the maximum number of filling cycles for the design category.

17.4 Change of design

Category A and C container designs that are sufficiently similar to an existing fully qualified design shall be permitted to be qualified through a reduced test program as defined in Table 6.

Design changes not falling within the guidelines in Table 6 shall be qualified as an original design. If a minor design change is not defined in Table 6, the Inspector or test agency shall determine the level of reduced testing required for requalification.

A design approved by a reduced series of tests (a design change) shall not be used as the sole basis for a second design change approval with a reduced set of tests (i.e., multiple changes from an original design are not permitted). However, if a test has been conducted on a design change (X) that falls within the testing requirements for a second design change (Y), the test result for the first design change (X) may be applied to the new design change (Y) test program.

Table 6 — Test requirements for designs and design changes for Category A and C containers (See 17.4)

Test	Original design	Fiber material or manufacturer[a]	Resin system material or manufacturer	Liner or metal container material or manufacturer[k]	Dia. ≤20 % change[f]	Dia. >20 % change[f]	Service pressure ≤20 % change[f]	Length ≤50 % change	Length >50 % change	Integral mounting brackets & valve protection shrouds	Pressure relief devices or valves	External coating	Boss material or geometry
Ambient cycling test (17.3.2)	X	X	X[m]	X	X[m]	X	X[m]	X[m]	X[m]	X[m]			X[m]
Environmental test[c] (17.3.3)	X	X[d]	X[i]									X	
Extreme temperature cycling[c] (17.3.4)	X	X[d]	X[i]	X									
Hydrostatic burst test (17.3.5)	X	X	X[m]	X[n]	X[m]	X	X[m]	X[m]	X[m]	X[m]			X[m]
Flaw tolerance test[c] (17.3.6)	X		X[i]										
Drop test[c] (17.3.7)	X	X	X[i]	X[e]	X	X			X				
Fire test (17.3.8)	X	X	X[i]	X		X		X[b]	X		X[g]		
Accelerated stress rupture test[c] (17.3.9)	X	X	X										
High strain rate impact test (17.3.10)	X	X	X[i]	X[n]	X[h]	X		X[o]					
Permeation test[e] (17.3.11)	X			X									X[p]
Boss torque test (17.3.12)	X										X[l]		X

Table 6 *(continued)*

Test	Original design	Fiber material or manufacturer[a]	Resin system material or manufacturer	Liner or metal container material or manufacturer[k]	Dia. ≤20 % change[f]	Dia. >20 % change[f]	Service pressure ≤20 % change[f]	Length ≤50 % change	Length >50 % change	Integral mounting brackets & valve protection shrouds	Pressure relief devices or valves	External coating	Boss material or geometry
Hydrogen gas cycling test (17.3.13)	X			X									X[j]
Leak before break (17.3.14)	X	X		X		X							

[a] Change of fiber type, e.g. glass to carbon is not applicable. Change of design applies only to changes of materials properties or manufacturer within a fiber type.

[b] Fire test is not required, provided safety relief devices or device configuration passed the required fire test on a container with equal or greater internal water volume.

[c] Test required only on composite reinforced containers.

[d] Not applicable to carbon fiber designs.

[e] Test required only for Type 4 containers.

[f] When changes in diameter or pressure are made, the structural wall elements shall be operating at the same or lower nominal stress levels as the original design (e.g., if pressure or diameter increase, the wall thickness increases proportionally).

[g] Required if the new valve design has reduced relief channel flow area compared with previously qualified valves or if the mass of the valve and PRD increase by more than 30 % or when the pressure relief device is changed.

[h] Test required only if the diameter decreases.

[i] Test not required when resins of the same chemical and physical properties are substituted.

[j] Test required for Type 4 containers when the boss to liner interface is affected by design changes.

[k] Change of liner or metal container material, e.g. steel to aluminum is not applicable. Change of design applies only to changes of materials properties or manufacturer within a material type.

[l] Only applicable for an increase in the valve torque.

[m] Only one unit required for design change; may be done as part of the batch test.

[n] Test not required for Type 4 containers.

[o] Test only required when the resulting container sidewall length is less than the diameter.

[p] Geometry only.

17.5 Category B: design qualification tests

17.5.1 General test requirements

Category B containers shall be subjected to the tests specified in 17.5.

Containers subjected to these tests are intended to be integrated into a compressed hydrogen storage system, including all closure devices (such as shut-off valves, check valves, pressure relief devices, etc.) and piping, and are expected to meet the additional test requirements [Verification Test for Expected On-Road Performance (Sequential Pneumatic Tests), Verification Test for Service Terminating Performance in Fire in the UN GTR No. 13 or SAE J2579].

17.5.2 Ambient cycling test

Containers shall be subjected to the pressure cycling test specified in 17.3.2.

17.5.3 Hydrostatic burst test

Containers shall be subjected to the burst test specified in 17.3.5. The container manufacturer shall supply documentation (measurements and statistical analyses) that establishes the midpoint burst pressure of new containers.

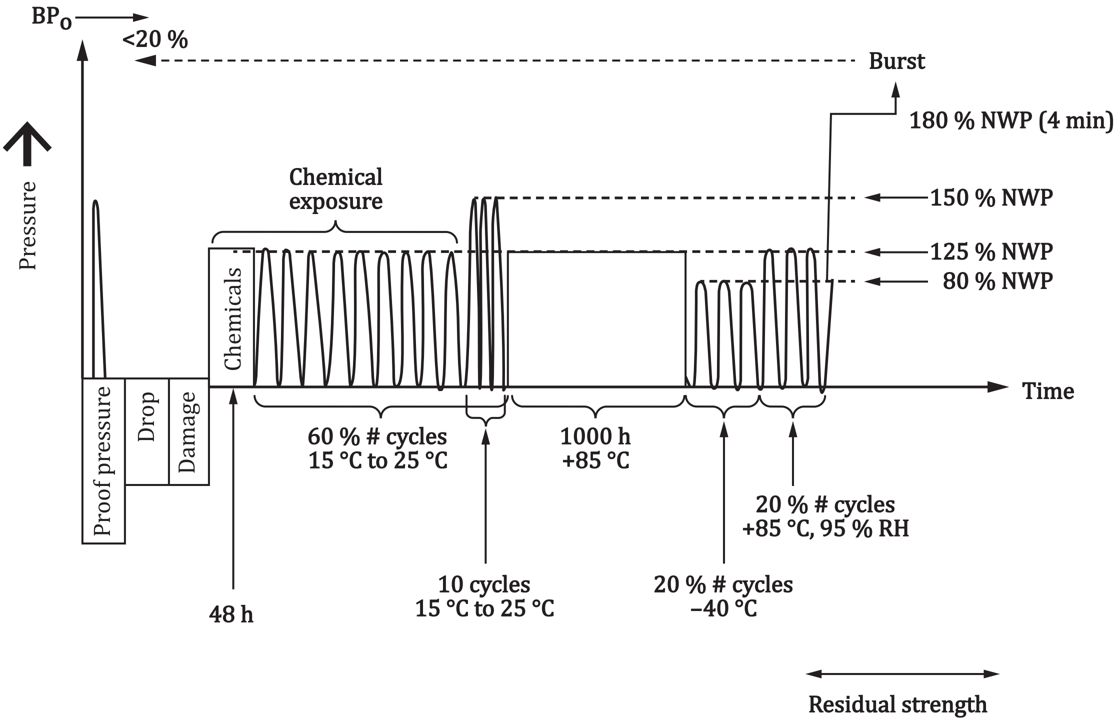
All containers tested shall have a burst pressure within ±10 % of the midpoint and greater than 225 % of the nominal working pressure and in no case less than the value necessary to meet the burst/nominal working pressure ratio requirement of 7.1, for Type 1 containers, or the stress ratio requirement of 7.3.2, when analysed in accordance with the requirements of 7.3.1. The actual burst pressure shall be recorded.

17.5.4 Container test for performance durability

17.5.4.1 Test requirements

If all three pressure cycle life measurements determined per 17.5.2 are greater than 11 000 cycles or if they are all within ±25 % of each other, only one container shall be subjected to the tests specified in 17.5.4. Otherwise, three containers shall be tested.

The container(s) shall not leak during the following sequence of tests, which are applied in series to an individual container(s) and which are illustrated in Figure 3.



NOTE BP$_0$ is the midpoint burst pressure of new containers.

Figure 3 — Verification test for performance durability (See 17.5.4.1.)

17.5.4.2 Proof pressure test

Containers shall be subjected to the proof pressure test specified in 11.2. If a container has previously undergone a proof pressure test in manufacture, then the container shall be exempt from this test.

17.5.4.3 Drop test

Containers shall be subjected to the drop test conditioning specified in 17.3.7.2 a).

17.5.4.4 Surface damage test

Containers shall be subjected to the surface flaw conditioning specified in 17.3.6.2 a) or 17.3.6.2 c), except that the flaws shall be introduced in the bottom surface of the container and the 25 mm long cut shall be situated toward the valve end of the container and the 200 mm long cut shall be situated opposite the valve end of the container.

The upper surface of the container shall be subjected to the pendulum impact conditioning specified in 17.3.3.2.1 and 17.3.3.2.2, except that the container shall be preconditioned at −40 °C for 12 h prior to the pendulum impacts.

17.5.4.5 Chemical exposure and ambient pressure cycling

Containers shall be subjected to the chemical conditioning specified in 17.3.3.2.3, except that the container shall be held at the ambient temperature and 125 % of the nominal working pressure (±1 MPa) for 48 h before the container is subjected to further testing.

Containers shall be subjected to the pressure cycling test specified in 17.3.2 to 60 % of 5 500, 7 500 or 11 000 cycles, as appropriate. Chemical exposure shall be discontinued by removing the glass wool pads and rinsing the container surface with water before the last 10 cycles, which shall be conducted to 150 % of the nominal working pressure (±1 MPa).

17.5.4.6 High temperature static pressure test

Containers shall be pressurized to 125 % of the nominal working pressure (±1 MPa) while at a temperature of 85 °C. The container shall be held at this pressure and temperature for 1 000 h.

17.5.4.7 Extreme temperature pressure cycling test

Containers shall be pressure cycled at −40 °C or lower to 80 % of the nominal working pressure (±1 MPa) in accordance with the test procedure specified in 17.3.4.2 c), d) and e), except that the container shall be cycled to 20 % of 5 500, 7 500 or 11 000 cycles, as appropriate.

Containers shall be pressure cycled at 85 °C or higher to 125 % of the nominal working pressure (±1 MPa) in accordance with the test procedure specified in 17.3.4.2 a) and b), except that the container shall be cycled at 95 % relative humidity and to 20 % of 5 500, 7 500 or 11 000 cycles, as appropriate.

17.5.4.8 Hydraulic residual pressure test

Containers shall be pressurized to 180 % of the nominal working pressure and held for 4 min. The container shall not rupture.

17.5.4.9 Residual burst test

Containers shall be subjected to the burst test specified in 17.3.5. The container shall burst at a pressure that is at least 80 % of the burst pressure determined in 17.3.5.

17.5.5 Container test for expected on-road performance

In order for a Category B container to be fully qualified for on-road vehicle usage, a container test shall be conducted at a system level in accordance with the UN GTR No. 13, SAE J2579 or equivalent hydrogen and fuel cell vehicle standards.

17.6 Category C: design qualification conditions and limitations

17.6.1 Marking information

15.1.2 a) 8) does not apply.

17.6.2 Material tests for steel containers and liners

If the container or liner is made of steel, appropriate material tests in accordance with ISO 9809-1:2010, 10.2 to 10.4, or ISO 9809-2:2010, 10.2 to 10.4, shall be carried out on one liner. The tensile strength shall meet the container manufacturer’s design specifications. For Type 1 and Type 2 containers the steel elongation shall be at least 14 %. For Type 3 containers the tensile strength and elongation shall meet the container manufacturer’s design specifications.

17.6.3 Material tests for aluminum alloy containers and liners

For Type 1 containers and Type 2 liners using aluminum alloy, appropriate material tests as required in ISO 7866:2012 10.2 and 10.3, as well as Annexes A and B, shall be carried out on one container or liner. The materials properties shall meet the container manufacturer’s design specifications. The elongation shall be at least 12 %. For Type 3 liners using aluminum alloy, materials tests as required in ISO 7866:2012 10.2 and Annex B shall be carried out on one liner. The materials properties, including elongation, shall meet the container manufacturer’s design specifications.

A suitable aluminium alloy for hydrogen service is AA6061 in the T6, T62, T651 or T6511 heat treats.

17.7 Qualification test results

A record of all tests for each design describing test setup, procedure and result shall be kept on file by the container manufacturer. These records shall include the complete Inspector's Record and the information contained in Table 7 and Table 8 for each container design tested.

Table 7 — Container design information (See 17.7)

Container type (check one): 1 _________ 2 _________ 3 _________ 4 _________

Manufacturer ____ Part No. ____________
Service pressure _____________________ MPa
Hydrostatic test pressure _____________________ MPa
Autofrettage pressure _____________________ MPa
Minimum prescribed burst pressure ____________________MPa
Volume (water) _____________________ l
Length _____________________ mm
Inside diameter _____________________ mm
Outside diameter _____________________ mm
Liner material _____________________
Boss material _____________________
Filament material _____________________
Resin system material _____________________
Container weight (nominal) _____________________ kg
Liner weight (nominal) _____________________ kg
Composite weight (nominal) _____________________ kg
Liner sidewall thickness (minimum) _____________________ mm
Liner yield strength (minimum) _____________________ MPa
Composite longitudinal thickness (nominal) _____________________ mm
Composite circumferential thickness (nominal) _____________________ mm
Composite resin shear strength water boil (minimum) _____________________ MPa

Table 8 — Container stress distribution information (See 17.7)

	Stress distribution					
	Direction		**Distribution** MPa		**Distribution** %	
Pressure	**Long.**	**Circ.**	**Liner**	**Overwrap**	**Liner**	**Overwrap**
Zero	X	—				
	—	X				
Service	X	—				
	—	X				
Test	X	—				
	—	X				
Burst	X	—				
	—	X				

Inspector ____ Date ________________

Annex A
(informative)

Visual inspection

NOTE This informative Annex has been written in mandatory language to facilitate the adoption by anyone wishing to do so.

A.1 Methods for external visual inspection of compressed hydrogen gas vehicle (HGV) fuel containers and their installations

The inspection shall be performed by a qualified container Inspector in accordance with the container manufacturer's recommendations and the inspection procedures provided in ISO 19078 or Compressed Gas Association (CGA) C-6.4. Inspections shall be documented by the Inspector and the documentation shall be made available to the AHJ upon request. Alternatively, containers may be inspected as installed using a non-destructive test method approved by the container manufacturer.

Containers without labels containing mandatory information, or with labels containing mandatory information that is illegible in any way, shall be removed from service. If the container can be positively identified by container manufacturer and serial number, a replacement label supplied by the container manufacturer may be applied to the container and it may remain in service.

A.2 Conditions requiring immediate inspections

Containers that have been involved in collisions, accidents, fires or other events [for a more comprehensive list, see ISO 19078:2013, 7.4.1 or the Compressed Gas Association (CGA) C-6.4] that may cause damage shall be subjected to inspection procedures provided in ISO 19078:2013 or CGA C-6.4. Containers that have not experienced any rejectable damage may be returned to service; otherwise, the container shall be destroyed per ISO 19078:2013 or CGA C-6.4 or returned to the container manufacturer for evaluation.

Annex B
(informative)

Non-destructive examination

NOTE This informative Annex has been written in mandatory language to facilitate the adoption by anyone wishing to do so.

B.1 Non-destructive examination (NDE) defect size determination

For Type 1, 2, and 3 designs, the NDE defect size required for production inspection under 10.1 shall be determined using a method as described under B.2, B.3, or other suitable methods.

B.2 NDE defect size by engineering critical assessment

For any metal whose fatigue performance is adversely affected by exposure to high-pressure hydrogen, all fatigue calculations shall use property data that has been determined by test in the representative hydrogen environment. ANSI/CSA CHMC 1 provides guidance for appropriate material test methods.

Calculations shall be performed in accordance with BS 7910-2005, section 8, using the following steps:

a) Fatigue cracks shall be modelled at the high stress location in the wall/liner as planar flaws.

b) The applied stress range at the fatigue sensitive site, due to a pressure between 10 % of the nominal working pressure and the nominal working pressure, shall be established from the stress analysis as outlined above.

c) The bending and membrane stress component may be used separately.

d) The minimum number of pressure cycles is 750 times the service life in years.

e) The fatigue crack propagation data shall be determined in air in accordance with ASTM E647, or ISO 12108. The crack plane orientation shall be in the C-L direction (i.e. crack plane perpendicular to the circumferences and along the axis of the container), as illustrated in ASTM E399. The rate shall be determined as an average of three specimen tests. Where specific fatigue crack propagation data are available for the material and service condition, they may be used in the assessment.

f) The amount of crack growth in the thickness direction and in the length direction per pressure cycle shall be determined in accordance with the steps outlined in BS 7910, section 8.4, by integrating the relationship between the rate of fatigue crack propagation, as established in B.2 e), and the range of crack driving force corresponding to the applied pressure cycle.

g) The incremental crack dimension or stress intensity factor calculated in B.2 f) should be compared with the limiting value, as per BS 7910, section 8.2.4.

h) Using the above steps, calculate the maximum allowable defect depth and length that shall not cause the failure of the container during the service life due to either fatigue or rupture. The defect size for NDE shall be equal to or less than the calculated maximum allowable defect size for the design.

B.3 NDE defect size by flawed container cycling

When metals whose fatigue performance is adversely affected by exposure to high-pressure hydrogen are used, the flawed container cycling shall be performed using hydrogen gas meeting the purity limits in 4.5.

For Type 1, 2, and 3 designs, three containers containing artificial defects that exceed the defect length and depth detection capability of the NDE inspection method required in 10.1 shall be pressure cycled to failure in accordance with the test method in 17.3.2. For Type 1 designs having a fatigue sensitive site in the cylindrical part, external flaws shall be introduced in the side wall. For Type 1 designs having the fatigue sensitive site outside the side wall and for Type 2 and 3 designs, internal flaws shall be introduced. Internal flaws may be machined prior to the heat treating and closing of the end of the container.

The containers shall not leak or rupture in less than a number of cycles equivalent to 750 times the service life of the container in years.

The allowable defect size for NDE shall be equal to or less than the artificial flaw size at that location.

Annex C
(informative)

Records of manufacture

C.1 Record of manufacture of compressed hydrogen vehicle fuel containers

Manufactured by ____

Located at ____

Certification number or symbol ____

Manufacturer's number ____

Serial numbers __________________________ to ___________________________________inclusive

Container type (check one): 1 ______ 2 ______ 3 ______ 4 ______

Size: ______ mm outside diameter by ______ mm overall length (excluding container appurtenances).

Marks stamped on the shoulder or on labels of the container are:

Manufacturer name/Contact information ____

Date of manufacture____

Date of removal from service____

Number of cycles (Category B only)____

“ISO 19881:xxxx-Hyyz”____

“MFP xx.x”____

Manufacturer part number and serial number____

“For Use Only With the Container Manufacturer’s Approved Pressure Relief Devices and Valves.” (Not required for Category 3 containers)

“Container Service Life Ends After Use in a Single Vehicle — Container Transfer Between Vehicles is Prohibited.”

“Mounting Shall Be In Accordance With The Container Manufacturer’s Instructions.”

Each container was made in compliance with all details of ISO 19881 in accordance with the specified type. Required records of test results are attached.

I hereby certify that all these containers proved satisfactory in every way and are in compliance with the requirements of ISO 19881.

Comments: ____

____

Inspection agency ____

Inspector's signature ____

Manufacturer's signature ____

Place ____ Date _________

C.2 Record of chemical analysis of material for metallic containers, liners and bosses

Container type (check one): 1 ______ 2 ______ 3 ______ 4 ______

Size: ______ mm outside diameter by ______ mm overall length (excluding container appurtenances).

Material description ____

Steel

Test No.	Heat No.	Jominy Hardness (HRC)		Check analysis number	Containers represented (serial Nos.)	Chemical analysis								
		First	Last			C	P	S	Si	Mn	Cr	Mo	B	Al

Aluminum

Alloy designation (per alum. assoc.)	Containers represented (serial Nos.)	Chemical analysis											
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Others	
												Ea.	Total

Inspection agency ____

Inspector's signature ____

Manufacturer's signature ____

Place ____ Date ________________

C.3 Record of mechanical properties of material for metallic containers, liners, and bosses

Container type (check one): 1 ______ 2 ______ 3 ______ 4 ______

Size: ______ mm outside diameter by ______ mm overall length (excluding container appurtenances).

Material description

Tensile specimen size: Width ______ mm by mm ______ gauge length.

Impact specimen size: 10 mm deep by ______ mm wide. (Not applicable to aluminum.)

Heat or batch code number	Containers represented (serial Nos.)	Yield strength at 0,2 % offset MPa	Tensile strength MPa	Elongation %

Charpy V-notch test		
Energy		Lateral expansion
Average value for 3 specimens J/cm^2	Minimum value for 1 specimen J/cm^2	Range value for 3 specimens mm

Heat codes stamped into each container (yes or no)

Inspection agency ____

Inspector's signature ____

Manufacturer's signature ____

Place ____ Date ________________

Annex D
(informative)

Design qualification test rationale

D.1 Category A, B and C design qualification tests

D.1.1 Ambient cycling test

The minimum number of pressure cycles without leakage (between 5 500 and 11 000) is established to verify the resistance to leakage. 22 000 cycles provides additional assurance with respect to rupture. 22 000 empty-to-full fueling cycles is expected to be equivalent to over 10 million km of driving. Absence of rupture in hydraulic pressure cycling is demonstrated under the most stressful pressure cycling condition, which is the empty-to-full fill (from less than 2 MPa to 125 % of the nominal working pressure). Note that a faster test time (lower number of pressure cycles until leakage occurs) can be achieved by cycling to higher pressures but that can elicit failure modes that could not occur in real world service.

See also the rationale in D.3, D.4 and D.5 for the number of fill cycles.

D.1.2 Environmental test

The primary historical cause of rupture of high pressure vehicle containers (CNG containers), other than fire and physical damage, has been stress corrosion cracking — this cracking can occur during exposure to a combination of corrosive chemicals and pressurization. Stress corrosion cracking of on-road glass-composite wrapped containers exposed to battery acid was replicated by the proposed test protocol; other chemicals were added to the test protocol once the generic risk of chemical exposure was recognized.

D.1.3 Pendulum impact preconditioning

On-road impacts that degrade the exterior structural strength and/or penetrate protective coatings (e.g. flying stone chips) is simulated by pendulum impact. The pendulum impact simulates a sharp stone measuring 25,4 mm in diameter travelling at 100 km/h.

D.1.4 Environmental fluids for exposure

D.1.4.1 General

In a study conducted by Battelle Memorial Institute (Columbus), “Categorization and Ranking of Potential NGV Environments and Their Influence”, a list of over 160 chemicals encountered in vehicular environments was grouped into five categories, and one from each was selected. The five categories were acid, base, hydrocarbon, ammonia and surfactant.

a) Fluids include fluids used on vehicles (battery acid and washer fluid), chemicals used on or near roadways (fertilizer nitrates and lye), and fluids used in fueling stations (methanol and gasoline).

b) The primary historical cause of rupture of high pressure vehicle containers (CNG containers), other than fire and physical damage, has been stress corrosion rupture — rupture occurring after a combination of exposure to corrosive chemicals and pressurization.

c) Stress corrosion rupture of on-road glass-composite wrapped containers exposed to battery acid was replicated by the proposed test protocol; other chemicals were added to the test protocol once the generic risk of chemical exposure was recognized.

d) Penetration of coatings from impacts and expected on-road wear can degrade the function of protective coatings — recognized as a contributing risk factor for stress corrosion cracking (rupture); capability to manage that risk is therefore required (pendulum impact).

D.1.4.2 Pressure cycle and pressure hold

The 3 000 cycle number was based on the concept of 750 cycles per year = 4 years, which is the period between visual re-inspections, at which time environmental damage should be detected.

D.1.4.3 Acceptable results

Fueling station over-pressurization is constrained by fueling station requirements to less than or equal to 150 % of the nominal working pressure.

Laboratory data on static stress rupture used to define equivalent probability of stress rupture of composite strands after 4 min at 180 % of the nominal working pressure with after 10 h at 150 % of the nominal working pressure as the worst case[15]. Fueling stations are expected to provide over-pressure protection up to 150 % of the nominal working pressure.

Testing at the "end-of-life" provides assurance to survive fueling station failure throughout the service life.

D.1.5 Extreme temperature cycling test

The extreme temperature values have been defined by automotive OEM design conditions. Limiting the cold temperature test to 4 000 cycles and the hot temperature test to 4 000 cycles recognizes the fact that vehicle containers do not experience only a combination of extreme cold and extreme hot cycles during their lifetime. The 180 % of the nominal working pressure residual burst pressure at the end of cycle testing recognizes that a container at the end of life must survive possible fueling station overpressure exceeding 150 % of the nominal working pressure. Note that the temperature of the fluid in the container shall be monitored, as the temperature measured on the outside skin of a composite-reinforced container is insulated from the internal skin temperature.

D.1.6 Flaw tolerance test

Cuts characteristic of wear from mounting straps can cause severe abrasion of protective coatings or composite reinforcement.

The 3 000 cycle number without leak or rupture was based on the concept of 750 cycles per year = 4 years, which is the period between visual re-inspections, at which time drop damage should be detected. Additional cycles are required to ensure that the container would not fail during its intended service life, or if it did fail, it would only leak.

D.1.7 Drop test

The risk is primarily an aftermarket risk during vehicle repair where a new storage system, or an older system removed during vehicle service, is dropped from a fork lift during handling. The test procedure requires drops from several angles from a maximum utility forklift height. The test is designed to demonstrate that containers have the capability to survive representative pre-installation drop impacts.

D.1.8 Fire test

The fire test is designed to demonstrate that finished containers, complete with the fire protection system specified in the design, will prevent the rupture of the container when tested under the specified fire conditions. The rationale for the test conditions is provided in UN GTR No. 13, section (d) “Rationale for paragraphs 5.1.4. and 6.2.5. verification test for service-terminating performance in fire”.

Verification of performance under service-terminating conditions is designed to prevent rupture under conditions so severe that hydrogen containment cannot be maintained. Fire is the only service-terminating condition accounted for in design qualification.

A comprehensive examination of CNG container in-service failures during the past decade[14] showed that the majority of fire incidents occurred on storage systems that did not utilize properly designed pressure relief devices (PRDs), and the remainder resulted when PRDs did not respond to protect the container due to the lack of adequate heat exposure on the PRDs even though the localized fire was able to degrade the container wall and eventually cause the storage container to burst. The localized fire exposure has not been addressed in previous industry standards.

The fire test conditions were based on vehicle-level tests by the Japanese Automobile Research Institute (JARI) and US vehicle manufacturers. A summary of data is found in Reference [14]. Key findings are as follows:

a) About 40 % of the vehicle laboratory fires investigated resulted in conditions that could be categorized as a localized fire since the data indicates that a composite compressed gas container could have been locally degraded before conventional PRDs on end bosses (away from the local fire exposure) would have activated.

   Note A temperature of 300 °C was selected as the temperature where the localized fire condition could start as thermal gravimetric analysis (TGA) indicates that container materials begin to degrade rapidly at this temperature.

b) While vehicle laboratory fires often lasted 30 min to 60 min, the period of localized fire degradation on the storage containers lasted less than 10 min;

c) The average of the maximum temperature during the localized fire period was less than 570 °C with peak temperatures reaching approximately between 600 °C and 880 °C in some cases;

d) The rise in peak temperature near the end of the localized fire period often signalled the transition to an engulfing fire condition.

Based upon the above findings, the temperature profile in Figure 2 was adopted. The selection of 600 °C as the minimum temperature for the localized fire hold period ensures that the average temperature and time of localized fire test exposure are consistent with test data. Thermocouples located at 25 mm ± 10 mm from the outside surface of the test article are used to control the heat input and confirm that the required temperature profile is met. In order to improve the response and controllability of the fire during testing (as well as the reproducibility of results), the use of Liquefied Petroleum Gas (LPG) and wind guards are specified. Experience indicates that the controllability of the LPG fire is approximately ±100 °C in outdoor situations, producing peak temperatures that also agree favourably with test results.

The proposed localized fire test set-up is based on the preliminary work done by Transport Canada and the National Highway Traffic Safety Administration (NHTSA) in the United States of America, but the approach was expanded to allow the storage system to be qualified by either a generic installation test or a specific vehicle installation test. Differences between the two methods are as follows:

a) The generic (non-vehicle specific) one allows the localized fire test to apply to more than one vehicle but the mitigation devices (such as shields) need to be permanently affixed to the storage system and should protect the entire system, not just the area exposed to the localized fire. The size for the generic localized fire test was selected to be 250 mm ± 50 mm longitudinally with a width covering the diameter of the container;

b) The specific vehicle installation localized fire test can be customized to align with the actual fire exposure area and can include protective features from the vehicle. If the vehicle manufacturer elects to use the specific vehicle test approach, the direction and size of the localized fire exposure is adjusted to account for vehicle features such as openings in adjacent sheet metal for lightening holes and pass-throughs for wires and piping or holes formed by the melting of materials in the path of the fire. If such openings or holes are small, the size of the localized fire is reduced from the generic size to create a more challenging (and realistic) test.

D.1.9 Accelerated stress rupture test

The test was originally developed to determine if the applied stresses in an as-built composite reinforcement exceeded the stress ratios. It was found that sustained loading for 1 000 h at high temperature could cause the stress rupture of glass fiber composite container designs that had otherwise failed in 2 years of active service.

The test is also used to simulate high temperature full-fill parking up to 25 years (prolonged exposure to high pressure). To avoid a performance test lasting for 25 years, a time-accelerated performance test using increased pressure developed using experimental material data on currently used metals and composites, and selecting the worst-case for stress rupture susceptibility, which is glass fibre reinforced composite. The use of laboratory data to establish the equivalence of testing for stress rupture at 100 % of the nominal working pressure for 25 years and testing at 125 % of the nominal working pressure for 1 000 h (equal probability of failure from stress rupture) is described in Reference [15]. Laboratory data on high pressure container composite strands — documentation of time-to-rupture as a function of static stress without exposure to corrosives — is summarized in Reference [16].

a) No formal data is available on parking duration per vehicle at different fill conditions. Examples of expected lengthy full fill occurrences include vehicles maintained by owners at near full fill conditions, abandoned vehicles and collectors' vehicles. Therefore, 25 years at full fill is taken as the test requirement.

b) The testing is performed at +85 °C because some composites exhibit a temperature-dependent fatigue rate [potentially associated with resin oxidation per joule. Composite Materials 11, 79 (1977)]. A temperature of +85 °C is selected as the maximum potential exposure because an under-hood maximum temperature of +82 °C has been measured within a dark-coloured vehicle parked outside on asphalt in direct sunlight in 50 °C ambient conditions. Also, a compressed gas container, painted black, with no cover, in the box of a black pickup truck in direct sunlight in 49 °C had maximum/average measured container skin surface temperatures of 87 °C/70 °C.

D.1.10 High strain rate impact test

The test demonstrates impact and fragmentation resistance of a container design, and is specifically retained to address the key differences of new materials technologies.

D.1.11 Permeation test

The permeation value for light duty vehicles results from a European Commission Network of Excellence “HySafe” activity to estimate an allowable hydrogen permeation rate for automotive legal requirements and standards[17]. The allowable permeation rate for hydrogen has been estimated based on a number of key assumptions:

- a structure should be safe regardless of the vehicle that enters it (although what vehicle can physically enter the structure is a limit in itself);
- the allowable rate should be set so the vehicle is safe throughout its intended service life;
- the allowable rate should not rely on regulations affecting the structure to ensure safety, i.e. safety should be assured independent of the combination of vehicle and structure.

Accordingly, the specific assumptions used in the analysis included the following:

- permeated hydrogen can be considered to disperse homogeneously;
- worst credible natural ventilation rate for a domestic garage is 0,03 air changes per hour;
- maximum permitted hydrogen concentration is 1 % by volume, i.e. 25 % LFL;
- maximum long term material temperature is 55 °C;
- new container, with a factor of 2 to convert from the worst case end of life condition;

- — for a test conducted at a temperature of 20 °C, a factor of 3,5 is used to convert from the maximum prolonged material temperature to the test temperature (factor 4,7 at 15 °C).

Based on the above assumptions, scenarios and methodology, the theoretical allowable permeation rates to give a hydrogen concentration less than 1 % in air is 6,0 ml/h/l water capacity at a 15 °C testing temperature.

D.1.12 Boss torque test

A safety margin of 2 is applied to the container manufacturer's recommended torque value for fittings attached to the metal end boss in plastic-lined containers.

D.1.13 Hydrogen gas cycling test

This is a performance test to evaluate the durability of the plastic liner in compressed hydrogen environments, including

- — integrity of the plastic liner/end boss interface,
- — excessive static electric discharges causing pinhole leaks,
- — effects of permeation over time on porosity in the liner, and
- — effects of extreme temperatures generated with fast fills and discharges.

D.1.14 Leak before break test

A potential failure mode in all-metal or metal-lined containers is the growth of a fatigue crack. The design shall demonstrate that it will leak and not "break" when a fatigue crack grows through the metal wall. Pressure cycle testing is conducted at 150 % of the nominal working pressure to maximize the aspect ratio of fatigue cracks that grow from defects on the liner surface. Pressure cycle testing at even higher pressures would increase the risk of generating failure mechanisms that would not occur in service. This test does not apply to Type 3 designs because the metal liner does not carry the majority of the wall stress, thus a through-wall fatigue crack in the liner can only result in a leak condition. This test does not apply to Type 4 designs because a failure of the plastic liner, which is non-loadsharing, will not result in rupture of the container, and because the fatigue life of the reinforcing fibers is significantly greater than the required life of the container.

D.2 Category B design qualification tests

The rationale for Category B container tests are detailed in the ECE/TRANS/180/Add.13, UN GTR No. 13, established in the Global Registry on 27 June 2013.

D.3 Category A container fill cycles

Category A containers are containers that are intended to be used in light duty and heavy duty land vehicle applications, regardless of the potential for further qualification to the UN GTR No. 13 for hydrogen and fuel cell vehicles. The 750 cycles per year is based on the extreme condition of assuming 2 empty-to-full fuelings per day for continual full-day service. Transit authorities have required up to 25 years of life × 750 cycles = 18 750 cycles total. The robustness of this specification is assured by the recognition that 18 750 cycles × 320 km (200 miles) per fueling cycle exceeds 6 million km (3,5 million miles) driven.

D.4 Category B container fill cycles

Category B containers are containers that are intended to be further qualified in accordance with the UN GTR No. 13 for hydrogen and fuel cell vehicles with a gross vehicle mass of 4 536 kg or less. Pressure cycles are greater than or equal to 5 500 and less than or equal to 11 000.

The differences in the anticipated maximum number of fuelings are primarily associated with high usage commercial taxi applications, which can be subjected to very different operating constraints in different regulatory jurisdictions. For example:

a) Vehicle fleet odometer data (including taxis): Sierra Research Report No. SR2004-09-04 for the California Air Resource Board (2004) reported on vehicle lifetime distance traveled by scrapped California vehicles, which all showed lifetime distances traveled below 560 000 km (350 000 miles). Based on these figures and 320 km to 480 km (200 miles to 300 miles) driven per full fueling, the maximum number of lifetime empty-to-full fuelings can be estimated as 1 200 to 1 800.

b) Vehicle fleet odometer data (including taxis): Transport Canada reported that required emissions testing in British Columbia, Canada, in 2009 showed the 5 most extreme usage vehicles had odometer readings in the 800 000 km to 1 000 000 km (500 000 miles to 600 000 miles) range. Using the reported model year for each of these vehicles, this corresponds to less than 300 full fuelings per year, or less than 1 full fueling per day. Based on these figures and 320 km to 480 km (200 miles to 300 miles) driven per full fueling, the maximum number of empty-to-full fuelings can be estimated as 1 650 to 3 100.

c) Taxi usage (shifts/day & days/week) data: The New York City (NYC) Taxicab Fact Book (Schaller Consulting, 2006) reports extreme usage of 320 km (200 miles) in a shift and a maximum service life of 5 years. Less than 10 % of vehicles remain in service as long as 5 years. The average mileage per year is 72 000 for vehicles operating 2 shifts per day and 7 days per week.

d) There is no record of any vehicle remaining in high usage through-out the full 5 year service life. However, if a vehicle were projected to have fueled as often as 1,5 to 2 times per day and to have remained in service for the maximum 5-year NYC taxi service life, the maximum number of fuelings during the taxi service life would be 2 750 to 3 600 fuelings.

e) Taxi usage (shifts/day & days/week) data: Transport Canada reported a survey of taxis operating in Toronto and Ottawa that showed common high usage of 20 h per day, 7 days per week with daily driving distances of 540 km to 720 km (335 miles to 450 miles). Vehicle odometer readings were not reported. In the extreme worst-case, it might be projected that if a vehicle could remain at this high level of usage for 7 years (the maximum reported taxi service life); then a maximum extreme driving distance of 1 400 000 km to 1 900 000 km (870 000 miles to 1 200 000 miles) is projected. Based on 320 km to 480 km (200 miles to 300 miles) driven per full fueling, the projected full-usage 15-year number of full fuelings could be 2 900 to 6 000.

Consistent with these extreme usage projections, the minimum number of full pressure hydraulic qualification test cycles for hydrogen storage systems is set at 5 500. The upper limit on the number of full-fill pressure cycles is set at 11,000, which corresponds to a vehicle that remains in the high usage service of 2 full fueling per day for an entire service life of 15 years, providing a lifetime vehicle mileage of 3,5 million km to 5,3 million km (2,2 million miles to 3,3 million miles).

Personal vehicles — Number of fueling/de-fueling cycles for verification test

The number of fueling cycles that a hydrogen storage system must be capable of performing requires the consideration of two scenarios of risk:

1) Expected service: the worst-case fueling exposure for a typical vehicle is taken as a lifetime consisting of the most stressful fuelings — fuelings from <2 MPa to 125 % of the nominal working pressure, which causes the maximum pressure and temperature change.
    i) The maximum number of empty-to-full fuelings during expected service is given by: (expected lifetime vehicle range)/(expected driving range per full fill).
    ii) Expected vehicle lifetime range is taken to be 250 000 km.
    iii) Expected vehicle range per full fueling is taken to be 483 km based on 2006 to 2007 market survey (Nissan, Daimler, Chrysler, General Motors, Ford, Honda, Toyota).
    iv) Therefore, the expected number of full fuelings in the worst-case (only full fuelings in vehicle lifetime) is taken to be 500 (approximately 250 000/483).
    v) Since the stress of full fuelings exceeds the stress of partial fuelings, the design verification test provides a significant margin of additional robustness.
2) Extended durability: extreme usage — where the vehicle sustains an extreme number of fuelings.
    i) A higher than expected number of fuelings occurs if the vehicle lifetime mileage is higher than expected, the vehicle range per full fill is lower than expected, and/or the average vehicle fueling is less than a full fill.
    ii) The high-frequency extreme number of partial fuelings is given by: (extreme-usage lifetime vehicle range)/(minimal vehicle range per full fill)/(minimal lifetime average fill volume fraction).
    iii) The minimal lifetime average fill volume fraction is taken as 0,33. Reliable statistics on current fill volume fraction are not available; statistics for hydrogen-fueled vehicles will be influenced by the availability of hydrogen fueling stations. The qualification test specification is based on the assumption that a lifetime of fuelings needing <33 % of fuel capacity provides a high-frequency extreme associated with a lifetime average of fuelings on intervals of 112 km to 160 km traveled.
    iv) Extreme-usage lifetime vehicle range is taken as 590 000 km. Sierra Research Report No. SR2004-09-04 for the California Air Resource Board (2004) on vehicle lifetime mileage showed all scrapped vehicles had mileage below 563 500 km (the 3-sigma value, the 99,8th percentile, was 418 000 km; the 6-sigma value was 590 000 km).
    v) Minimal vehicle range per full fill is taken as 322 km. At present all on-road vehicles produced by high volume vehicle manufacturers have a vehicle range per full fill greater than 500 km.
    vi) Therefore, the extreme number of fuelings is taken as 5 500 = 3 × 590 000/322.
    vii) Robustness (safety margin) of extended durability design-qualification requirement.
3) A vehicle with a modest driving range of 322 km per full fueling would have to be driven over 1,6 million km to require 5 500 empty-to-full fuelings.
4) Low-volume partial fills cause markedly lower swings in temperature and pressure, and consequently markedly lower stresses than empty-to-full fill stresses. Comprehensive data is not available (stresses an order of magnitude lower than empty-to-full fuelings have been seen). Therefore, conducting the high frequency fueling pressure cycle tests with empty-to-full fueling pressure swings provides a margin of robustness potentially on the order of ×10.

D.5 Category C container fill cycles

Category C containers are containers that are intended to be used on hydrogen powered industrial trucks. The 1 125 cycles per year is based on the extreme condition of assuming 3 empty-to-full fuelings per day for continual full-day service, which is a very realistic possibility for industrial truck applications.

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Committee representation

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The committee consisted of representatives of the following nominating organisations:

Coregas
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Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
GNS
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HW Richardson Group
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New Zealand Standard

Gaseous hydrogen − Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers

Contents

Preface
[ISO] standard

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the minimum requirements for pressure-relief devices intended for use on hydrogen-fuelled vehicle fuel containers that comply with:

(a) ISO 19881 *Gaseous hydrogen − Land vehicle fuel container*; or
(b) IEC 62282-4-101 *Fuel cell technologies − Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety*; or
(c) CSA/ANSI HGV 2 *Compressed hydrogen gas vehicle fuel containers*; or
(d) CSA B51 *Boiler, pressure vessel, and pressure piping code*; or
(e) J2579 *Standard for fuel systems in fuel cell and other hydrogen vehicles*; or
(f) UN global technical regulation (GTR) No. 13 *Hydrogen and fuel cell vehicles*; or
(g) Commission regulation 2010/406/EU of the European Parliament and of the Council of 26 April 2010 implementing regulation (EC) 2009/79 on type-approval of hydrogen-powered motor vehicles.

The scope of this document is limited to thermally activated pressure-relief devices installed on fuel containers used with:

(h) Fuel-cell-grade hydrogen according to J2719 *Hydrogen fuel quality for fuel cell vehicles* or section 5 (Hydrogen quality requirements for PEM fuel cell road vehicle application) of ISO 14687 *Hydrogen fuel quality − Product specification* for fuel cell land vehicles; and
(i) Grade A or better hydrogen according to ISO 14687 *Hydrogen fuel quality – Product specification* for internal combustion engine land vehicles.

This document also contains requirements for thermally activated pressure-relief devices acceptable for use aboard light-duty vehicles, heavy-duty vehicles, and powered industrial trucks, such as forklifts and other material-handling vehicles, as it pertains to UN GTR No. 13.

Pressure-relief devices designed to comply with this document are intended to be used with high-quality hydrogen fuel such as fuel complying with ISO 14687 Type 1 Grade D or J2719. Pressure-relief devices can be of any design or manufacturing method that meets the requirements of this document.

This document does not apply to reseating, resealing, or pressure-activated devices.

Documents which apply to hydrogen fuel vehicles and hydrogen fuel subsystems include IEC 62282-4-101 *Fuel cell technologies − Part 4-101: Fuel cell power systems for electrically powered industrial trucks − Safety*, J2578 *Recommended practice for general fuel cell vehicle safety*, and J2579 *Standard for fuel systems in fuel cell and other hydrogen vehicles*.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 19882:2018 *Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*.

As this standard is reproduced from an international standard, the following applies:

(j) In the source text, 'this International Standard' should read 'this New Zealand standard';
(k) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL
STANDARD

**ISO
19882**

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Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers

Hydrogène gazeux — Dispositifs limiteurs de pression thermiquement activés pour les conteneurs de carburant de véhicules à hydrogène comprimé

Reference number
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Contents

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to promote the implementation of hydrogen powered land vehicles through the creation of performance based testing requirements for thermally activated pressure relief devices for compressed hydrogen fuel containers. The successful commercialization of hydrogen land vehicle technologies requires standards pertaining to fueling stations, vehicle fuel system components and the global homologation of standards requirements for technologies with the same end use. This will allow manufacturers to achieve economies of scale in production through the ability to manufacture one product for global use.

This document is based on the CSA Standard ANSI/CSA HPRD 1-2013.

Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers

1 Scope

This document establishes minimum requirements for pressure relief devices intended for use on hydrogen fuelled vehicle fuel containers that comply with ISO 19881, IEC 62282-4-101, ANSI HGV 2, CSA B51 Part 2, EC79/EU406, SAE J2579, or the UN GTR No. 13.

The scope of this document is limited to thermally activated pressure relief devices installed on fuel containers used with fuel cell grade hydrogen according to SAE J2719 or ISO 14687 for fuel cell land vehicles, and Grade A or better hydrogen according to ISO 14687 for internal combustion engine land vehicles. This document also contains requirements for thermally activated pressure relief devices acceptable for use on-board light duty vehicles, heavy duty vehicles and industrial powered trucks such as forklifts and other material handling vehicles, as it pertains to UN GTR No. 13.

Pressure relief devices designed to comply with this document are intended to be used with high quality hydrogen fuel such as fuel complying with SAE J2719 or ISO 14687 Type 1 Grade D.

Pressure relief devices can be of any design or manufacturing method that meets the requirements of this document.

This document does not apply to reseating, resealing, or pressure activated devices.

Documents which apply to hydrogen fuel vehicles and hydrogen fuel subsystems include IEC 62282- 4- 101, SAE J2578 and SAE J2579.

Annex A presents an informative record of recommended fuel container, fuel storage subsystem and vehicle level requirements. The statements in Annex A are intended as recommendations for consideration of inclusion by the organizations and committees developing standards on these sub system and vehicle level standards.

Annex B presents a rationale for the design qualification tests in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1431-1, *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static and dynamic strain testing*

ISO 6270-2, *Paints and varnishes — Determination of resistance to humidity — Part 2: Condensation (in-cabinet exposure with heated water reservoir)*

ISO 14687[1], *Hydrogen fuel quality — Product specification*

ISO 19881, *Gaseous hydrogen — Land vehicle fuel containers*

ASTM D1149, *Standard Test Method for Rubber Deterioration-Surface Ozone Cracking in a Chamber*

ASTM D1193-06(R2011), *Standard Specification for Reagent Water*

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[1] To be published. Current stage 40.60

CSA ANSI HGV 2, *Compressed hydrogen gas vehicle fuel containers*

CSA B51-14, *Boiler, Pressure Vessel, and Pressure Piping Code*

EC79 (EU406), *Type-approval of hydrogen-powered motor vehicles*

SAE J2579:2013, *Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles*

SAE J2719, *Hydrogen Fuel Quality for Fuel Cell Vehicles*

UN GTR No. 13, *UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
flow capacity
<pressure relief device> capacity in volume per unit time at specified conditions

3.2
fusible material
metal, alloy, or other material capable of being melted by heat where the melting is integral to the function of the *pressure relief device* (3.6)

3.3
manufacturer's specified activation temperature
temperature, as specified by the pressure relief device manufacturer, at which the *pressure relief device* (3.6) is designed to release pressure

3.4
manufacturer's specified nominal working pressure
highest settled pressure at a uniform gas temperature of 15 °C of the container or container assembly with which the *pressure relief device* (3.6) may be used, as specified by the pressure relief device manufacturer

3.5
normal cubic centimeters
Ncc
dry gas that occupies a volume of 1 cm^3 at a temperature of 273,15 K (0 °C) and an absolute pressure of 101,325 kPa

3.6
pressure relief device
device that, when activated under specified performance conditions, is used to vent the container contents

Note 1 to entry: Reseating and resealing devices are not addressed by this document.

3.7
thermally activated pressure relief device
TPRD
pressure relief device (3.6) activated by temperature

4 Service conditions

4.1 General

Fuel containers may accidentally be exposed to fire or elevated temperature. These conditions may act to increase the contained pressure or to degrade the structural materials, depending on the container type and materials of construction. A pressure relief device provides a means to vent the fuel container under these conditions.

A specific pressure relief device may not be suitable for all container types, sizes or installations. Fuel container or installation standards may require that a pressure relief device be tested in conjunction with other components.

CGA S1.1 states: “relief devices may not prevent burst of a cylinder under all conditions of fire exposure. When the heat transferred to the cylinder is localized, intensive, and remote to the relief device, or when the fire builds rapidly, such as in an explosion, and is of very high intensity, the cylinder can weaken sufficiently to rupture before the relief device operates, or while it is operating”.

The following service conditions are representative of what can be seen in an automotive service. These service conditions are provided as a basis for the design, manufacture, inspection and testing of pressure relief devices which are used in compressed hydrogen vehicle fuel containers.

4.2 Design service life

The design service life of the pressure relief device shall be specified by the pressure relief device manufacturer.

4.3 Nominal working pressure

This document applies to pressure relief devices that have a nominal working pressure, as specified by the manufacturer, of 25 MPa, 35 MPa, 50 MPa or 70 MPa at 15 °C, hereinafter referred to in this document as the following:

a) “H25” — 25 MPa;

b) “H35” — 35 MPa;

c) “H50” — 50 MPa;

d) “H70” — 70 MPa.

Other nominal working pressures for hydrogen gas besides those defined are allowed if the required qualification test requirements of this document are met.

4.4 Durability test cycles

The design pressure cycles for pressure relief devices shall be between not more than 10 % of the manufacturer's specified nominal working pressure and not less than 150 % of the manufacturer's specified nominal working pressure for ten cycles and between not more than 10 % of the manufacturer's specified nominal working pressure and not less than 125 % of the manufacturer's specified nominal working pressure for 14 990 cycles.

NOTE The maximum pressure under the condition of fueling station dispenser fault management is 150 % of the vehicle nominal working pressure, as defined in: SAE J2760, SAE J2579:2013, Appendix A and CSA HGV 4.1.

4.5 Temperature range

The pressure relief device shall be designed to maintain pressure integrity from −40 °C to 85 °C.

5 Quality assurance

Quality system programs shall be established and operated to demonstrate that pressure relief devices are produced in accordance with the qualified design.

6 General requirements

6.1 Material requirements

Materials normally in contact with hydrogen shall be determined to be acceptable in hydrogen service, with the consideration of hydrogen embrittlement and hydrogen accelerated fatigue. The performance tests cannot guarantee that all cases and conditions of the hydrogen service are validated, so it is still incumbent on the designer/builder to carefully screen materials of construction for their intended use. The materials and design shall be such that there is no significant change in the functioning of the device, deformation or mechanical change in the device, and no harmful corrosion, deformation or deterioration of the materials when subject to the service conditions given in Clause 4.

NOTE 1 Material performance data and/or acceptance criteria in hydrogen environments can be found in the ISO 11114 series, the Sandia National Laboratory Technical Reference for Hydrogen Compatibility of Materials, ANSI/AIAA G-095, ANSI/CSA CHMC 1, ASME B31.12, SAE J2579:2013, Appendix B or in equivalent national requirements.

NOTE 2 Some fusible alloys can contain heavy metals that can be considered environmentally unacceptable by some customers and which can be prohibited by some jurisdictions.

Non-metallic materials normally in contact with hydrogen shall be verified to be acceptable in the hydrogen service. Consideration shall be given to the fact that hydrogen diffuses through these materials more easily than through metals; therefore the suitability of materials shall be verified. Non-metallic materials shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of service conditions and lifetime as specified by the container manufacturer. Materials shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation. The chemical and physical properties necessary for operational safety shall not be significantly affected within the scheduled lifetime of the equipment unless a replacement is foreseen; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, aging resistance, the effects of temperature variations, the effects arising when materials are put together (for example, galvanic corrosion), the effects of ultraviolet radiation, and to the degradation effects of hydrogen on the mechanical performance of a material.

6.2 Design requirements

The design shall be such that, once activated, the device fully vents the contents of the fuel container. The design should minimize the possibility of external hazards (e.g. projectiles) resulting from the activation of the device. Any material released shall not interfere with the proper venting of the pressure relief device.

The pressure relief device shall be designed to address degradation from creep or plastic deformation. The design or manufacturing process should account for the effects of material defects, particularly casting and shrinkage voids, which adversely impact the robustness of the design.

6.3 Flow capacity

The flow capacity shall be indicated in the manufacturer’s published literature and verified by the flow capacity test under 7.13.

The adequacy of the flow capacity of pressure relief devices for a given application shall be demonstrated by bonfire testing in accordance with ISO 19881, ANSI HGV 2, CSA B51 Part 2, EC79/EU406, SAE J2579, or the UN GTR No. 13 for fuel cell vehicles and by the minimization of the hazardous effects of the pressure peaking phenomenon which can take place during high flow rate releases from small diameter vents in enclosed spaces.

6.4 Rework and repair

New pressure relief devices that do not meet the requirements of this document may be reworked or repaired as long as they satisfy the requirements of this document.

6.5 Failure modes and effects analysis (FMEA)

Design FMEA and Process FMEA shall be performed for pressure relief devices. The documents shall be made available for review by fuel container or vehicle manufacturers upon request. A verification of the existence of these documents satisfies the intent of this provision.

NOTE FMEA is a methodology used in the automotive industry to identify potentially hazardous failure modes of safety devices and recommend changes in design, manufacturing, inspection or testing which eliminate such failure modes or minimize their effects. FMEA is applied to both device design and to the manufacturing and assembly process to identify corrective actions that improve device reliability and safety. Available references include SAE J1739.

7 Design qualification testing

7.1 General

Design qualification testing shall be conducted on finished pressure relief devices that are representative of the normal production. Test reports shall be kept on file by the pressure relief device manufacturer and made available for review by fuel container manufacturers and end users upon request.

The design qualification testing required by this document shall, as appropriate and necessary, be supplemented by additional tests defined in “design controls” or “recommended action” in the Design FMEA.

Pressure relief devices representative of each design and design change shall be subjected to tests as prescribed in Table 1. Designs which are sufficiently similar to an existing fully qualified design shall be permitted to be qualified through a reduced test program as defined in Table 1. Design changes not falling within the guidelines in Table 1 shall be qualified as original designs.

Any additional tests or requirements shall be performed in accordance with appropriate published standards or procedures, as available.

Unless stated otherwise, the tests specified herein shall be conducted at an ambient temperature of 20 °C ± 5 °C.

Unless stated otherwise, the tests specified herein shall be conducted with the following tolerances on specified pressures and temperatures:

Pressures 2 MPa or less: +0/−1 MPa

Pressures 125 % NWP or greater: +2 MPa/−0 MPa

Temperatures ±5 °C

Hydrogen used for testing shall be high quality hydrogen fuel, such as fuel meeting the requirements of SAE J2719 or ISO 14687 Type 1 Grade D.

Table 1 — Test requirements for design and design changes

ISO 19882 Tests	Original design	Manufacturer's specified nominal working pressure	Manufacturer's specified activation temperature	Elastomeric seals	Orifice size	Body material	Surface coating	Inlet connection	Outlet connection
7.2 Pressure cycling	X	X	X	X		X		X	
7.3 Accelerated life	X	X	X	X		X			
7.4 Thermal cycling	X		X	X		X	X		
7.5 Accelerated cyclic corrosion	X			X		X	X		
7.6 Automotive fluid exposure	X	X				X	X		
7.7 Atmospheric exposure	X			External only					
7.8 Stress corrosion cracking resistance	X	X				X	X	X	
7.9 Impact due to drop & vibration	X	X	X			X		X	
7.10 Leakage	X	X	X	X		X	X	X	X
7.11 Bench top activation	X	X	X	X	X	X	X		
7.12 Flow capacity	X	X			X			X	X
7.13 High pressure activation and flow	X	X			X			X	X

NOTE "X" requires physical testing.

7.2 Pressure cycling

7.2.1 Sampling

Five finished pressure relief devices shall be subjected to the pressure cycling test.

7.2.2 Procedure

Pressure cycling shall be performed in accordance with the following procedure:

At a sample temperature not less than 85 °C, the first 10 pressure cycles shall be from not greater than 2 MPa to not less than 150 percent of the manufacturer's specified nominal working pressure rating, followed by 2 240 pressure cycles from not greater than 2 MPa to not less than 125 percent of the manufacturer's specified nominal working pressure, followed by 10 000 pressure cycles at a sample temperature not less than 20 °C from not greater than 2 MPa to not less than 125 percent of the manufacturer's specified nominal working pressure, followed by a final 2 750 pressure cycles at a sample temperature not more than −40 °C from not greater than 2 MPa to not less than 80 percent of the manufacturer's specified nominal working pressure. The pressure cycling shall be performed with hydrogen gas at a rate not exceeding 10 cycles per minute.

Table 2 — Pressure cycling conditions

Pressure cycles to %	No. of cycles	Sample temperature for cycles
2 MPa to 150 %	First 10	85 °C
2 MPa to 125 %	Next 2 240	85 °C
2 MPa to 125 %	Next 10 000	20 °C
2 MPa to 80 %	Final 2 750	−40 °C
NOTE All cycles are conducted at a rate not greater than 10 cycles per minute.		

7.2.3 Acceptable results

Following the pressure cycling test, the pressure relief devices shall meet the requirements of 7.10, 7.11, and 7.12.

7.3 Accelerated life

7.3.1 Sampling

a) Five finished pressure relief devices shall be subjected to the accelerated life test.

b) Three additional pressure relief devices shall be subjected to the manufacturer's specified activation temperature until activation.

Pressure relief devices employing a glass bulb (thermobulb) or shape memory alloys (or other materials that do not exhibit creep rupture phenomena) for activation are exempted from this Clause.

7.3.2 Procedure

Accelerated life testing shall be performed in accordance with the following procedure:

Pressure relief devices shall be placed in an oven or liquid bath with the temperature of the specimens held constant within ±1 °C throughout the test. Pressure on the inlet of the devices shall be elevated to 125 % of the manufacturer's specified nominal working pressure and held constant within ±0,7 MPa. The pressure supply may be located outside the controlled temperature oven or bath. The volume of liquid or gas should be limited to prevent damage to the test apparatus upon activation and venting. Each device may be pressurized individually or through a manifold system.

The accelerated life test temperature is T_L, given in °C by the expression:

$$T_L = 9{,}1 T_f^{0{,}503} \qquad (1)$$

where T_f is the manufacturer's specified activation temperature in °C.

7.3.3 Acceptable results

a) The five pressure relief devices tested at their accelerated life test temperature shall not activate in less than 500 h and shall meet the requirements of 7.10.

b) The three pressure relief devices tested at the manufacturer's specified activation temperature shall activate in less than 10 h.

NOTE The 10 h time is to confirm conformance for the basis for Formula (1).

7.4 Thermal cycling

7.4.1 Sampling

One finished pressure relief device shall be subjected to the thermal cycling test.

7.4.2 Procedure

Thermal cycling shall be performed in accordance with the following procedure:

The pressure relief device shall be thermally cycled between 85 °C or higher and −40 °C or lower as follows:

a) Place an unpressurized pressure relief device in a liquid bath maintained at −40 °C or lower for a period of 2 h or more. Transfer to a liquid bath maintained at 85 °C or higher within 5 min.

b) Maintain the unpressurized pressure relief device in a liquid bath maintained at 85 °C or higher for a period of 2 h or more. Transfer to a liquid bath maintained at −40 °C or lower within 5 min.

c) Repeat steps a) and b) until a total of 15 thermal cycles have been achieved.

d) With the pressure relief device conditioned for a minimum of 2 h in the −40 °C or lower liquid bath, cycle the pressure relief device between not more than 10 % of the manufacturer's specified nominal working pressure and not less than 80 % of the manufacturer's specified nominal working pressure for a total of 100 cycles. The liquid bath shall be maintained at −40 °C or lower during this test.

When testing long trigger devices, the longest length permitted by the design shall be used for this test.

7.4.3 Acceptable results

Following the thermal and pressure cycling, the pressure relief device shall meet the requirements of 7.10 (except that the test shall be conducted at −40 °C or lower), 7.11, and 7.12.

7.5 Accelerated cyclic corrosion

7.5.1 Sampling

Three finished pressure relief devices shall be subjected to the accelerated cyclic corrosion test.

7.5.2 Procedure

Accelerated cyclic corrosion shall be performed in accordance with the following procedure:

The pressure relief devices shall be exposed to an accelerated laboratory corrosion test, under a combination of cyclic conditions (salt solution, various temperatures, humidity, and ambient environment). The test method is comprised of 1 % (approximate) complex salt mist applications coupled with high temperature, high humidity and high temperature dry off. One (1) test cycle is equal to 24 h, as illustrated in Figure 1.

The apparatus used for this test shall consist of a fog/environmental chamber, suitable water supply conforming to ASTM D1193 Type IV, provisions for heating the chamber and the necessary means of controlling the temperature between 22 °C and 62 °C. The apparatus shall include provisions for a supply of suitably conditioned compressed air and one or more nozzles for fog generation. The nozzle or nozzles used for the generation of the fog shall be directed or baffled to minimize any direct impingement on the test samples.

The apparatus shall consist of the chamber design as defined in ISO 6270-2. During “wet-bottom” generated humidity cycles, the testing agency shall confirm that visible water droplets are found on the samples to verify proper wetness.

Steam generated humidity may be used provided the source of water used in generating the steam is free of corrosion inhibitors. During steam generated humidity cycles, the testing agency shall confirm that visible water droplets are found on the samples to verify proper wetness.

The apparatus for the dry off stage shall have the ability to obtain and maintain the following environmental conditions: temperature: 60 °C ± 2 °C and humidity: ≤30 % RH. The apparatus shall also have sufficient air circulation to prevent temperature stratification and also allow thorough drying of the test samples.

The force/impingement from this salt application should not remove corrosion or damage the coatings/paints system of test samples.

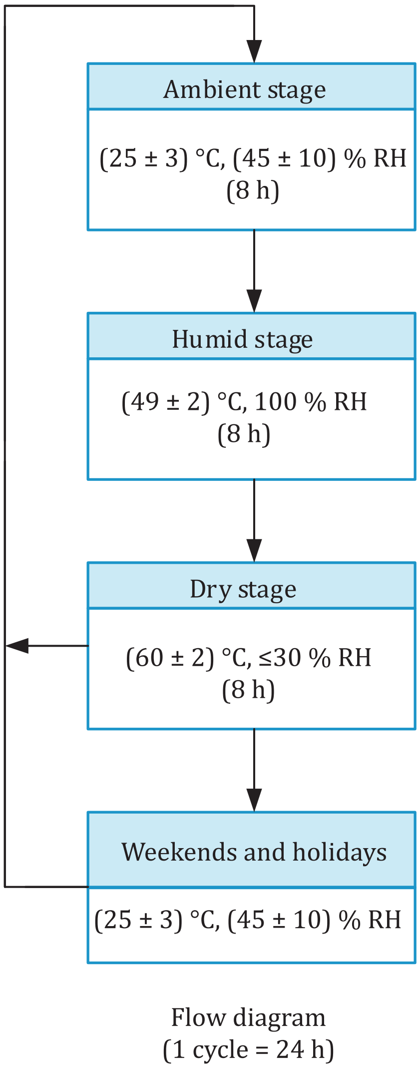

Figure 1 — Accelerated cyclic corrosion flow diagram

The complex salt solution in percent by mass shall be as specified below:

a) Sodium Chloride ($NaCl$): 0,9 %;

b) Calcium Chloride ($CaCl_2$): 0,1 %;

c) Sodium Bicarbonate ($NaHCO_3$): 0,075 %.

Sodium Chloride shall be reagent grade or food grade. Calcium Chloride shall be reagent grade. Sodium Bicarbonate shall be reagent grade (e.g., Baking Soda or comparable product is acceptable). Water shall meet ASTM D1193 Type IV requirements.

Either $CaCl_2$ or $NaHCO_3$ material shall be dissolved separately in water and added to the solution of the other materials. If all solid materials are added dry, an insoluble precipitate may result.

The pressure relief devices shall be installed in accordance with the manufacturer's recommended procedure and exposed to the cyclic corrosion test method illustrated in the Flow Diagram (Figure 1). Repeat the cycle daily until 100 cycles of exposure have been completed. For each salt mist application, the solution shall be sprayed as an atomized mist, using the spray apparatus to mist the components until all areas are thoroughly wet/dripping. Suitable application techniques include using a plastic bottle, or a siphon spray powered by oil-free regulated air to spray the test samples. The quantity of spray applied should be sufficient to visibly rinse away salt accumulation left from previous sprays. The first salt mist application occurs at the beginning of the ambient stage. Each subsequent salt mist application should be applied approximately 90 min after the previous application in order to allow adequate time for the test sample to dry.

Humidity ramp times between the ambient and wet condition, and between the wet and dry conditions, can have a significant effect on test acceleration (this is because corrosion rates are highest during these transition periods). The time from ambient to wet conditions shall be (60 + 5) min and the transition time between wet and dry conditions shall be (180 + 10) min.

7.5.3 Acceptable results

Immediately following the cyclic corrosion test, the pressure relief devices shall be rinsed with fresh tap water and allowed to dry. The tested samples shall then be subjected to 7.10, 7.11 and 7.12.

7.6 Automotive fluids exposure

7.6.1 Sampling

One finished pressure relief device shall be subjected to the automotive fluids exposure test.

7.6.2 Procedure

Automotive fluids exposure shall be performed in accordance with the following procedure:

External portions of components shall be able to withstand exposure to the following fluids without mechanical degradation. Resistance may be determined by the following test, by comparable published data, or by known properties (e.g., 300 series stainless steel). The decision about the applicability of test data and known properties is at the discretion of the testing authority.

The external surfaces of the pressure relief device shall be exposed to the following test. The inlet and outlet connections of one device shall be connected or capped in accordance with the pressure relief device manufacturer's installation instructions. The pressure relief device shall be exposed at an ambient temperature by spraying the exterior of the component once per hour, 24 times, over a period of up to three days (3 8 h shifts over 3 days or 24 h straight, for example). Alternatively, the pressure relief device may be immersed in the solution for a period of 24 h. In the immersion method, the fluid shall be replenished as needed to assure complete exposure for the duration of the test. A distinct test shall be performed with each of the following three fluids. One pressure relief device may be used for all three exposures sequentially.

a) Sulfuric acid – 19 % solution by volume in water;

b) Methanol/gasoline – 5 %/95 % concentration of M5 fuel meeting the requirements of Standard Specification for Automotive Spark-Ignition Engine Fuel, ASTM D4814;

c) Windshield washer fluid (50 % by volume solution of methyl alcohol and water).

7.6.3 Acceptable results

After exposure to each chemical solution, the device shall be wiped off and rinsed with water and examined. The device shall not show signs of mechanical degradation that can impair the function of the device such as cracking, softening or swelling. Cosmetic changes such as pitting or staining are not considered failures. At the conclusion of all exposures, the device(s) shall meet the requirements of 7.10 and 7.11.

7.7 Atmospheric exposure test

7.7.1 General

The atmospheric exposure test applies to the qualification of pressure relief devices that have non-metallic materials exposed to the atmosphere during normal operating conditions.

7.7.2 Oxygen aging

7.7.2.1 Sampling

Three samples of each non-metallic material that provides a fuel containing seal shall be subjected to the oxygen aging test.

7.7.2.2 Procedure

The oxygen aging test shall be performed in accordance with the following procedure:

The samples shall be exposed to oxygen for 96 h at 70 °C at 2 MPa in accordance with ASTM D572.

7.7.2.3 Acceptable results

The samples shall not crack or show visible evidence of deterioration after exposure to oxygen aging.

7.7.3 Ozone

7.7.3.1 Sampling

Three samples of each non-metallic material shall be subjected to the ozone test.

7.7.3.2 Procedure

The ozone test shall be performed in accordance with one of the following procedures:

a) specification of elastomer compounds with established resistance to ozone;

b) pressure relief device testing in accordance with ISO 1431-1, ASTM D1149, or equivalent test methods;

c) the test piece which shall be stressed to 20 % elongation shall be exposed to air at 40 °C with an ozone concentration of 50 parts per hundred million during 120 h.

7.7.3.3 Acceptable results

The samples shall not crack or show visible evidence of deterioration after exposure to ozone.

7.8 Stress corrosion cracking resistance

7.8.1 Sampling

One finished pressure relief device shall be subjected to the stress corrosion cracking resistance test.

7.8.2 Procedure

The stress corrosion cracking resistance test shall be performed in accordance with the following procedure:

For pressure relief devices containing components made of a copper based alloy, one unit shall be tested as an assembly, such that the copper alloy components are subjected to the stresses normally imposed on them as a result of assembly.

All copper alloy components shall be degreased and then continuously exposed for ten days to a moist ammonia-air mixture maintained in a glass chamber having a glass cover. Aqueous ammonia having a specific gravity of 0,94 shall be maintained at the bottom of the glass chamber below the samples at a concentration of 20 ml per liter of chamber volume. The samples shall be positioned 38 mm above the aqueous ammonia solution and supported in an inert tray. The moist ammonia-air mixture shall be maintained at the atmospheric pressure with the temperature constant at 34 °C ± 2 °C.

7.8.3 Acceptable results

Copper alloy components shall not exhibit cracking or delamination due to this test.

7.9 Impact due to drop and vibration

7.9.1 Impact due to drop

7.9.1.1 Sampling

Six finished pressure relief devices shall be subjected to the impact due to drop test.

When subjected to a vertical drop of 1,83 m onto a smooth concrete floor or pad, pressure relief devices shall meet all operational performance requirements without loss of function or degradation of service life, or shall exhibit obvious visible exterior (physical) damage which indicates the part is unsuitable for use.

7.9.1.2 Procedure

The impact due to drop test shall be performed in accordance with the following procedure:

The pressure relief device samples shall be subjected to impact by being dropped from a height of 1,83 m, from the lowest point on the device, at the room ambient temperature, onto a smooth concrete pad or floor. For devices having extended flexible elements such as hoses, these shall be dropped with the flexible element in the pre-installation condition, with no packaging material. Each sample shall be allowed to bounce on the concrete pad or floor after the initial impact. One sample shall be dropped in each of the six major axes of orientation (opposing directions of 3 orthogonal axes, vertical, lateral and longitudinal).

7.9.1.3 Acceptable results

After each drop, the sample shall be examined for visible damages.

If each of the six dropped samples does not show a visible exterior damage that indicates the part is unsuitable for use, then it shall meet the requirements of 7.9.2.

If one or more of the dropped samples exhibits a visible exterior damage that indicates the part is unsuitable for use, the damage signature(s) shall be graphically documented and provided to the pressure relief device manufacturer as the relative measure for the rejection of visibly damaged parts. In this case, the samples have failed the test.

7.9.2 Vibration

7.9.2.1 Sampling

Each of the six samples identified in 7.9.1 and one finished pressure relief device not subjected to a drop shall be shall be subjected to the vibration test.

7.9.2.2 Procedure

The vibration test shall be performed in accordance with the following procedure:

The samples shall be mounted in accordance with the pressure relief device manufacturer's installation instructions and vibrated for 30 min along each of the three orthogonal axes (vertical, lateral and longitudinal) at the most severe resonant frequencies. Devices with long triggering elements shall be mounted and tested with a length that tests all relevant mounting conditions covered by the manufacturer's installation instructions. More than one unit may be used if needed. This shall include at least one end and intermediate mounting, if mounts at intervals are used. The frequencies shall be determined by the following: acceleration of 1,5 g with a sweep time of 10 min, within a sinusoidal frequency range of 10 Hz to 500 Hz. If the resonance frequency is not found in this range, the test shall be conducted at 40 Hz.

7.9.2.3 Acceptable results

Following this test, each sample shall not show any indication of fatigue or component damage, and shall meet the requirements of 7.10, 7.11 and 7.12.

7.10 Leakage

7.10.1 Sampling

Previously tested pressure relief devices shall be subjected to the leakage test.

7.10.2 Procedure

The leakage test shall be performed in accordance with the following procedure:

Prior to conditioning, purge the component with nitrogen or any inert gas. The outlet opening is plugged with the appropriate mating connection and 2,5 % of the nominal working pressure, using hydrogen, is applied to the inlet. All tests shall be conducted while the component is continuously exposed to the specified test temperatures.

At all test temperatures, immerse the components in a suitable test medium for 1 min, or use a global accumulation method (or equivalent).

The component shall be conditioned at −40 °C or lower, or until thermal stability is attained, and pressurized at both 100 % and then at 5 % of the nominal working pressure.

The component shall be conditioned at room temperature 20 °C ± 5 °C, or until thermal stability is attained, and pressurized at 150 % and then at 5 % of the nominal working pressure.

The component shall be conditioned at 85 °C or higher, or until thermal stability is attained, and pressurized at 150 % and then at 5 % of the nominal working pressure.

7.10.3 Acceptable results

If no bubbles are observed for 1 min, the sample passes the test. If bubbles are detected, the leak rate shall be measured by an appropriate method (e.g. gas chromatography, etc.).

The leak rate shall not exceed 10 Ncc/h of hydrogen gas.

7.11 Bench top activation

7.11.1 Sampling

Two finished pressure relief devices and pressure relief devices subjected to the tests of 7.2, 7.4, 7.5, 7.6 and 7.9 shall be subjected to the bench top activation test.

NOTE The bench top activation test does not predict the performance of any pressure relief device in the system level bonfire test, as the performance of a given device in the bonfire test is dependent upon the system integration of the pressure relief device, container valve and fuel storage container.

7.11.2 Procedure

The bench top activation test shall be performed in accordance with the following procedure:

The test setup shall consist of a chimney, capable of controlling the air temperature and flow, to achieve a consistent temperature of 600 °C ± 10 °C in the air surrounding the pressure relief device. The pressure relief device shall not be exposed directly to flame. The pressure relief device shall be mounted in a fixture according to the manufacturer's installation instructions that shall be documented in accordance with Clause 11. The testing conditions for the new and aged pressure relief device comparison samples should be the same.

Pressurize one pressure relief device that has not been subject to previous testing, to no more than 25 % of the manufacturer's specified nominal working pressure. Place a thermocouple in the chimney to monitor the temperature. The temperature shall remain within the acceptable range for 2 min prior to running the test. Insert the pressure relief device and/or a portion of the triggering element into the chimney and record the time for the device to activate to establish the baseline time for comparison.

If the entire pressure relief device is not being placed in the chimney, the size of the chimney or heat exposure shall be determined by the manufacturer and be documented.

Pressurize the pressure relief devices that were subject to the tests of 7.2, 7.4, 7.5, 7.6 and 7.9 to no more than 25 % of the manufacturer's specified nominal working pressure, and test under the same conditions.

Pressurize one pressure relief device that has not been subject to previous testing to 100 % of the manufacturer's specified nominal working pressure, and test under the same conditions.

7.11.3 Acceptable results

The difference in the activation time of the pressure relief devices that have not previously undergone testing shall be no more than 2 min.

The pressure relief devices subjected to the tests of 7.2, 7.4, 7.5, 7.6 and 7.9 shall activate no more than 2 min longer than the baseline activation time of the pressure relief device which had not been subjected to previous design qualification tests and subjected to no more than 25 % of the manufacturer's specified nominal working pressure.

7.12 Flow capacity

7.12.1 Sampling

Eight pressure relief devices shall be tested for flow capacity. The sample population shall consist of one device from those previously tested in each of 7.2, 7.4, 7.5, 7.6 and 7.9, and three new devices.

7.12.2 Procedure

The flow capacity test shall be performed in accordance with the following procedure:

Each device tested shall be activated using the test procedure in 7.11.

After activation and without cleaning, removing parts or reconditioning, each pressure relief device shall be subjected to the flow test using hydrogen, air or an inert gas wherein the rate of gas released by the device is measured.

Flow testing shall be conducted with a gas inlet pressure of (2,0 ± 0,5) MPa. The outlet shall be under ambient pressure. The inlet temperature, pressure and flow rate shall be recorded.

The flow shall be measured with an accuracy within ±2 %.

7.12.3 Acceptable results

The lowest measured value of the eight pressure relief devices shall not be less than 90 % of the highest flow value.

Flow capacity shall be reported as the lowest measured value of the nine pressure relief devices. The flow rate may also be reported in grams per second.

7.13 High pressure activation and flow

7.13.1 Sampling

Six finished pressure relief devices shall be subjected to the high pressure activation and flow test.

Since minimum gas volume in the setup of the test depends in part on the final results, more devices may be required to determine the correct initial setup.

7.13.2 Procedure

The high pressure activation and flow test shall be performed in accordance with the following procedure:

The test setup shall consist of a chimney which is capable of controlling the air temperature and flow to achieve a consistent temperature of 600 °C ± 10 °C in the air surrounding the pressure relief device. The pressure relief device shall not be exposed directly to flame. The pressure relief device shall be mounted in a fixture that shall be documented. A volume of gas shall be installed ahead of the pressure relief device, in accordance with the manufacturer's installation instructions. The volume of gas shall be sufficient that the pressure relief device vents down to 10 % of the start pressure in greater than 10 s, and shall be enough that the pressure relief device reaches a stable Cv before reaching 25 % of the starting pressure. The testing conditions for the new and aged pressure relief device comparison samples shall be the same.

Pressurize the pressure relief device to the manufacturer's specified nominal working pressure ±2 %. In the case of multiple rated nominal working pressures of a single design, the highest may be used as acceptable test conditions for all pressures. The gas temperature shall be below 40 °C. The pressure of the stored gas shall be measured in such a way that it is not affected by the flow past the pressure measurement device.

Place a thermocouple in the chimney to monitor the temperature. The temperature shall remain within the acceptable range for 2 min prior to running the test. Insert the pressure relief device into the chimney.

Record the pressure over time, from the point of insertion into the chimney, until venting is complete.

The graph of the pressure data for all devices shall be made available in the component literature.

7.13.3 Acceptable results

The flow of the devices shall not stop until the tank is below 1 MPa.

8 Inspection and acceptance testing

8.1 Inspection and acceptance testing plan

The pressure relief device manufacturer shall prepare a plan for inspection and acceptance testing. Inspections and tests may be conducted by suppliers, the pressure relief device manufacturer or by an independent agency.

8.2 Inspector's responsibilities

The inspector is responsible for verifying that all drawing, test and specification requirements have been met. The inspector shall select units to be tested and shall prepare or review all inspection and test reports.

8.3 Inspection of system critical components

System critical components identified in the FMEA shall be inspected using a suitable system before assembly or shipment.

Fusible components not within the manufacturer's tolerances for voids, inclusions or other harmful defects shall be destroyed.

8.4 Leak testing

All pressure relief devices shall be tested for leakage at both 5 % and a minimum of 125 % of the manufacturer's specified nominal working pressure. Devices which leak greater than 10 Ncc/h hydrogen or hydrogen equivalent shall be rejected. Helium or hydrogen, at any concentration, may be used to measure leakage in this test, provided the leak rate of the test gas is converted to an equivalent leak rate for hydrogen.

9 Production batch testing

9.1 General

For testing purposes, the ambient temperature shall be between 16 °C and 38 °C.

Batch testing shall be conducted on system critical components identified in the FMEA, and finished pressure relief devices. Batch tests of system critical components may be conducted by the supplier, an independent agency or the pressure relief device manufacturer. Batch tests for pressure relief devices may be conducted by the pressure relief device manufacturer or by an independent agency. Test reports shall be kept on file by the pressure relief device manufacturer for the design service life of the pressure relief device plus five years, and made available to fuel container manufacturers and end users upon request.

When the test results fail to meet the requirements, the pressure relief device or component batch shall be rejected. Retest of a rejected batch is authorized if the test equipment or procedure was faulty.

9.2 Production batch sizes

9.2.1 General

The size of batches for pressure relief device components, except as specified in 9.2.2 and 9.2.3, shall be determined by the manufacturer. Batch sizes shall be consistent with good manufacturing practice and appropriate levels of inspection utilizing the results of the FMEA performed in accordance with the requirements of 6.5.

9.2.2 Fusible materials

The batch size is limited to what can be produced by one common set of raw materials (e.g., a single oven melt).

9.2.3 Pressure relief devices

The batch size is limited to what can be produced from a single batch of system critical components. The batch size shall be determined and managed under the container manufacturer's quality control system.

9.3 Pressure relief device components

The pressure relief device manufacturer shall either obtain certification from component suppliers that their components are in accordance with the appropriate specifications for materials, heat treat, physical properties and mechanical properties, or conduct tests or inspections to confirm that the appropriate specifications have been met.

9.4 Thermal activation verification

9.4.1 General

One unit of the pressure relief device shall be selected at random from its batch.

9.4.2 High temperature soak

The pressure relief device shall be immersed in a liquid bath that is maintained at a temperature from 0 °C to 5 °C lower than the manufacturer's specified activation temperature. The pressure relief device shall be pressurized to 1,38 MPa ± 0,2 MPa . The temperature and pressure shall be maintained for at least 24 h. The pressure relief device shall not activate within this time.

9.4.3 Activation

The pressure relief device shall be pressurized to 25 % of the manufacturer's specified nominal working pressure. The temperature of the fluid bath shall be increased to a level from 0 °C to 5 °C higher than the manufacturers specified activation temperature. The pressure relief device shall activate within 4 h of reaching the target temperature range.

9.5 Pressure cycle verification

9.5.1 General

One unit of the pressure relief device shall be selected at random from its batch.

9.5.2 Procedure

The pressure relief device shall be subjected to 15 000 hydraulic pressure cycles at 20 °C from 2 MPa to not less than 125 % of the manufacturer's specified nominal working pressure.

9.5.3 Acceptable results

Following this test, the sample shall not show any indication of fatigue or component damage, and shall meet the requirements of 7.10.

10 Marking

10.1 Required information

Pressure relief devices shall be marked with the name and year of this document (ISO 19882), type of gas (H2), the manufacturer's specified nominal working pressure or pressure class (H25, H35, etc.), the manufacturer's identification, part number, and traceability code.

If it is possible to install the pressure relief device to allow the flow in the wrong direction, the pressure relief device shall be marked with an arrow to show the direction of the flow.

10.2 Marking methods

Markings shall be permanent. Permanent adhesive labels are permissible, or markings may be etched or stamped onto the pressure relief device housing.

11 Component literature

Manufacturers of pressure relief devices shall provide component literature for their devices. These instructions shall provide information to guide the installer in making a proper installation, and applicable concerns as identified in Annex A. The instructions shall also require that intermediate assemblers or container manufacturers who assemble a pressure relief device to a container must transmit the warning and instructions to the installer. The manufacturer shall provide duplicate instructions in response to requests, including service parts. The instructions shall be published in the predominant language(s) of the destination country. Critical parts of the component literature shall be worded in the imperative (shall or must, not should or may).

Component literature shall include at least

a) gasses the device is certified to,

b) maximum nominal working pressure,

c) activation temperature and/or pressure,

d) flow rate as determined by 7.12,

e) flow data as determined by 7.13,

f) design cycle life or service life, and

g) identification of parts which require regular periodic replacement.

Component literature should include the following items, if applicable:

h) installation torques or similar values;

i) mounting location limitations;

j) installation orientations, if any, particularly considering the accumulation of contaminants in the high pressure or vent outlet lines;

k) vent line requirements for the flow, protection of the pressure relief device from contamination and containment of projectiles;

l) inspection procedures, if any;

m) inlet connection requirements, including minimum flow characteristics;

n) requirements for warning labels that may be required as part of the installation.

All of these requirements need only to be addressed as it affects the function of the pressure relief device. Requirements that arise from other standards, such as vent line routing, do not need to be addressed in the instructions.

Annex A
(informative)

Subsystem and vehicle level considerations

A.1 Purpose

The purpose of this annex is to record the fuel container, fuel storage subsystem and vehicle level requirements. As this document is a component level standard, these recommendations are outside the scope of this document, and the pressure relief device manufacturers would not be able to demonstrate compliance if they were included in this document. In addition, the pressure relief device manufacturer does not control the usage and installation of their devices, and therefore cannot certify that they comply with the following statements.

These statements are intended as recommendations for consideration of inclusion to the organizations and committees developing these sub system and vehicle level standards, such as IEC 62282-4-101, SAE J2578 and SAE J2579.

A.2 Design service life

The design service life of the pressure relief device should meet or exceed the design service life of the fuel container with which it is used.

A.3 Design nominal working pressure

The design nominal working pressure of the pressure relief device should meet or exceed the design nominal working pressure of the fuel container for which it is used.

A.4 External environment

A.4.1 Location of pressure relief devices

The thermally reactive portion of the thermally activated pressure relief devices should be located in the same area or compartment, and should be exposed to the same environment, as the fuel container or systems that are being protected.

A.4.2 Pressure relief device cautionary labelling

Pressure relief devices that are mounted externally to the container valve assembly should have a yellow caution label affixed to them, stating that the component contains high pressure even when the service valve is closed.

A.4.3 Pressure relief device discharge vent and leakage capture systems

A.4.3.1 General

The primary function of the pressure relief device discharge vent system, if used, is to direct the discharge from a pressure relief device. The primary function of a leakage capture system, if used, is to capture potential leakage from the various connections to pressure relief devices, valves and bosses of containers and direct the gas out of the compartment to prevent a combustible mixture in a confined space.

A.4.3.2 Pressure relief device discharge vent system vent line materials of construction

Pressure relief device discharge vent systems, which may consist of interconnecting lines, ducting, vent tubes, outlets and restraining systems, should be protected, by design, routing and materials of construction, from mechanical or thermal failure or degradation, and maintain system integrity until venting is completed. Accumulation of electrostatic charge during discharge should be mitigated (e.g. by avoiding the use of nonconductive vent lines). Additionally, the materials of construction should mitigate the risk of corrosion, and should not cause galvanic corrosion at the interface connection to the pressure relief device.

A.4.3.3 Pressure relief device discharge vent system routing

Pressure relief devices and discharge vent systems should transfer the pressure relief device discharge outside of the passenger, luggage or cargo compartments. The discharge vent system should also be able to release the build-up of permeation from the pressure relief device while still remaining functional. Consideration should be given to the minimization of risk to occupants or persons outside the vehicle, as well as the reduction of risk of progression of hazards within the vehicle or its surroundings, when directing the flow of the pressure relief device discharge. The pressure relief device discharge should not direct the exhaust into or toward the passenger, luggage or cargo compartment, into or toward wheel housings, toward hydrogen storage systems, or toward the front of the vehicle. The design and installation should minimize the possibility of external hazards (e.g., projectiles) resulting from the activation of the device.

Routing of the interconnecting lines, ducting, vent tubes and outlets of pressure relief devices should avoid constrictions or pinching, as well as be protected in case of vehicle collisions, such that functionality is not compromised due to flow restrictions. The vent line should not reduce the intended flow capacity of the pressure relief device by introducing choke points or other restrictions.

Vent lines should be adequately secured to prevent damage during the vehicle's lifetime usage or uncontrolled movement during venting.

Examples of design requirements may include specifications for the size, restriction and routing of the vent piping to prevent restriction by lodging of the material released. Orientation of the discharge in a direction away from locations likely to be occupied by people may be used to minimize hazards from projectiles. Directing the discharge against some fixed surface so as to intercept projectiles may reduce safety by promoting turbulent mixing of compressed hydrogen gas and air. If the activation occurs during a fire, small projectiles may not pose a significant hazard to the emergency personnel in the protective gear. The important goal is to minimize hazards in an already inherently hazardous situation.

A.4.3.4 Pressure relief device discharge vent system intrusion

Pressure relief device discharge vent systems should be designed to prevent the ingress of foreign material or accumulation of moisture in the system. Moisture may collect in the vent side of the pressure relief device or in the discharge vent system due to the condensation and/or ingress of water. Water or ice in discharge vent systems may inhibit the function of the pressure relief device, cause unexpected venting or damage discharge vent system components. Discharge vent systems, including vent line closures if used, should prevent water invasion due to rain or car wash, and should maintain functional integrity when exposed to vehicle washing or environmental exposure. The discharge vent system shall be able to preclude or relieve the pressure build-up occurring due to allowable leakage of the pressure relief device without losing function or integrity.

Pressure relief device discharge vent systems and vent line closures shall not restrict the flow from the pressure relief device in such a way as to affect function.

A.4.3.5 Leakage capture systems (boxes/housings)

Leakage capture system design and materials of construction, if used, should not retard the thermal input to thermally activated pressure relief devices.

Vent box or gas-tight housing are a form of flow barrier that is sometimes used by the industry to capture potential leakage from the bosses of containers and direct the gas into vent lines. Care should be taken with these configurations so that these devices do not interfere with the ability of pressure relief devices to protect the containers.

The primary function of a leakage capture system, if used, is to capture potential leakage from the various connections to pressure relief devices, valves and bosses of containers, and direct the gas out of the compartment to prevent a combustible mixture in a confined space. The thermal effect of the leakage capture system design and material of construction to the safety performance of thermally activated pressure relief devices should be taken into consideration.

Leakage capture systems or gas-tight housings are forms of flow barriers that are sometimes used by the industry to capture potential leakage from the bosses of containers and direct the gas into vent lines. Care should be taken with these configurations so that these devices do not interfere with the ability of pressure relief devices to protect the containers.

Pressure relief device leakage capture systems should be protected from thermal degradation if they are functional components of the pressure relief device discharge vent system.

A.4.3.6 Fuel storage system barriers/shields

Shields may be used to protect the fuel storage system from physical, chemical and thermal effects. Solar shields should be considered to protect against thermal and UV effects due to direct exposure to sunlight. Thermal shields should be also used (when necessary) on hydrogen storage systems to minimize local thermal exposures due to fire in adjacent compartments/areas of the vehicle (such as the passenger compartment or wheel wells) until pressure relief devices can activate to mitigate potentially hazardous events. Consideration as to the location and design of seams, maintenance access holes and hatchways in the vehicle, shields or flow barriers, should be such that the effectiveness of the pressure relief device is not compromised.

The design and location of both shields and flow barriers should not interfere with the ability of the pressure relief device to protect the fuel storage system.

A.4.3.7 Pressure relief device pressure connections

Pressure relief devices and connections can also be damaged by water accumulating and freezing in the high pressure passages. This may occur due to filling equipment faults or excessively wet gas, but is not a normal occurrence. Consideration should be given to avoiding having the pressure relief device or associated connections and tubes becoming a trap for liquid.

A.5 Flow capacity

The adequacy of flow capacity of the pressure relief device for a given application should be demonstrated by bonfire testing and by the minimization of the hazardous effects of the pressure peaking phenomenon which can take place during high flow rate releases from small diameter vents in enclosed spaces. The supply and discharge lines, if used, should not reduce the intended flow capacity of the pressure relief device by introducing unintended choke points or other restrictions, thereby compromising its performance. If the system configuration allows more than one fuel container to flow through a single pressure relief device, then the flow capacity should be capable of handling the flow from all the containers.

A.6 In-service conditions

A.6.1 Inspection

The pressure relief device should be inspected at the same time as the container for which it is installed in accordance with the pressure relief device, container or vehicle manufacturer's instructions for damage or deterioration. The exterior of the pressure relief device may be cleaned with non-corrosive cleaners during inspection or at other times. The pressure relief device vent lines and vent caps, if used, should be inspected at the same time, in accordance with the vehicle manufacturer's instructions.

A.6.2 Rework and repair

No pressure relief device that has been in service should be repaired or reworked without the written authorization of the pressure relief device manufacturer, fuel container manufacturer, systems manufacturer or vehicle manufacturer.

A.6.3 Replacement

A pressure relief device that requires replacement during its service life should only be replaced with an identical unit or a suitable substitute authorized by the fuel container manufacturer, systems manufacturer or vehicle manufacturer.

A.6.4 Reuse and reinstallation

No pressure relief device that has been in service should be moved or reused on another fuel container.

Pressure relief devices should only be reinstalled on the same container if it is done in accordance with the systems or vehicle manufacturer's recommended service procedures.

A.6.5 Destroyed

A pressure relief device should be considered destroyed when it has been rendered impossible to hold pressure by mechanical means.

EXAMPLE Crushing sufficiently to prevent reattachment or drilling a minimum 5 mm hole through the body of the device.

Annex B
(informative)

Design qualification test rationale

B.1 Pressure cycling test

The life of fuel containers is defined to range between 11 000 and 15 000 cycles to 125 % of the nominal working pressure. The pressure relief device should not leak and should not have a significant change in actuation time after passing the pressure cycling test.

The specification of the first ten cycles to 150 % of the manufacturer's specified nominal working pressure is added to test the devices at the maximum station default fill pressure. This also harmonizes with the ten cycles to the same pressure that is specified for the hydrogen storage system, including the pressure relief device, in SAE J2579 and the UN GTR No. 13 for fuel cell vehicles.

B.2 Accelerated life test

The assessment of long-term, reliable performance is perhaps the most significant and difficult task for qualification testing of pressure relief devices. Elevated temperatures are used to accelerate testing in order to project successful performance for a cumulative exposure of 3 years at 85 °C over a 20 year lifetime, and for a 20 year lifetime at 57 °C. The requirement for 3 years at 85 °C addresses the cumulative time expected from heating due to fast fill conditions, and for elevated ambient temperatures if mounted in the trunk in a warm, sunny environment or if mounted beneath the vehicle and subject to heating from the engine or exhaust system.

Testing is conducted at 125 % of the nominal working pressure since the highest temperature conditions are likely to be combined with fast fill pressure limits. Requiring multiple data points at multiple temperatures provides statistical significance to the data. The Arrhenius rate equation is expected to give the best correlation for results.

B.3 Thermal cycling test

Pressure relief devices see thermal shock during operation, due in part to moving between cold ambient environments and a garage and in part by fast fill and blowdown cycles. The requirement for only 15 cycles reflects a belief that the number of severe thermal shock cycles is limited, and that relief devices are either sensitive to them in a few cycles or not sensitive to them at all. The pressure cycles conducted at a cold temperature are to demonstrate that the relief device components are not brittle at low temperatures and do not develop leaks due to differences in thermal coefficients of expansion.

B.4 Accelerated cyclic corrosion test

The accelerated cyclic corrosion test is replacing 500 h of salt fog testing since it has been demonstrated that the accelerated cyclic corrosion test is more representative of the in-use exposures for these components. In addition, this procedure is effective for evaluating a variety of corrosion mechanisms, such as general, galvanic, crevice, etc. This test was loosely based upon the General Motors cyclic corrosion test (GMW14872). One hundred cycles was selected as the test duration to evaluate part failures which can lead to safety concerns in service, as pressure relief devices are a primary container pressure retention component. The parts are evaluated for post corrosion exposure functional performance by means of the leakage and bench top activation tests.

B.5 Automotive fluid exposure test

The components, while in service, are most likely exposed to either a splash or spray condition, so the methodology proposed is to spray the exterior surface. As the highest risk factors are for fluids that can be expected to be present normally in an automotive environment, sodium hydroxide and ammonium nitrate exposures have been eliminated, as they are not chemicals to which these components are normally exposed in automotive service.

B.6 Atmospheric exposure test

The atmospheric exposure test applies to the qualification of pressure relief devices that have non-metallic materials exposed to the atmosphere during normal operating conditions.

B.7 Stress corrosion cracking resistance test

This test demonstrates that copper alloy components are not subject to stress corrosion cracking.

B.8 Impact due to drop and vibration test

The impact due to drop requirement addresses damage that may be incurred during handling, shipping and installation of the pressure relief device. This requirement documents visible damage that renders the part unsuitable for use, or ensure that parts with no visible signs of damage after drop meet all functional requirements (no hidden damage).

The vibration requirement has been changed from a single frequency for testing purposes to a sweep of a sinusoidal frequency range from 10 Hz to 500 Hz. The original frequency of 17 Hz was established through the demonstration of one vehicle traveling over a variety of road surfaces. The change to determine the most severe resonant frequency for a given pressure relief device more accurately measures the performance of a given design. The resonant frequency changes based upon the pressure relief device design and mounting provisions, therefore the change in procedure demonstrates more accurately the performance of the assembly.

B.9 Leakage test

The pressure relief device assembly should not exhibit leakage after being subjected to the various non-destructive design qualification tests. The test conditions are harmonized with the UN GTR No. 13 for fuel cell vehicles.

B.10 Benchtop activation test

This test is intended to be a quick and inexpensive way to assess whether the response characteristics of the relief device are affected by the various non-destructive qualification tests. This test is not intended to replace the bonfire test as a means of determining the acceptability of a given pressure relief device with a given fuel container. Some vehicle fuel container bonfire tests specify a minimum flame temperature of 593 °C, which is the basis for the flue gas temperature in this test. Since it is a comparative test between relief devices which have been subjected to various non-destructive qualification tests and devices which have not been so tested, there is no requirement to maintain the temperature within the target range once the relief device is put into the flue. The comparative time to activate is intended to show that the qualification tests do not prevent the device from activating or cause it to activate prematurely.

B.11 Flow capacity test

This measurement is taken for the information of the purchaser of the pressure relief device.

B.12 High pressure activation and flow test

Some pressure relief devices, in some tests, open and then reclose. This has been seen in bonfire tests with different devices and by various labs, and has resulted in container rupture during the test. Some devices do not open fully when first activated. They may open progressively. This is not, in itself, a problem if it is consistent. The opening characteristics, including the above noted conditions, are not consistent between different models of pressure relief devices. This may not itself be a problem, but the existing flow rating, namely a single flow value, implies that a given PRD flows a given amount, throughout its activation. This may lead to improper PRD selection. The two opening characteristics listed above are not consistent from test to test or unit to unit, so significant variation in the cumulative flow exists and is not tested for. This is counter to the assumption that a single bonfire test is representative, and the requirement of ±5 % flow variation in the existing test. The current test is not representative of actual use, in that a tiny volume of gas at 25 % nominal working pressure is used in the test, avoiding any effect of the continuous flow, such as cooling, or other effects of the continuous flow and high pressure. This may overlook certain failure modes or create others. Both false high and false low values have been observed in testing.

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[7] ASTM D572, *Standard Test Method for Rubber-Deterioration by Heat and Oxygen*

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[11] CSA ANSI/CSA HGV 4.1-2013, *Hydrogen dispensing systems*

[12] CSA ANSI HPRD 1-2013, *Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

[13] SAE J1739, *Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*

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Committee representation

This standard was prepared by the P3652 Hydrogen Standards Committee. Membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Coregas

Energy Resources Aotearoa

Fabrum

Fonterra Co-operative Group

Gas Appliance Industry

GasNZ

GNS

Hiringa Energy

HW Richardson Group

HyPotential

Methanex

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PEC

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New Zealand Standard

Road vehicles − Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems

Part 1: Safety requirements

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the minimum safety requirements for the functionality of compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel systems, intended for use on the types of motor vehicles defined in ISO 3833 *Road vehicles – Types – Terms and definitions.*

The use of this standard is applicable to vehicles using compressed gaseous hydrogen (CGH2), in accordance with ISO 14687:2019 *Hydrogen fuel quality – Product specification* and hydrogen/natural gas blends using natural gas, in accordance with ISO 15403-1 *Natural gas – Natural gas for use as a compressed fuel for vehicles – Part 1: Designation of the quality.*

It is not applicable to the following:
(a) Liquefied hydrogen (LH2) fuel system components;
(b) Fuel containers;
(c) Stationary gas engines;
(d) Container mounting hardware;
(e) Electronic fuel management;
(f) Refuelling receptacles; and
(g) Fuel cell vehicles.

NOTE −

(1) It is recognised that miscellaneous components not specifically covered herein can be examined to meet the criteria of this document and tested according to the appropriate functional tests.

(2) All references to pressure in this document are considered gauge pressures, unless otherwise specified.

All matters relating to the skills of installers and converters have been excluded from this document.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 21266-1:2018 *Road vehicles – Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems – Part 1: Safety requirements*.

As this standard is reproduced from an international standard, the following applies:
(h) In the source text, 'this International Standard' should read 'this New Zealand standard';
(i) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL STANDARD

ISO 21266-1

First edition
2018-10

Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems —

Part 1:
Safety requirements

Véhicules routiers — Systèmes d'alimentation pour hydrogène gazeux comprimé (CGH2) et mélanges d'hydrogène et de gaz naturel —

Partie 1: Exigences de sécurité

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee TC 22, *Road vehicles*, Subcommittee SC 41, *Specific aspects for gaseous fuels*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

A list of all the parts in the ISO 21266 series can be found on the ISO website.

Introduction

For the purposes of this document, all fuel system components in contact with natural gas have been considered suitable for compressed gaseous hydrogen (CGH2), in accordance with ISO 14687-1 or ISO 14687-2, and hydrogen/natural gas blends using natural gas, in accordance with ISO 15403-1 and ISO/TR 15403-2.

When applying this document, it should be understood that a safety device to prevent overfilling the vehicle's fuel system is part of the fuelling station. The pressure gauge has not been considered as a safety component.

When necessary, technical solutions regarding functional requirements are given in this document, as in Annex A.

This document refers to a service pressure of 20 MPa.

NOTE This document is based on a service pressure for compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends as fuels of 20 MPa settled at 15 °C. Other service pressures can be accommodated by adjusting the pressure by the appropriate factor (ratio). For example, pressures to be multiplied by 1,25 for a 25 MPa service pressure system.

Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems —

Part 1:
Safety requirements

1 Scope

This document specifies the minimum safety requirements applicable for the functionality of compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel systems intended for use on the types of motor vehicles defined in ISO 3833.

It is applicable to vehicles using compressed gaseous hydrogen (CGH2), in accordance with ISO 14687-1 or ISO 14687-2, and hydrogen/natural gas blends using natural gas, in accordance with ISO 15403-1 and ISO/TR 15403-2. It is not applicable to the following:

1) liquefied hydrogen (LH2) fuel system components;
2) fuel containers;
3) stationary gas engines;
4) container mounting hardware;
5) electronic fuel management;
6) refuelling receptacles; and
7) fuel cell vehicles.

NOTE 1 It is recognized that miscellaneous components not specifically covered herein can be examined to meet the criteria of this document and tested according to the appropriate functional tests.

NOTE 2 All references to pressure in this document are considered gauge pressures unless otherwise specified.

All matters relating to the skills of installers and converters have been excluded from this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1176, *Road vehicles — Masses — Vocabulary and codes*

ISO 12619 (all parts), *Road vehicles —Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components*

ISO 16380, *Road vehicles — Blended fuels refuelling connector*

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices*

ISO 21266-2, *Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blend fuel system components — Part 2: test methods*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

ISO 14687-1, *Hydrogen fuel — Product specification — Part 1: All applications except proton exchange membrane (PEM) fuel cell for road vehicles*

ISO 14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

ISO 19881[1], *Gaseous hydrogen — Land vehicle fuel containers*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12619-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1 General terms

3.1.1
service pressure
settled pressure of 20 MPa at a uniform gas temperature of 15 °C

3.1.2
compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system
compressed natural gas fuel system comprising cylinder, or cylinders according to ISO 19881 or ISO/TS 15869 as applicable, mounting, one or more refuelling receptacles according to ISO 16380 or ISO 17268 as applicable, and the components described in ISO 12619-3 and following parts

3.1.3
main shut-off valve
automatic valve designed to isolate a high-pressure source

3.1.4
bi-fuel HNGV
vehicle that has two independent fuel systems (one of them for compressed gaseous hydrogen and hydrogen/natural gas blend) and can run alternatively on either fuel, but only on one at a time

Note 1 to entry: The term Bi-fuel also applies to vehicles that run on both fuels simultaneously in limited amount or duration.

3.2 Vehicle mass

3.2.1
kerb mass
complete shipping mass of a vehicle fitted with all equipment necessary for normal operation plus the mass of the following elements for M1, N1 and M2 having a maximum authorized mass not exceeding 3 500 kg:

- lubricants, coolant (if needed), washer fluid;
- fuel (tank filled to at least 90 % of the capacity specified by the manufacturer);

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[1] Under preparation. Stage at the time of publication: ISO/FDIS 19881.

— other equipment if included as basic parts for the vehicle, such as spare wheel(s), wheel chocks, fire extinguisher(s), spare parts and tool kit

Note 1 to entry: The definition of kerb mass may vary from country to country, but in this document it refers to the definition contained in ISO 1176.

3.2.2
maximum authorized mass
kerb mass plus the maximum allowable payload

3.3 Vehicle categories

3.3.1
category M
power-driven vehicles having at least four wheels and used for the carriage of passengers

3.3.1.1
category M1
vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat

3.3.1.2
category M2
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat and having a maximum authorized mass not exceeding 5 000 kg

3.3.1.3
category M3
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat and having a maximum authorized mass exceeding 5 000 kg

3.4.2
category N
power-driven vehicles having at least four wheels and used for the carriage of goods

3.4.2.1
category N1
vehicles used for the carriage of goods and having a maximum authorized mass not exceeding 3 500 kg

3.4.2.2
category N2
vehicles used for the carriage of goods and having a maximum authorized mass exceeding 3 500 kg but not exceeding 12 000 kg

3.4.2.3
category N3
vehicles used for the carriage of goods and having a maximum authorized mass exceeding 12 000 kg

3.5
electronic control unit
device which controls the compressed gaseous hydrogen (CGH2) or hydrogen/natural gas blends demand of the engine and establishes the cut-off of the automatic valve in case of a broken fuel supply pipe or in case of stalling of the engine, or during a crash

4 Requirements

4.1 Design

4.1.1 General

The compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system components shall comply with ISO 19881[2] ISO/TS 15869, ISO 16380, ISO 17268 and ISO 12619, as applicable.

For bi-fuel HNGV, provision shall be made to avoid accelerated deterioration of the non-compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system as a result of sustained operation on compressed gaseous hydrogen and hydrogen/natural gas blends. Such measures shall be as recommended by the original vehicle manufacturer (e.g. fuel hoses).

All fuel system components shall fulfil the following conditions.

a) They shall withstand the environmental temperatures and other environmental conditions safely during their operational life.

b) They shall be located with full regard for anticipated damage while the vehicle is being used safely. Such damage can be caused by the vehicle itself, by extraneous factors such as heat, road debris, automotive fluids (brake liquid, oil, petrol, cooling liquid, etc.), or by rust, etc.

c) They shall be fitted so that they are not the outermost, highest or lowest parts of the vehicles; otherwise they shall be protected.

d) They shall be fitted so as not to affect ground clearance, approach angle, ramp (break-over) angle or departure angles as defined by the vehicle manufacturer.

e) They shall be located so that they do not suffer corrosion damage by accumulation of water or cargo chemicals.

f) They shall assure the proper electrical conductivity throughout the fuel system in order to avoid the electrostatic charges. This provision does not apply to gas-tight housing and ventilation hoses.

g) All connections shall be made in locations where access is possible for inspection.

The compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends system shall be installed in such a way that it has suitable protection against damage, such as damage due to moving vehicle components, collision, grit or due to the loading or unloading of the vehicle or the shifting of those loads.

The compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends system shall include automatic valves designed to close when the engine is not running on compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends, and shall be able to be manually opened or closed in case of failure of the automatism (see Annex B).

The compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system shall include:

- an automatic valve installed directly on every compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends cylinder, with a manual valve rigidly fixed to the compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends cylinder, which may be integrated into the automatic valve. The manual valve shall be able to isolate the cylinder content from the automatic valve;
- a PRD installed on each cylinder, functionally independent from any other component;

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[2] Under preparation. Stage at the time of publication: ISO/FDIS 19881.

- one or more additional PRD as applicable to the approval of the cylinder according to ISO 19881[3] or according to any other recommendations of ISO/TS 15869;
- an excess flow valve inside, and optionally outside, every cylinder or a functionally equivalent system to control the gas leakage in the event of an abnormal flow (see Annex A).

The automatic valve shall be closed when:

- the vehicle is not operating on compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends;
- the engine is not running.

Where it has to remain open by design, the valve may remain open when the engine stops during the stop phase in start-stop systems.

Only automatic valves that are normally closed when deactivated shall be used in the compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system.

4.1.2 Components

4.1.2.1 Receptacle

The receptacle shall comply with ISO 16380 or with ISO 17268, as applicable.

The receptacle shall be provided with a protective cap, to prevent the entry of dust, fluid or other foreign matter. The protective cap shall be attached in such a way as to prevent loss of the cap.

The following data shall be displayed near the receptacle (marking shall be permanent):

- type of fuel (i.e. “compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends” for compressed gaseous hydrogen and hydrogen/natural gas blends);
- periodic inspection date for gas cylinders according to ISO 19881 or applicable standards; and
- service pressure for the vehicle.

4.1.2.2 Gas cylinder

Gas cylinders shall be provided with cylinder valves, automatic valves, excess-flow valves (or a functionally equivalent system) and pressure-relief devices, and shall be mounted in accordance with the requirements set out in 4.4.

To prevent heat damage, gas cylinders and appurtenances shall either use a heat shield or be located in relation to the exhaust system such that their skin temperature does not exceed the value specified by the vehicle, valves (including PRD) or cylinder manufacturers and in accordance with ISO 19881, ISO 12619 and ISO/TS 15869. If no shielding is provided, there shall be a clearance of at least 100 mm between the fuel container and the exhaust system.

All fibre-reinforced gas cylinders (types 2, 3, and 4 according to ISO 19881[4]) shall be protected from ultra-violet radiation and automotive fluids.

4.1.2.3 Pressure regulator

Components located downstream of the pressure regulator shall be protected from over pressurization due to regulator failure. This protection may be provided by components inside the pressure regulator (i.e. pressure relief valve) as specified in ISO 12619-9.

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3) Under preparation. Stage at the time of publication: ISO/FDIS 19881.

4) Under preparation. Stage at the time of publication: ISO/FDIS 19881.

4.1.2.4 PRD and PRV

The suggested configuration for PRDs is parallel combination or thermal relief device for every type of cylinder. Series PRDs may only be used in type 1 steel cylinders and shall not be used in type 2, type 3 and type 4 cylinders.

The PRD shall be protected from dirt and water ingress and shall be located as far away as possible from sources of ignition and heat in the vehicle.

The PRD shall comply with ISO 12619-10, venting gas to protect cylinder rupture.

The PRV shall be used to prevent over pressurization of the system downstream of the first stage of the pressure regulator or regulators. If multiple regulators are used, it may be necessary to provide additional PRVs.

PRVs may be used upstream of the first stage of the pressure regulator.

PRVs shall be protected from dirt and water ingress.

4.1.2.5 Pipework

Pipework shall be laid, if possible on the chassis, in such a way that no damage from intrinsic vibrations occurs (e.g. resonance with engine vibration) and there are no friction points. The intervals between two attachment points shall not exceed 0,60 m, and pipework installation and bending shall be in accordance with the pipe and fitting manufacturer's specifications. Adequate provision shall be made to allow adequate essential flexibility.

4.1.2.6 Electronic control unit

The switching off delay of the automatic valve after stalling of the engine may not be more than 2 seconds.

The electronic control unit may be equipped with an automatic ignition advance timing adjuster integrated in the electronic module or separated.

The electronic control unit may be integrated with dummy injectors to permit a correct functioning of the gasoline electronic control unit during compressed gaseous hydrogen (CGH2) or hydrogen/natural gas blends operation.

The electronic control unit shall be so designed to operate at low temperature of −40 °C or −20 °C, as applicable, and at high temperature of 105 °C or 120 °C, as applicable.

4.1.2.7 Electrical connections

The electrical connections inside the boot and passengers compartment shall comply with protection degree class IP 40 according to ISO 20653

All other electrical connections shall comply with protection degree class IP 54 according to ISO 20653.

4.2 Refuelling connection

4.2.1 General

The piping, receptacle and all valves and fittings installed on board the compressed gaseous hydrogen and hydrogen/natural gas blends vehicle should be selected to minimize the pressure drop along the lines, and hence minimize the filling time of, and maximize the fill volume into, the compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system.

4.2.2 Receptacle location

The receptacle should be installed in a suitable on-board location that is easy to reach, allowing safe operation. The preferred location is on the side of the vehicle.

Receptacles installed inside the engine compartment shall be attached to the vehicle chassis or body.

They shall not be fixed near the battery or the ignition high-tension circuit or possible ignition sources.

The receptacle shall not be installed in a wheel arch, or close to a heat source such as the exhaust.

4.2.3 Receptacle mounting

The vehicle's compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system shall be able to withstand the values of force and torque specified in ISO 21266-2, of loading on the receptacle in any direction without its gas tightness being affected (in the case of a refuelling hose breakaway).

4.2.4 Minimum receptacle clearance

The minimum receptacle clearances are specified in ISO 16380 or ISO 17268 as applicable.

4.3 Leakage control

4.3.1 Pressurized gas systems shall be designed so that they withstand the stresses that can be expected during operation.

4.3.2 Connections shall either be bubble-free for 3 minutes or have a leak rate for each connection that is in compliance with the leak test in ISO 21266-2. After assembly, the vehicle's compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system shall be tested for leakage in accordance to ISO 21266-2.

4.3.3 The cylinder or parts of the gas system, or both, shall be mounted in a position which ensures that any leaking or venting gas from the fuel systems does not directly enter the driver or passenger compartment, boot or other spaces not sufficiently ventilated. Alternatively, it shall be ensured that any leaked gas is directed safely to the atmosphere (see Annex A).

4.3.4 Where a cylinder is located within the driver or passenger compartment, or other insufficiently ventilated space, the valves, connections and pipework shall be enclosed in a gas-tight housing such that any gas leakage is vented and directed to the outside of the vehicle. When the valves are self-venting, the gas tight housing/ventilation hose shall enclose the connections, pipework and venting orifices. There is no need to enclose the body of the valve, if all the possible leakage sources (included the cylinder-valve interface) are sealed and vented into the valve's interior venting passages.

In case of fire, the requirement of venting gas to the outside of the vehicle does not apply.

4.3.5 Any ventilation opening shall be positioned away from any openings into any vehicle compartment, away from any ignition source, and in a location where it is not susceptible to blockage.

4.3.6 Any enclosure containing the thermal-reactive elements of a PRD shall be permeable to heat to allow the temperature of the PRD to rise to the temperature of the cylinder surroundings.

4.4 Mounting of the cylinder(s)

4.4.1 The cylinder or cylinders shall be securely attached to the vehicle to prevent slipping, rotating and dislodging.

The installation shall be according to the cylinder manufacturer's instructions and ISO 19881[5] or ISO/TS 15869.

The cylinder shall be mounted on the same vehicle as the engine and any equipment being fuelled by the fuel container.

The cylinder shall be mounted in a manner that prevents contact of the container with other vehicle components that would lead to container damage or abrasion over time.

The cylinder shall be at two support points designed to minimize the effects of external loads on the fuel container.

Mounting hardware and instructions specified by the cylinder manufacturer shall be used, if available. The mounting system shall minimize damage or corrosion between the cylinder and the mounting system.

A resilient gasket that does not retain water shall be installed between the supports or clamping bands and a fuel cylinder such that there is no direct contact between metal on the bracket and the fuel cylinder. The gasket material shall be of a thickness and hardness such that the fuel cylinder remains secure at all fuel cylinder fill pressures and all operating temperatures.

When the cylinder is clamped by the neck, a resilient gasket may not be required.

When installing the cylinder, consideration should be given to factors such as:

- the undue stresses created in an overwrap by cylinder expansion against a metal support;
- the need to specify a gasket material to prevent support damage to cylinder(s); and
- the required properties of any gasket material.

Type 2, Type 3, and Type 4 designs should be provided with shielding arrangements to protect the composite wrapping from mechanical damage.

4.4.2 Gas cylinder and attachments for mounting on the vehicle shall be constructed so that the mountings are not be subject to failure by wear, corrosion or fatigue during the service life of the vehicle. Welding on cylinders is not permitted.

4.4.3 When tested in accordance with ISO 21266-2, the cylinder shall remain attached to the vehicle under the following accelerations, where g is the gravitational acceleration.

The fuel container(s) or cylinder(s) shall be mounted and fixed so that the following accelerations can be absorbed (without damage occurring) when the containers are full at the service pressure:

1) Vehicles of categories M1 and N1:
    a) $20g$ in the direction of travel (forward/backward);
    b) $8g$ horizontally perpendicular to the direction of travel;
    c) if the cylinders are mounted under the vehicle, $5g$ in the vertical downward direction.
2) Vehicles of categories M2 and N2:
    a) $10g$ in the direction of travel (forward/backward);

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5) Under preparation. Stage at the time of publication: ISO/FDIS 19881.

   b) 5*g* horizontally perpendicular to the direction of travel;

   c) if the cylinders are mounted under the vehicle, 5*g* in the vertical downward direction.

3) Vehicles of categories M3 and N3:

   a) 6,6*g* in the direction of travel (forward/backward);

   b) 5*g* horizontally perpendicular to the direction of travel;

   c) if the cylinders are mounted under the vehicle, 5*g* in the vertical downward direction.

A calculation method may be used instead of practical testing if its equivalence can be demonstrated.

Cylinders shall be located or given protection such that its piping, fittings, and valve are protected from damage due to contact with objects encountered during operation of the vehicle.

4.5 Heat protection

Components (except gas cylinders and appurtenances, which shall comply with 4.1.2.2) shall be installed at least 100 mm from the exhaust system; otherwise heat shields shall be installed.

4.6 Minimizing risk of gas ignition

To prevent fire in a vehicle, the ignition sources shall be minimized.

Electric and electronic components in gas-tight housings over cylinder valve fittings shall be suitable for hazardous areas as defined in IEC 60079-10-1.

The location of electrical cables and mountings of compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel system components shall be designed to protect against the potential ignition of leaked gas.

4.7 Venting system

4.7.1 General requirements

There is no general best direction to release the gas through the PRV or PRD; it should be evaluated on a case by case design. The gas shall be released in a dispersed manner.

The dispersion method shall not restrict the venting capacity of any PRV or PRD.

Vent systems must prevent the accumulation of water or debris in the tubes or in the PRV or PRD, as this can cause the PRV or PRD to fail or prevent proper venting after activation. Ice, in particular, can damage PRDs or vent lines. Care shall be taken that any vent line closures are durable and not damaged by use, including power washers and brushes, impact with overhead branches, or other handling.

In addition, the PRV or PRD vent ports on each fuel cylinder shall be arranged such that no gas jet can impinge directly on other compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends cylinders in the on-board fuel storage systems.

Leakage and venting of compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends (or other flammable substances) from the PRVs shall be dealt with properly to avoid the dangers due to releasing flammable substances in enclosed spaces.

4.7.2 Ventilation lines for PRDs and PRVs

If a ventilation line is installed on a pressure relief device or on a pressure relief valve, it shall be of sufficient diameter for its purpose. In addition, this ventilation line and system shall:

a) have a minimum internal diameter not less than the pressure relief device/valve discharge opening(s), and the diameter shall be of sufficient size to not be obstructed by any material discharged by the PRD or PRV;

b) be secured at intervals in a manner that minimizes the possibility of damage, corrosion, or breakage due to expansion, contraction, vibration, strains, or wear and that precludes any loosening while in operation;

c) have a minimum burst pressure at least 1,5 times the service pressure of the fuel cylinder. Where vent lines are discharged into an increased diameter manifold or line, the pressure requirement of that manifold or line shall be fit for purpose;

d) not lose its gas-carrying capability when exposed for 12 min to a temperature of 590 °C. The vent lines may be shielded or sleeved to comply with this requirement;

e) not direct the discharge into or toward the passenger or luggage compartment, into or toward wheel housings, toward compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends storage systems, or toward the front of the vehicle;

f) minimize the possibility of external hazards (e.g. projectiles) resulting from activation of the device;

g) be constructed of materials that mitigate the risk of corrosion, and shall not cause galvanic corrosion at the interface connection to the pressure relief device/valve.

5 Instruction for use

An instruction manual shall be provided which includes specific instructions regarding compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends operation and that alerts the owner to the cylinder inspection or expiration date.

6 Marking

If other than vehicle original equipment manufacturer (OEM), a label or plate identifying the installer of the compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends system with reference to this document shall be permanently attached to the vehicle.

Annex A
(informative)

Technical solutions to functional requirements

A.1 Prevention of hydrate and ice formation

As a guideline, in order to prevent hydrate and ice formation:

— the gas quality designation should be as defined in ISO 15403-1 and ISO 15403-2; and

— the high-pressure regulator should be heated.

A.2 Ventilation

Ventilation of the valves, connections and pipework may be achieved by either:

a) placing the cylinder and its fittings in a durable enclosure which is sealed such that it is gas tight to the compartment or space and which is provided with permanent ventilation;

b) enclosing the neck of the cylinder and its fittings with a specially designed durable envelope that is gastight to the compartment and that is provided with permanent ventilation;

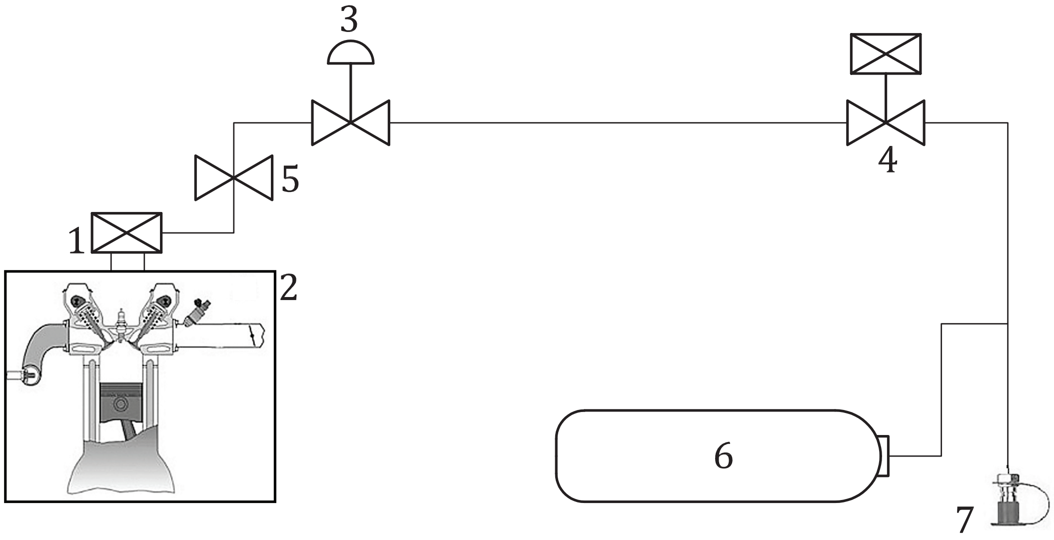
c) installing a self-venting valve that vents every possible leakage source (including the connection between the valve and the cylinder) through internal passages, and enclosing pipework, connections and the valve's venting outlets in venting hoses that direct the gas to a safe location outside the vehicle;

Any ventilation method used shall not prevent proper function of the PRD, particularly by separating it from the heat that the cylinder is exposed to. Fire testing of the cylinder and PRD combination should be done with representative ventilation enclosures

Annex B
(informative)

Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel systems

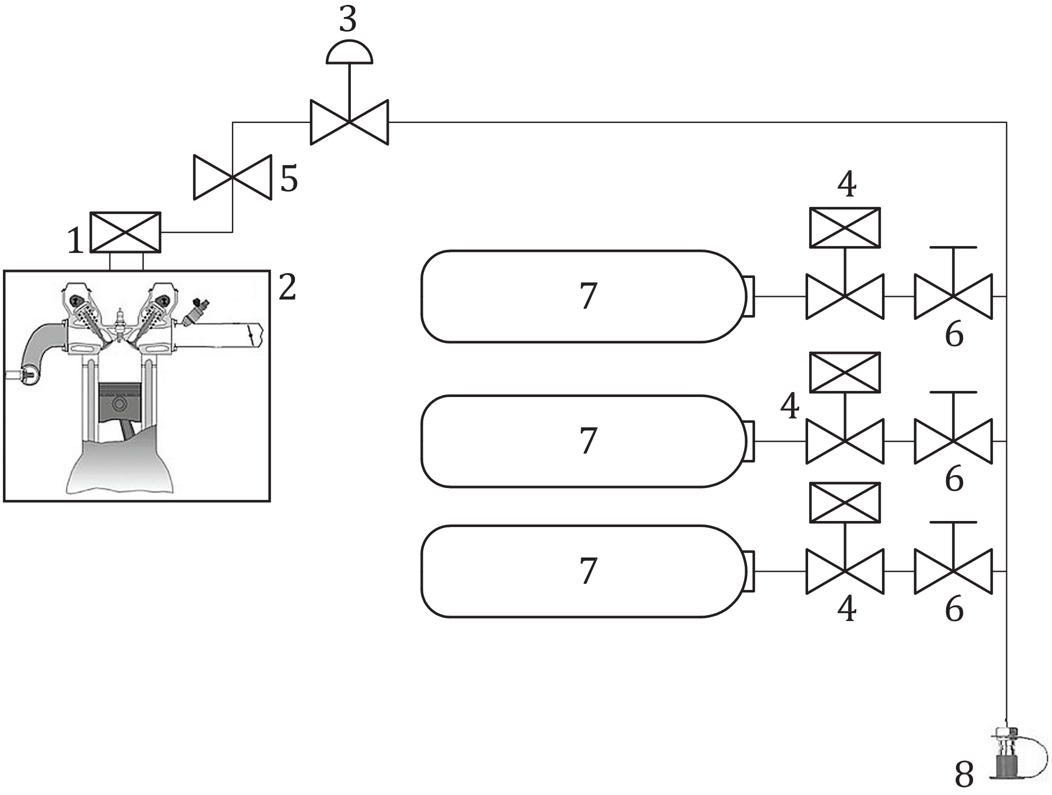
Examples of compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends on-board fuel systems are shown in Figure B.1 and Figure B.2.



Key

1 gas/air mixer (or gas injection system)
2 engine
3 pressure regulator
4 main shut-off valve
5 PRV (safety device to prevent overpressure)
6 gas cylinder + cylinder valve + PRD
7 refuelling receptacle

Figure B.1 — Single-cylinder system



Key

1	gas/air mixer (or gas injection system)
2	engine
3	pressure regulator
4	main shut-off valve
5	PRV (safety device to prevent overpressure)
6	manual shut-off valve
7	gas cylinder + PRD
8	refuelling receptacle

Figure B.2 — Multiple-cylinder system

Bibliography

[1] ISO 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

[2] ISO 15501-1, *Road vehicles — Compressed natural gas (CNG) fuel systems — Part 1: Safety requirements*

[3] ISO 15501-2, *Road vehicles — Compressed natural gas (CNG) fuel systems — Part 2: Test methods*

[4] ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

[5] SAE J2600, *Compressed Hydrogen Surface Vehicle Refuelling Connection Devices*

[6] SAE J2601, *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*

[7] SAE J2799, *70 MPa Compressed Hydrogen Surface Vehicle Fueling Connection Device and Optional Vehicle to Station Communications*

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

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

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

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Committee representation

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The committee consisted of representatives of the following nominating organisations:

Coregas
Energy Resources Aotearoa
Fabrum
Fonterra Co-operative Group
Gas Appliance Industry
GasNZ
GNS
Hiringa Energy
HW Richardson Group
HyPotential
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PEC
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New Zealand Standard

Fuel cell road vehicles – Saftey specifications – Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen

Contents

Preface

The government has a legislated 2050 target of net zero greenhouse gas (GHG) emissions, other than from biogenic methane, and a target under the Paris Agreement to reduce net GHG emissions to 50 per cent below gross 2005 levels by 2030.

Hydrogen is set to play a key role in meeting these targets. (New Zealand has considerable renewable energy resources which could be harnessed to sustainably produce hydrogen for use as a next-generation green fuel source and industrial feedstock.)

To enable the safe integration and novel use of hydrogen in all its forms across New Zealand's energy landscape, a suite of hydrogen-related equipment standards is being adopted.

This standard specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside the vehicle against hydrogen-related hazards. It applies only to such FCV where compressed hydrogen is used as fuel for the fuel cell system.

This standard does not apply to manufacturing, maintenance, and repair.

The requirements of this standard address both normal operating (fault-free) and single-fault conditions of the vehicles.

The standard was prepared by the P3652 Hydrogen Standards Committee and is identical to and has been reproduced from ISO 23273:2013 *Fuel cell road vehicles − Safety specifications − Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen.*

As this standard is reproduced from an international standard, the following applies:
(a) In the source text, 'this International Standard' should read 'this New Zealand standard';
(b) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix or annex to which they apply. A 'normative' appendix or annex is an integral part of a standard whereas an 'informative' appendix or annex is for information and guidance.

INTERNATIONAL
STANDARD

**ISO
23273**

First edition
2013-06-15

Fuel cell road vehicles — Safety specifications — Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen

Véhicules routiers alimentés par pile à combustible — Spécifications de sécurité — Protection contre les dangers de l'hydrogène pour les véhicules utilisant de l'hydrogène comprimé

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Contents

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

This first edition of ISO 23273 cancels and replaces ISO 23273-2:2006, of which it constitutes a minor revision.

Fuel cell road vehicles — Safety specifications — Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen

1 Scope

This International Standard specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside the vehicle against hydrogen-related hazards.

It applies only to such FCV where compressed hydrogen is used as fuel for the fuel cell system.

This International Standard does not apply to manufacturing, maintenance, and repair.

The requirements of this International Standard address both normal operating (fault-free) and single-fault conditions of the vehicles.

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 17268, *Gaseous hydrogen land vehicle refuelling connection devices*

ISO 6469-2, *Electrically propelled road vehicles — Safety specifications — Part 2: Vehicle operational safety means and protection against failures*

3 Terms and definitions

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

3.1
air processing system
system that processes (i.e. that filters, meters, conditions, and pressurizes) the incoming air for the fuel cell system

3.2
contaminant
substances within raw fuel, such as sulphur, that, at or above a specified concentration level, may poison reaction catalysts

3.3
electric chassis
conductive mechanical structure of the vehicle, including all associated electric and electronic components, whose parts are electrically connected and whose potential is taken as reference

3.4
excess flow valve
valve which automatically shuts off or limits the gas flow when the flow exceeds a set design value

3.5
fuel cell
electrochemical device that generates electricity by the conversion of fuel and an oxidant without any physical or chemical consumption of the electrodes or electrolyte

3.6
fuel cell stack
assembly of two or more fuel cells, which are electrically connected

3.7
fuel cell system
system typically containing the following subsystems: fuel cell stack, air processing system, fuel processing system, thermal management, water management, and their control system

3.8
fuel cell vehicle
FCV
vehicle that receives propulsion power from an on-board fuel cell power system

Note 1 to entry: The general term FCV also includes vehicles with an additional other source of propulsion power.

3.9
fuel processing system
system that converts (if necessary) and/or conditions the fuel as stored in the on-board fuel storage into fuel suitable for operation in the fuel cell stack

3.10
fuel system
combination of the on-board fuel storage, the fuel processing system, and the fuel cell stack

3.11
main hydrogen shut-off valve
valve designed to automatically isolate the high-pressure hydrogen source

3.12
maximum allowable working pressure
MAWP
maximum working pressure at which a component or system may be normally operated without damage, including leakage and deformation

Note 1 to entry: The maximum allowable working pressure is used in determining the setting of pressure-limiting/relieving devices installed to protect the part or system from accidental over-pressurizing.

3.13
nominal working pressure
pressure level at which a component typically operates

Note 1 to entry: For fuel containers, it is the settled pressure at a uniformed temperature of 15 °C (288 K) for a full fuel container.

3.14
purge
process to eliminate unwanted gas constituents from the hydrogen system

3.15
temperature-triggered pressure relief device
PRD
excessive temperature-triggered, activated non-reclosing resealing device which vents gas to protect the fuel container from rupture when subjected to a standard fire test

4 Environmental and operational conditions

The requirement given in this International Standard shall be met across the range of environmental and operational conditions for which the vehicle is designed to operate, as specified by the vehicle manufacturer.

5 Design and performance requirements of the fuel system

5.1 General

The fuel system consists of a high-pressure section, where the inner pressure is the same as in the fuel container, and an intermediate- to low-pressure section, where the inner pressure is lower than that of the high-pressure section.

The fuel system shall be equipped with

- a fire protection system incorporating one or more temperature-triggered PRD(s),
- a main hydrogen shut-off valve that shall be closed when the energizing power to the valve is lost, and which shall also be closed when the vehicle fuel cell system is not operating,
- a hydrogen shut-off system according to 5.2.4, and
- an excess flow valve or a system providing the same function.

5.2 Components

5.2.1 General

The components of the fuel system shall satisfy the following requirements.

The components shall be designed, installed, and serviced in such a way that they can operate safely under the environmental and operational conditions as specified by the manufacturer.

All components used in the high-pressure section shall have an adequate pressure rating based on the nominal working pressure.

All components used in the intermediate- and low-pressure sections shall have an adequate pressure rating based on the maximum allowable working pressure.

Electrically conductive housings of components in possible flammable areas should be bonded to the electric chassis to prevent inadvertent ignition of hydrogen discharges.

5.2.2 Fuel container

A vehicle fuel container according to legal requirements, if applicable, shall be used. Otherwise, requirements shall be specified by the vehicle manufacturer.

The fuel container system shall be equipped with at least one temperature-triggered PRD located near the hydrogen fuel container(s) so that hydrogen in the fuel container can be discharged before rupture (see also 5.3).

5.2.3 Overpressure protection

Any parts located in the intermediate or low pressure section shall be capable of withstanding or be protected against an extraordinary pressure increase due to a single failure of the first pressure regulator upstream.

NOTE For guidance, see SAE J2578.

5.2.4 Hydrogen shut-off system

The fuel system and its control shall provide a means to close the main hydrogen shut-off valve and thereby prevent unwanted discharge of hydrogen or other hazards arising from single-point failures, as per ISO 6469-2.

5.3 Location and installation of components

All components and interconnecting piping and wiring shall be securely mounted or supported in the vehicle to minimize damage and prevent leakage and/or malfunction.

Components shall be located within the vehicle to reduce the possibility of accidental damage, unless the components are adequately protected and no part of the component lies outside of the protective structure.

Fuel pipes shall be located and protected in such a way that no damage can be caused by vehicle vibrations under normal operational conditions as specified by the vehicle manufacturer.

5.4 Discharges

The vehicle design for all fuel system exhausts, purges, vents, and other discharges that occur during normal operation of the vehicle shall prevent hydrogen-related hazardous conditions. All normal operating modes including start, run, stop, and off (parked) should be considered in these requirements.

Discharges into all vehicle compartments under normal operation and single-failure conditions shall not lead to any hazardous conditions.

In areas of contemplated use, such as outdoors, mechanically ventilated buildings and structures, and non-mechanically ventilated residential garages, legal requirements shall be met. Normal discharges from the vehicle to the outside shall be non-flammable.

NOTE Guidance relative to evaluating vehicles for commonly contemplated situations such as driving outdoors, idling the vehicle in commercial buildings, and parking in a residential garage is provided in SAE J2578.

Discharges from the PRD shall be vented to the outside of the vehicle, and shall be protected as well as all associated piping and outlet, such that functionality is not compromised due to flow restrictions.

The release of hydrogen from traction batteries shall not lead to any hazardous conditions.

6 Test methods for determining flammability around the vehicle from fuel discharges

Tests shall be performed according to applicable national or International Standards or legal requirements. Otherwise, test methods shall be specified by the vehicle manufacturer.

7 Complementary or alternative approach to verify hydrogen-related safety requirements

7.1 General

Complementary to the requirements in Clause 5, protection for persons and the environment inside and outside the vehicle against hydrogen-related hazards may be achieved by the following procedure. This procedure may also be applied instead of the requirements in Clause 5, resulting in requirements more specific to the conditions of a given fuel cell vehicle design.

NOTE Such approach is applied to vehicle electronic systems in several ECE Regulations (R13, R79).

7.2 Hydrogen-related components and systems

Components and systems containing and/or carrying and/or processing hydrogen shall be specified by the vehicle manufacturer unless legal requirements apply.

7.3 Integration of the hydrogen-related components and systems into the FCV

7.3.1 Normal (fault-free) hydrogen-related conditions of the vehicle

The vehicle manufacturer shall establish a process that, under normal (fault-free) conditions of the hydrogen-related components and systems, no hazard for persons in or in the vicinity of the FCV in normal environmental and operational conditions can occur.

7.3.2 Hydrogen-related fault conditions of the vehicle

A hazard analysis in relation to hydrogen shall be performed considering primarily the interface between the components and systems, as established during assembly into the vehicle. This analysis may use an FMEA (failure mode and effect analysis), an FTA (fault tree analysis), or another appropriate method, and shall determine potential single hardware and software failures or conditions which could form a hazard for persons in or around the vicinity of the vehicle.

Based on this analysis, a description shall be provided of the hardware and software measures enacted to prevent or limit failures or conditions to non-hazardous levels for persons, i.e. such that the fundamental safety requirements and criteria expressed in this International Standard are met (safety concept).

7.4 Verification of the safety concept

The vehicle manufacturer shall define and perform an appropriate combination of necessary analyses and tests that are required to sufficiently demonstrate that the alternative concept provides protection against potential hazards that is equivalent to the means provided in this International Standard.

8 Fuelling requirements

8.1 General

Vehicle movement by its own propulsion system should be prevented when the vehicle is being refuelled.

NOTE 1 For guidance on design of fuel systems, see also SAE J2578.

NOTE 2 Safety for persons during refuelling at a hydrogen filling station has mainly been provided by appropriate measures regarding safety-related design and operation of the station, including the interface between pump/nozzle and vehicle/receptacle (see also 8.2).

8.2 Fuelling inlet

See ISO 17268 for nozzle and receptacle requirements. Nozzle and receptacle shall be provided with a cap to prevent invasion of dust, liquid, contaminants, etc.

The fuelling location on the vehicle shall be designed so as to prevent the accumulation of flammable gases and the ingress of foreign material. It shall be placed in an appropriate position to ensure safe operation. The side of the vehicle is preferable.

Measures against electrostatic discharges of the vehicle at the receptacle should be taken.

The receptacle shall be able to withstand a minimum of 670 N of loading in any direction without its gas tightness being affected (e.g. in the case of a refuelling hose breakaway).

Bibliography

[1] SAE J2578, *Recommended practice for general fuel cell vehicle safety*

[2] United Nations ECE R13, *Uniform provisions concerning the approval of vehicles of categories M, N, and O with regard to braking*

[3] United Nations ECE R79, *Uniform provisions concerning the approval of vehicles with regard to steering equipment*

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