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Gaseous Hydrogen — Fuel system components for hydrogen-fuelled vehicles —

Part 1:
Land vehicles

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Foreword

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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 document 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 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 Technical Committee ISO/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.

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 components on hydrogen-fuelled vehicles. The successful commercialization of hydrogen land vehicle technologies requires standards pertaining to 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 CSA/ANSI HGV 3.1:22.

Gaseous Hydrogen — Fuel system components for hydrogen-fuelled vehicles —

Part 1:
Land vehicles

1 Scope

1.1 Inclusions

This document establishes requirements for newly produced compressed hydrogen gas fuel system components, as listed below, that are intended for use on hydrogen gas powered land vehicles:

a) check valves (see Clause 8);

b) manual valves (see Clause 9);

c) manual container valves (see Clause 10);

d) automatic valves and automatic container valves (see Clause 11);

e) hydrogen injectors (see Clause 12);

f) pressure sensors, temperature sensors, and pressure gauges (see Clause 13);

g) pressure regulators (see Clause 14);

h) pressure relief valves (PRV) (see Clause 15);

i) pressure relief devices (PRD) (see Clause 16, and refer to ISO 19882);

j) excess flow valves (see Clause 17);

k) gastight housing and leakage capture passages (see Clause 18);

l) rigid fuel lines (see Clause 19);

m) flexible fuel lines, hoses, and hose assemblies (see Clause 20);

n) filter assemblies (see Clause 21);

o) fittings (see Clause 22);

p) non-metallic, low-pressure rigid fuel lines (see Clause 23);

q) discharge line closures (see Clause 24).

NOTE Other components not specifically identified here can be examined to meet the criteria of ISO 19887-1 and tested according to the appropriate functional needs.

1.2 Applicability

This document applies to components that have a nominal working pressure, as specified by the manufacturer, of 25 MPa, 35 MPa, 50 MPa, or 70 MPa at 15 °C, referred to in this document as the following pressure classes:

a) “H25” – 25 MPa;

b) “H35” – 35 MPa;

c) “H50” – 50 MPa; and

d) “H70” – 70 MPa.

Other nominal working pressures for hydrogen gas besides those defined can be used if the qualification test requirements of this document are met.

This document also applies to components downstream of the first stage of pressure reduction with a maximum operating pressure designated by the manufacturer in MPa or kPa.

1.3 Exclusions

This document does not apply to the following:

a) hydrogen gas fuel system components incorporated during the manufacture of motor vehicles originally manufactured in compliance with the international regulations on hydrogen and fuel cell vehicles, such as UN GTR No. 13, UN Regulation No. 134, UN Regulation No. 146, or IEC 62282-4-101;

b) fuel containers;

c) stationary power generation applications;

d) container mounting hardware;

e) electronic fuel management;

f) refuelling receptacles; or

g) components intended for liquid hydrogen.

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 6270-2, *Paints and varnishes — Determination of resistance to humidity — Part 2: Condensation (in-cabinet exposure with heated water reservoir)*

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

ISO/TR 11340, *Rubber and rubber products — Hydraulic hose assemblies — External leakage classification for hydraulic systems*

ISO 14687, *Hydrogen fuel quality — Product specification*

ISO 19882, *Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM D572, *Standard Test Method for Rubber—Deterioration by Heat and Oxygen*

ASTM D1149, *Standard Test Methods for Rubber Deterioration—Cracking in an Ozone Controlled Environment*

ASTM D1193-06, *Standard Specification for Reagent Water*

ASTM G154, *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials*

SAE J343, *Test and Test Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies*

SAE J2719, *Hydrogen Fuel Quality for Fuel Cell Vehicles*

3 Terms and definitions

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

ISO and IEC maintain terminology 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
bypass flow
intentional flow through or around an excess flow valve, or similar valve, in its activated position

3.2
compressed hydrogen gas
hydrogen gas that has been compressed

Note 1 to entry: For more information on compressed hydrogen gas composition, see 5.1.4.3.

3.3
discharge line
components attached to the exhaust port of pressure relief devices or pressure relief valves or other devices releasing gas

3.4
discharge line closure
device used to keep contamination out of a discharge line while still permitting escape of gas from the line to atmosphere

3.4.1
repeated-use discharge line closure
discharge line closure (3.4) intended to relieve multiple gas release events

3.4.2
single-use discharge line closure
discharge line closure (3.4) intended to relieve a single gas release event

3.5
duty cycle
one complete operation of the component such as pressurization and depressurization or on and off, as applicable

3.5.1
injector duty cycle
operating frequency of an injector as specified by the manufacturer

3.6
external leakage
leakage from any pressure-retaining chamber to atmosphere, or to any chamber venting to atmosphere

3.7
filling cycle
pressure increase representing a vehicle fuelling for components subjected to container pressure

3.8
filter assembly
assembly that contains a filter media intended to remove contaminants from the gas stream

3.9
fitting
connector used to join sections of pipe, tube, hose, or components

3.10
flexible fuel line
non-rigid tubing or hose through which hydrogen gas flows

3.11
gastight housing
enclosure meant to capture leakage from pressure-retaining components

3.12
hydrogen injector
solenoid operating valve used to control hydrogen flow into an engine or associated intake

Note 1 to entry: Hydrogen injectors are primarily used for internal combustion engine applications but can also be used to control hydrogen flow into a fuel cell.

3.13
internal leakage
leakage from one pressure-retaining chamber to another, where both are intended to contain pressure during normal operation

3.14
leakage capture line
line or hose meant to capture or deliver hydrogen leakage from gastight housings to outside the vehicle

3.15
leakage capture passages
portions of pressure-retaining components meant to capture and direct gas leakage from the pressure-retaining seals of that component

3.16
lock-up pressure
stabilized pressure at the outlet of a pressure regulator at zero flow

3.17
non-metallic, low-pressure rigid fuel line
tubing constructed from non-metallic materials that has been designed not to flex in normal operation and through which fuel flows on the downstream side of pressure regulation

3.18
normal cubic centimetre
Ncm^3
quantity of the specified gas that occupies a volume of 1 cm^3 at a temperature of 293,15 K (20 °C) and an absolute pressure of 101,325 kPa (1 atm)

3.19
pressure
gauge pressure against atmospheric pressure, unless otherwise stated

3.19.1
burst pressure
pressure that causes structural failure of the component and consequential fluid loss through the component envelope

Note 1 to entry: Burst pressure is the highest pressure recorded when the component bursts during a hydrostatic strength test.

3.19.2
container pressure
gas pressure within a container, up to 125 % of the nominal working pressure immediately after filling

3.19.3
hydrostatic pressure
hydraulic pressure to which a component is subjected during testing

3.19.4
maximum inlet pressure
maximum pressure to be applied to the inlet of a pressure regulator or regulator stage

3.19.5
maximum operating pressure
MOP
maximum pressure that a component is expected to experience in actual service

Note 1 to entry: Maximum operating pressure pertains only to components that are downstream of the first stage of pressure reduction.

Note 2 to entry: MOP is typically the pressure regulator PRV set pressure.

3.19.6
nominal working pressure
NWP
settled pressure at a uniform gas temperature of 15 °C

Note 1 to entry: Nominal working pressure pertains only to components that are upstream of the first stage of pressure reduction.

3.19.7
opening pressure
pressure at which a closure device or pressure relief valve initially opens to allow flow out of the device

3.19.8
set pressure
pressure at which a pressure relief valve is intended to be fully open

3.20
pressure gauge
mechanical device that converts pressure into a visual indication or measure of pressure

3.21
pressure regulator
device used to control the delivery pressure of gaseous fuel

3.22
pressure relief device
PRD
device that, when activated under specified performance conditions, is used to vent the container contents

3.23
pressure relief valve
PRV
reclosing device that opens to relieve pressure at a pre-determined upstream pressure

3.24
pressure sensor
device that measures gas pressure for electronic transmission

3.25
rigid fuel line
tubing that has been designed not to flex in normal operation and through which fuel flows

Note 1 to entry: For example, fuel lines made of metallic materials or polymer tubing are considered rigid lines.

3.26
test gas
gas used for the component performance tests in this document, which may be either compressed hydrogen gas or non-reactive gas, unless otherwise specified in the specific test clauses

3.27
valve
component by which the flow of a fluid can be controlled

3.27.1
automatic container valve
automatic valve rigidly fixed to the container that controls the flow of gas to the fuel system

Note 1 to entry: An automatic container valve may also be considered a primary closure "shut-off valve", which is defined in UN GTR No. 13 as a valve between the container and the vehicle fuel system that must default to the "closed" position when not connected to a power source.

3.27.2
automatic valve
on/off valve for controlling flow of gas that is not manually operated

3.27.3
check valve
mechanical valve that allows gas to flow in only one direction

3.27.4
excess flow valve
valve intended to automatically shut off or limit flow when a specified flow rate (or pressure differential) through the valve is exceeded

Note 1 to entry: The excess flow valve can either be internal or external excess flow valves and either a flow-limiter type or shut-off type.

3.27.4.1
external excess flow valve
excess flow valve installed outside the container or container valve

3.27.4.2
flow-limiter type excess flow valve
excess flow valve that limits flow when activated

3.27.4.3
internal excess flow valve
excess flow valve installed inside the container or container valve

3.27.4.4
shut-off type excess flow valve
excess flow valve that stops flow when activated

3.27.5
manual container valve
manual valve intended to be rigidly mounted to fuel containers

3.27.6
manual valve
hand-operated device for controlling the flow of gas

3.27.7
service valve
valve intended for use only during maintenance or repair and which requires a tool to operate

4 General requirements

4.1 General construction and assembly

4.1.1 Intended use

Components shall be made of materials suitable for use with compressed hydrogen gas.

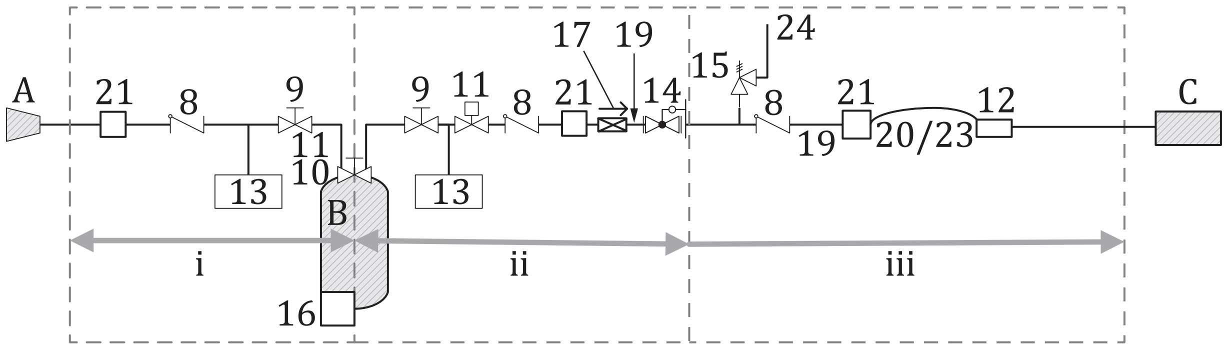
Components designed to comply with this document are intended to be used with hydrogen fuel complying with ISO 14687 or SAE J2719.

The tests and requirements in the following sections do not account for the presence of water in fuel cell components. Corrosive and other effects need to be accounted for if adapting this document for components which are designed for use with moist hydrogen.

Manufacturers of components for hydrogen gas powered vehicles shall consider the intended installation location and pressure class. Components that are upstream of the first stage of pressure reduction will be subjected to container pressure in service and shall be tested according to the nominal working pressure (NWP) requirements. Components that are downstream of the first stage of pressure reduction will be subjected to the maximum operating pressure (MOP), which is typically determined by the pressure relief valve (PRV) set pressure.

Additionally, components that are subjected to container pressure shall be categorized as filling cycle or duty cycle components to determine the appropriate testing requirements. Filling cycle components are those exposed to pressure and temperature cycles during vehicle fuelling. Duty cycle components are those exposed to pressure and temperature cycles by vehicle on/off cycles of the container valve or fluctuations during normal vehicle operation.

Figure 1 shows an example of a hypothetical compressed hydrogen fuel system with a separated inlet and outlet on the container valve. Another variation of the system shown in Figure 1 can be a single inlet and outlet on the container valve, which would expand the application of the filling cycles and duty cycles to the other components throughout the fuel system. Figure 1 is for illustrative purposes only and is intended to provide an example of the categorization of various components. The figure is not intended to be an exhaustive list of all components in all configurations.



Key

Component by Clause number:

8 check valves
9 manual valves
10 manual container valves
11 automatic valves and automatic container valves
12 hydrogen injectors
13 pressure sensors, temperature sensors, and pressure gauges
14 pressure regulators
15 pressure relief valves
16 pressure relief devices
17 excess flow valves
18 gastight housing and leakage capture passages (not in figure)
19 rigid fuel lines
20 flexible fuel lines, hoses, and hose assemblies
21 filter assemblies
22 fittings (not in figure)
23 non-metallic, low-pressure rigid fuel lines
24 discharge line closures
A receptacle (not in scope)
B container (not in scope)
C fuel cell/engine (not in scope)
i NWP (Filling cycles)
ii NWP (Duty cycles)
iii MOP (Duty cycles, downstream of first stage of pressure reduction)

Figure 1 — Hypothetical compressed hydrogen fuel system

4.1.2 Material requirements

4.1.2.1 General

Pressure-containing materials 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.

4.1.2.2 Metallic materials

Material acceptability for metallic materials shall be demonstrated by testing or by referencing published data for the same material, representative form (e.g., bar or plate, forging or casting, etc.), similar strength, and equivalent service conditions.

NOTE Information regarding material performance in hydrogen environments can be found in ISO/TR 15916, ANSI/CSA CHMC 1, ASME B31.12 and SAE J2579 Appendix B.

Hydrogen compatibility may be demonstrated by testing in hydrogen environments as anticipated in service, such as the continuous operation test specified in 5.6.

Resistance to chloride stress corrosion cracking shall be taken under consideration if selecting stainless steel materials. Resistance to corrosion cracking shall be taken under consideration if selecting carbon steel materials (e.g., by choosing appropriate coating, manufacturing processes).

Resistance to stress corrosion cracking and sustained load cracking shall be taken under consideration if selecting aluminium materials.

Resistance to galvanic corrosion shall be taken under consideration when joining components containing dissimilar materials.

4.1.2.3 Non-metallic materials

The suitability of non-metallic organic materials (e.g., rubbers, plastics) for hydrogen service shall be verified, taking into consideration the fact that hydrogen diffuses through these materials more easily than through metals.

Non-metallic materials shall retain their mechanical stability with respect to strength (e.g., 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 chemical and physical properties necessary for operational safety should not be significantly affected within the scheduled lifetime of the component. Specifically, when selecting materials and manufacturing methods, due account should be taken of the material's wear resistance, impact strength, aging resistance, the effects of temperature variations, effects that arise when materials are put together, the effects of ultraviolet radiation, rapid gas decompression and the degradation effects of hydrogen on the mechanical performance of a material.

The manufacturer shall verify the material's suitability, including consideration for such characteristics as permeability, creep, long-term aging, stress cracking, and retention of mechanical properties, as appropriate. Safety margin shall be demonstrated by the hydrostatic strength test, allowable leakage, and the use of materials below their creep threshold for their qualification temperature.

Guidance to account for the degradation effects of hydrogen on the mechanical performance of a material can be found in ISO/TR 15916 and ANSI/AIAA G-095.

Hydrogen compatibility for non-metallic materials may be demonstrated by testing in hydrogen environments as anticipated in service or by one or more of the following:

a) documented field experience with successful performance of the material in hydrogen environments with similar service conditions;

b) performance of industry approved standards for hydrogen compatibility, such as CSA/ANSI CHMC 2;

c) use of hydrogen as the test gas for the continuous operation test specified in 5.6 (and the other component specific clauses); and

d) the hydrogen gas exposure test specified in 5.12.2.

4.1.3 Threaded openings

All threads shall comply with a recognized international or national standard.

Tapered threads, such as National Pipe Threads (NPT) should not be used in high-pressure applications as tapered threads have proven to be less robust than other thread designs. If used, tapered threads shall be sealed with appropriate sealant as specified by the manufacturer.

4.1.4 Service temperatures

All components shall be suitable for service within a temperature range of −40 °C to 85 °C. Components in an internal combustion engine compartment shall be suitable for service within a temperature range of −40 °C to 120 °C.

It is possible that operational gas temperatures are outside of this range. The manufacturer may choose to test beyond the service temperatures listed above.

4.1.5 Design service life

The design service life of the component shall be specified by the component manufacturer.

NOTE 1 The testing described in this document is based on an expected service life of 20 years. Service life values can be extended by adjusting the filling or duty cycles, as applicable, by the appropriate factor (ratio). For example, a service life of 25 years will require cycling to be multiplied by 1,25.

NOTE 2 Filling cycle testing is based on 15,000 cycles, which includes an embedded factor of safety and considers a maximum of 750 fuellings per year multiplied by the service life of the component. Duty cycles are component specific for the intended usage and safety factor of that particular component.

4.2 Failure modes and effects analysis (FMEA)

Design and Process FMEA, or equivalent, shall be performed for all components covered by this document.

NOTE FMEA is a methodology used in the automotive industry to identify potentially hazardous failure modes of safety devices and to recommend changes in design, manufacturing, inspection, or testing that 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. See SAE J1739 for more information.

4.3 Electrical equipment and wiring

4.3.1 Openings

Any openings of the component through which electrical wiring components are routed shall be equipped with means to prevent chafing and abrasion of the conductor insulation.

4.3.2 Equipment

Electrically-operated valves and sensors used in areas where there is a potential for external hydrogen leakage into an oxidizing environment shall be inherently non-sparking (e.g., encapsulated solenoid coil and restrained connections such that the possibility for a spark is negligible).

Wiring in this region shall be protected against damage (e.g., by using insulated and sheathed cables or single insulated wires protected by outer coverings).

4.3.3 Materials

Materials used for electrical construction shall be suitable for their particular application. When determining the acceptability of an electrical insulating material, consideration shall be given to its mechanical strength, dielectric strength, heat-resistant properties, the degree to which it is enclosed or protected, and any other features influencing fire and accident hazards.

4.3.4 Connectors

The connectors shall be arranged such that the possibility of damage or loosening of wiring at the connection is negligible (e.g., connections with wires or cables that are encapsulated or moulded with the plug).

4.4 Component literature

4.4.1 General

Manufacturers of components for compressed hydrogen gas powered vehicles shall provide literature for their components. Literature may be provided in printed or electronic format. This literature shall provide information to guide the installer in making a proper installation. The literature shall also require that intermediate assemblers transmit the component warnings and literature to the installer. The manufacturer shall provide duplicate literature in response to requests, including service parts.

4.4.2 Instructions – General

Instructions shall include at least the following:

a) nominal working pressure (MPa) and specification for hydrogen use as indicated by “H25”, “H35”, “H50”, or “H70”, or maximum operating pressure for components not exposed to container pressure;

b) operating temperature limits;

c) mounting limitations with regards to corrosion resistance, including whether the component is suitable for underbody, exterior, or interior locations;

d) flow ratings (e.g., Kv) of connections if required for safety, such as flow requirements into and out of pressure relief valves;

e) requirements for warning labels that can be required as part of the installation;

f) components that require periodic replacement shall be identified;

g) manufacturer‘s or representative’s contact information;

h) the design service life of the components as specified by the manufacturer; and

i) other information as required by specific component clauses.

4.4.3 Instructions – Additional considerations

Instructions shall also include, as appropriate:

a) installation instructions, including torques;

b) installation orientation requirements;

c) service procedures including recommended service intervals; and

d) recommendations for service access.

4.4.4 Installation instructions

Installation instructions shall state that the installation shall be in accordance with the regulations of the local authority having jurisdiction.

4.5 Marking

4.5.1 General marking information

The components shall be marked with the following information as required by the relevant clause of this document:

a) the direction of flow (when necessary for correct installation);

b) the serial number, date code, or suitable traceability code;

c) the specification for compressed hydrogen gas use and either

   1) nominal working pressure, if the component is upstream of the first stage of pressure reduction (may be indicated by "H25", "H35", "H50", or "H70"); or

   2) maximum operating pressure if the component is downstream of the first stage of pressure reduction;

d) the manufacturer's or agent's name, trademark, or symbol;

e) the model designation (part number);

f) the service temperature range; and

g) the designation of this document "ISO 19887-1:2024".

NOTE Additional specific component marking requirements can be found in subsequent clauses of this document.

4.5.2 Marking methods

Markings 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.

NOTE Marking information can be provided by a suitable identification code on at least one part of the component when it consists of more than one part.

4.5.3 Exclusion of markings

When the size and shape of components does not allow for the required markings, the required information:

a) shall be provided in the manufacturer's literature; and

b) may be omitted from the component in the reverse order listed in the applicable marking clause (either the specific marking clause for the component or in 4.5.1).

5 General test methods

5.1 General test requirements

5.1.1 Testing samples

Testing shall be conducted on finished components that are representative of normal production or material samples when specified. Unless otherwise specified, a new component may be used for each test specified herein.

5.1.2 References to other standards

This document references other standards that might not take into account temperature, pressure, and environmental conditions for compressed hydrogen fuel systems. Since these conditions can affect material or operating characteristics of components, these conditions shall be taken into account and utilized when evaluating the component to the referenced standard. The components shall comply under such conditions with the provisions of the referenced standard.

5.1.3 Pressure and temperature requirements

5.1.3.1 Ambient temperature

Unless stated otherwise, the tests specified herein shall be conducted at ambient temperature, defined as 20 °C ± 15 °C.

5.1.3.2 Temperature tolerances

Unless stated otherwise, the tests specified herein shall be conducted with the following tolerances on specified temperatures:

a) −40 °C + 0 °C or lower;

b) 85 °C − 0 °C or higher; or

c) 120 °C − 0 °C or higher.

The "or lower" and "or higher" tolerance limit shall be defined by the component manufacturer.

5.1.3.3 Pressure tolerances

Unless stated otherwise, the tests specified herein shall be conducted with the following tolerances on specified pressures:

a) pressures 2 MPa or less: +0/−1 MPa;

b) pressures 125 % NWP or greater: +2 MPa/−0 MPa.

5.1.4 Test gases

5.1.4.1 General

Unless otherwise specified, all tests shall be conducted using hydrogen or non-reactive gas (e.g., nitrogen, helium).

The dew point of the test gas at the test pressure shall be at a temperature at which there is no icing, hydrate formation, or liquid formation.

If testing with hydrogen, the component should be purged with a non-reactive gas.

Testing described in these requirements can result in the sudden release of test gas at high pressure with dangerous explosive force. Adequate protection from explosion, concussion, and flying debris should be utilized to protect test personnel and facilities.

5.1.4.2 Leak test gas

The leak test gas shall be hydrogen, helium, or a non-reactive gas mixture containing a detectable amount of hydrogen or helium gas.

5.1.4.3 Hydrogen gas

Hydrogen gas used for testing shall be compliant with ISO 14687 or SAE J2719, or meet the following specifications:

a) hydrogen fuel index: ≥ 99,97 %;

b) total non-hydrogen gases: ≤ 300 µmol/mol;

c) water: ≤ 5 µmol/mol; and

d) particle concentrations: ≤ 1 mg/kg.

5.1.5 Material acceptance

Tests specified to establish the acceptance of a material (metallic or non-metallic) for use in a component may be waived when there is acceptable evidence in the form of a declaration, supplied by the manufacturer of the material, to substantiate its suitability for use in the expected environment.

5.1.6 Multi-functional components

It is recognized that multi-functional components can be made up of several components as defined in 1.1. Such components shall be examined for conformance to Clauses 4 and 5 of this document and tested in accordance with the appropriate functional tests per the component specific clauses (e.g., Clauses 8 through 24).

5.1.7 Pre-cooling effects

The effects of pre-cooling shall be considered for hydrogen components that can be exposed to hydrogen flow during fuelling (upstream of the container).

NOTE Additional information on hydrogen pre-cooling is shown in 5.16.

5.1.8 Electrically operated components

Unless stated otherwise, electrical operation of a component shall be conducted at the nominal voltage as specified by the manufacturer.

5.2 Hydrostatic strength

5.2.1 General

Components intended for use at rated pressures equal to or in excess of 14 kPa shall not leak or rupture when subjected to the test outlined in 5.2.2 a).

This test shall be conducted at ambient temperature. The outlet opening in components shall be plugged and valve seats or internal blocks made to assume the open position. One virgin component shall undergo this test, as well as additional components as specified in the subsequent tests.

5.2.2 Test method

The test method is as follows:

a) A hydrostatic pressure of 250 % of the specified nominal working pressure for components upstream of the first stage of pressure reduction, or 250 % of the maximum operating pressure for components downstream of the first stage of pressure reduction of the component, shall be applied to the inlet of the component for a period of at least 3 min. The component shall be examined to verify that leak or rupture has not occurred.

b) The hydrostatic pressure shall then be increased at a rate of less than or equal to 5 % of the nominal working pressure or maximum operating pressure per second, whichever is appropriate, until the component bursts. The hydrostatic pressure at burst shall be recorded. The burst pressure of components subjected to the performance tests per other clauses in this document shall be not less than 80 % of the burst pressure of the virgin component, unless the hydrostatic pressure exceeds 400 % of the nominal working pressure, or maximum operating pressure, as applicable.

5.3 Leakage

5.3.1 General

Prior to conditioning, the component shall be sealed with leak test gas at a minimum of 2,5 % of nominal working pressure for components upstream of the first stage of pressure reduction, or a minimum of 2,5 % of maximum operating pressure for components downstream of the first stage of pressure reduction.

All tests shall be conducted while the component is continuously exposed to the specified test temperatures. The component shall be thermally conditioned at each of the required test temperatures and held for at least 1 h to ensure thermal stability before testing. The component shall either be bubble-free or have a leakage rate less than the values specified in 5.3.2 and 5.3.3.

5.3.2 External leakage

Each component outlet opening shall be plugged with the appropriate mating connection and the leak test gas shall be applied to the inlet.

At all test temperatures, the external leakage rate of the component shall be monitored by an appropriate method (e.g., immersion in a suitable liquid, global accumulation method, or other equivalent methods) for at least 1 min.

If no leakage is observed for the specified time period, the sample passes the test. If leakage is detected, the leak rate shall be measured by an appropriate method and shall not exceed 10 Ncm^3/h of hydrogen gas.

5.3.3 Internal leakage

The internal leakage test shall be applicable only to components having a closed position. If the component is designed to be used with pressure differential in both directions, then the leakage test shall be conducted in each direction. Separate samples may be used for each direction.

The pressurized side of the component shall be connected with the appropriate mating connection, while leaving the opposite connection or connections open.

With the component in the closed position, leak test gas shall be applied to the connected opening and the leakage shall be measured at the other opening of the component for at least 1 min using an appropriate method.

The leak rate shall not exceed 10 Ncm^3/h of hydrogen gas unless otherwise specified.

5.3.4 Test conditions

5.3.4.1 Components exposed to container pressure

The component shall be conditioned at ambient temperature and pressurized at both 5 % and 125 % of nominal working pressure.

The component shall be conditioned at −40 °C and pressurized at both 100 % and 5 % of nominal working pressure.

The component shall be conditioned at 85 °C or 120 °C, as applicable, and pressurized at both 5 % and 125 % of nominal working pressure.

5.3.4.2 Components downstream of the first stage of pressure reduction

The component shall be conditioned at ambient temperature and pressurized at both 5 % and 100 % of maximum operating pressure.

The component shall be conditioned at −40 °C and pressurized at both 100 % and 5 % of maximum operating pressure.

The component shall be conditioned at 85 °C or 120 °C, as applicable, and pressurized at both 5 % and 100 % of maximum operating pressure.

5.4 Excess torque resistance

A component designed to be connected directly to threaded fittings shall be capable of withstanding without deformation, breakage, or leakage a turning effort of 150 % (or the overtorque test value as defined in the specific threaded connection standard) of the maximum rated turning effort exerted to install the component.

The component shall be tested as follows:

a) Test an unused component, applying the torque adjacent to the fitting, thereby installing it into a threaded fixture of suitable size.

b) For a component having a threaded connection or threaded connections, apply the torque for 15 min to each threaded connection, release the torque, then remove the component and visually examine it for deformation or breakage.

c) For a component that has been specified to be pulled up by turns (e.g., rotation angle), follow the manufacturer's instructions, apply 1,5 times the number of specified turns, or angle, as applicable, then remove the component and visually examine for deformation or breakage.

Subject the component to the external leakage test specified in 5.3.2 and the hydrostatic test specified in 5.2.

5.5 Bending moment

A component subject to bending moment tests shall be capable of operation without cracking, breaking, or leaking while being subjected to a bending moment, using the weight specified in Table 1 in accordance with the following test procedure:

a) The inlet and outlet connections of the component shall be assembled leak-tight to the appropriate fittings as described in Items 1) to 3). The length of the inlet fitting shall be such that, after assembly, the dimensions from the inlet fitting shall be 330 mm or greater:

   1) Pipe threaded connections shall be assembled to Schedule 80 pipe.

   2) Tubing connections shall be connected to tubing that can withstand the force as specified in Table 1.

   3) Connections designed for other than threaded pipe or tubing shall be connected to a test fixture(s) representative of the intended connection means.

b) The component outlet fitting shall be rigidly supported 25 mm from the component outlet, unless the following exceptions apply:

   1) When the component has an integral mounting means independent of the inlet and outlet connections, the component shall be mounted using the integral mounting means as specified by the manufacturer.

   2) When the component 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.

   3) The component shall be mounted in the horizontal position. Refer to Figure 2 for a typical test setup.

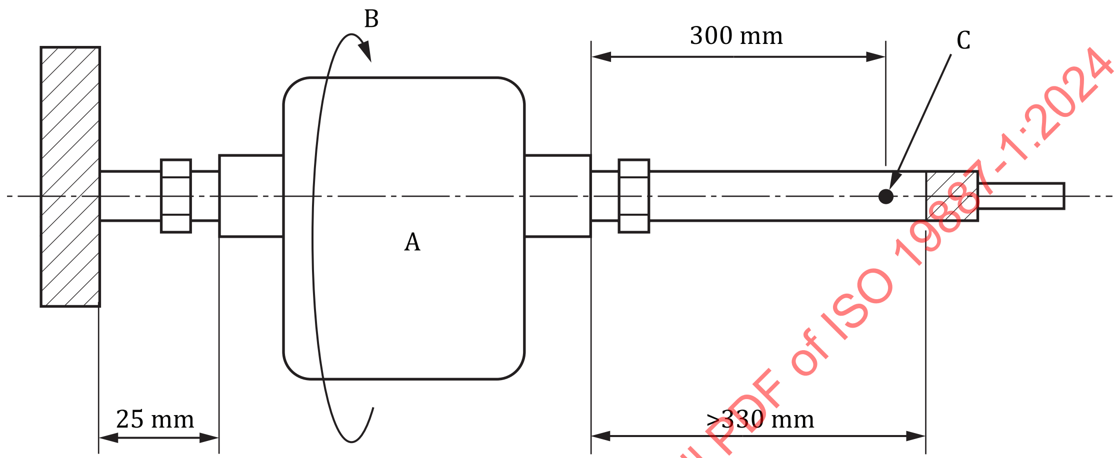
c) With the component in the closed position, the appropriate force shall be applied at 300 mm from the inlet and maintained for at least 15 min. Without removing the force, the component shall be checked for leakage. Components shall not leak externally in excess of the leakage rates specified in 5.3.2.

d) The test in Item c) shall be repeated three times with the component rotated 90° around the horizontal axis after each test.

e) At the completion of the above tests, the component shall be removed and visually examined for deformation and breakage, and then subjected to the leakage test as specified in 5.3 and the hydrostatic test in 5.2.

Table 1 — Bending moment test force

Outside diameter of tubing	Force
< 8 mm	3,4 N
≥ 8 mm to < 12 mm	9,0 N
≥ 12 mm	17,0 N



Key

A component

B rotate 90° between tests

C force point

Figure 2 — Bending moment illustration

5.6 Continuous operation

5.6.1 General

Three samples of the component shall be subjected to the continuous operation test. For the details of test methods for specific components, see the appropriate clauses (e.g., Clauses 8 through 24) of this document. Other components (i.e., those for which specific requirements are not specified) shall be subjected to the continuous operation test requirements in 5.6.2.

5.6.2 Test method

5.6.2.1 Number of cycles

Components shall be subjected to the following continuous operation test for a total number of cycles covering the expected service life of the component.

a) The components shall be installed as indicated by the manufacturer and cycled using test gas under all appropriate loads. Cycling may be interrupted, if desired, for intermediate leakage testing.

b) A cycle shall consist of one full operation and reset.

c) At the completion of all cycling and leakage tests per 5.6.2.2 to 5.6.2.4, the components shall be subjected to the hydrostatic test as specified in 5.2.

The determination of the total number of cycles should be generally based on 15 000 filling cycles or 50 000 duty cycles. The number and duration of cycles should be based upon the functionality of the component and expected service life.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

NOTE The leakage tests can be performed at the intervals listed in the procedure in 5.6.2.2 to 5.6.2.4, while the components are already conditioned to the appropriate temperatures. Alternatively, all leakage tests at all required temperatures can be performed per 5.3 at the completion of all cycling.

5.6.2.2 Ambient temperature cycling

The component shall be operated through 90 % of the total cycles with the part stabilized at ambient temperature and at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or maximum operating pressure for components downstream of the first stage of pressure reduction. For components subjected to filling cycles, the first 10 cycles shall be conducted from ≤ 10 % of nominal working pressure to ≥ 150 % of nominal working pressure. The component shall comply with the ambient temperature leakage test specified in 5.3 at the completion of the ambient temperature cycles.

5.6.2.3 High temperature cycling

The cycling procedure shall be repeated with the part stabilized at the appropriate maximum temperature, 85 °C or 120 °C, for 5 % of the total cycles at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or maximum operating pressure for components downstream of the first stage of pressure reduction. The component shall comply with the appropriate maximum temperature leakage test specified in 5.3 at the completion of the high temperature cycles.

5.6.2.4 Low temperature cycling

The cycling procedure shall be repeated with the part stabilized at −40 °C for 5 % of the total cycles at 80 % of the nominal working pressure for components upstream of the first stage of pressure reduction, or maximum operating pressure for components downstream of the first stage of pressure reduction. The component shall comply with the −40 °C leakage test specified in 5.3 at the completion of the low temperature cycles.

5.7 Corrosion resistance

5.7.1 General

All components shall be exposed to either a salt spray (fog) test or accelerated cyclic corrosion test (see Table 2).

NOTE 1 See 4.1.2 for stress corrosion concerns.

NOTE 2 Components with external surfaces made entirely of austenitic stainless steels, such as AISI Series 300 or equivalents as defined in ISO 15510:2014, Tables 1 and 2 are exempt from corrosion resistance salt spray and cyclic corrosion testing.

NOTE 3 See Annex A for additional solenoid valve extreme thermal cycling test.

Table 2 — Corrosion Test Applicability

Type of component	Vehicle location	Salt spray	20 cycles cyclic corrosion	100 cycles cyclic corrosion	60 cycles powered – Extreme thermal cycling
Primary container pressure retention	Underbody or unknown			X	
Non-container pressure retention	Underbody or unknown		X		
Primary container pressure retention	Other than underbody		X		
Non-container pressure retention	Other than underbody	X			
Solenoid valve	Underbody, underhood, or unknown				See Annex A
NOTE Primary container pressure retention components consist of automatic and manual container valves, fittings, tubing, and check valves, for example, as identified by the component manufacturer.					

5.7.2 Salt spray exposure

All components, other than those whose failure can result in uncontrolled release of the container contents, that are expected to operate in other than vehicle underbody service conditions shall be exposed to a salt spray (fog) test.

A minimum of three samples of the component shall be installed in accordance with the manufacturer's recommended procedure and exposed for 144 h to a salt spray (fog) test as specified in ISO 9227 or ASTM B117.

The temperature within the fog chamber shall be maintained at 35 °C ± 2 °C. The saline solution shall consist of 5 % sodium chloride and 95 % distilled water, by weight.

Immediately following the corrosion test, the components shall be rinsed and gently cleaned of salt deposits and examined for distortion. The components shall then be subjected to the leakage test specified in 5.3, followed by the hydrostatic strength test in 5.2.

5.7.3 Accelerated cyclic corrosion

5.7.3.1 General

Components shall be exposed to an accelerated laboratory corrosion test under a combination of cyclic conditions (salt solution, various temperatures, humidity, and ambient environment). This test is applicable to components that are:

a) expected to operate in vehicle underbody service conditions, or those components for which their in-vehicle locations are unknown, and

b) all components whose failure can result in uncontrolled release of the container contents (e.g., automatic and manual container valves, fittings, tubing, check valves, etc.).

The test method shall be comprised of 1 % (approximate) complex salt mist applications coupled with high temperature, high humidity, and high temperature dry-off. Electrical components shall be connected to an electrical source, caused to be energized at the rated voltage, cycled 1 h on/1 h off during the active test segments, and grounded as per the intended vehicle installation method. One test cycle is equal to 24 h, as illustrated in Figure 3.

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 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, a visual inspection shall be made to 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, a visual inspection shall be made to 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 a temperature of 60 °C ± 2 °C and relative humidity at ≤ 30 % RH.

The apparatus shall have sufficient air circulation to prevent temperature stratification and 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.

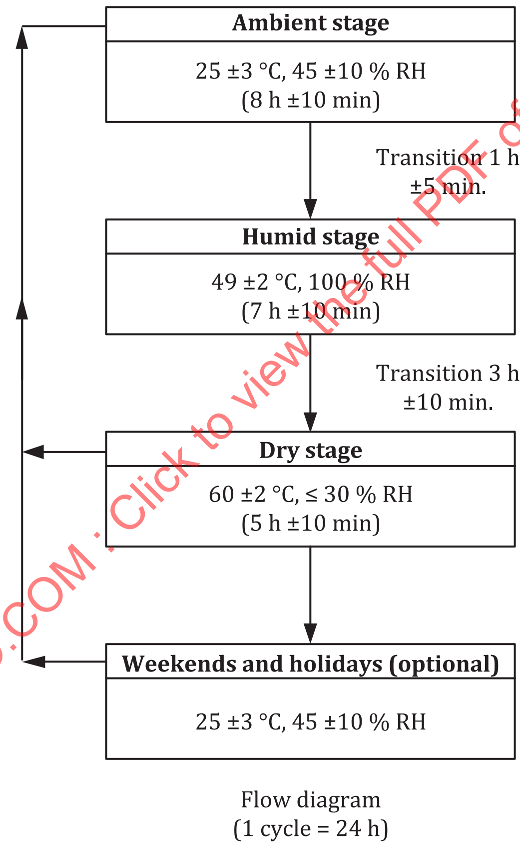


Figure 3 — Accelerated cyclic corrosion flow diagram

5.7.3.2 Salt solution

The complex salt solution in percent by mass shall be as follows:

a) sodium chloride (NaCl): 0,9 %;

b) calcium chloride ($CaCl_2$): 0,1 %; and

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 or food grade (e.g., baking soda or comparable product is acceptable). Water shall meet ASTM D1193 Type IV requirements.

Either CaCl2 or NaHCO3 material should be dissolved separately in water and added to the solution of the other materials. If all solid materials are added dry, an insoluble precipitate can result.

5.7.3.3 Method

A minimum of three samples of the component shall be supported in their normally installed position and exposed to the cyclic corrosion test method illustrated in Figure 3. Electrical components shall be connected to an electrical source, grounded as per the intended vehicle installation method, and caused to be energized at the rated voltage, and cycled 1 h on/1 h off for the active test segments. The cycle shall be completed daily until the specified number of cycles of exposure has been completed.

NOTE The weekends and holidays portion of the test is optional, and does not contribute towards the number of test cycles.

For each salt mist application, the solution shall be sprayed as an atomized mist, using the spray apparatus to mist the component until all areas are thoroughly wet and 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. A total of four salt mist applications shall be applied during the ambient stage. Salt mist is not applied during any other stage of the test. 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 to allow adequate time for test sample to dry.

Humidity ramp times between the ambient and wet conditions 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 condition shall be 60 min ± 5 min and the transition time between wet and dry conditions shall be 180 min ± 10 min.

Components where failure can result in uncontrolled release of the container contents (e.g., automatic and manual container valves, fittings, tubing, check valves, etc.) and that are in an underbody or unknown position shall be tested for a duration of 100 cycles. All other components in an underbody or in an unknown position, and components where failure can result in uncontrolled release of the container contents in other than an underbody position, shall be tested for a duration of 20 cycles.

5.7.3.4 Pass criteria

Immediately following the completion of the cyclic corrosion test, the components shall be rinsed with fresh water and allowed to dry before evaluating. The tested samples shall then be subjected to the leakage test specified in 5.3 followed by the hydrostatic strength test in 5.2.

The average hydrostatic burst pressure of the three corroded components shall be no less than 80 % of the failure pressure of the virgin component. Electrical components shall show no degradation of function.

5.8 Ultraviolet resistance of external surfaces

5.8.1 General

Ultraviolet resistance may be determined by the test in 5.8.2, by comparable published data, or by known material properties.

5.8.2 Ultraviolet resistance test

The external non-metallic surfaces, including coatings, of the component shall be evaluated for resistance to ultraviolet effects using a minimum 1 000 h exposure under a UVA 340 lamp in accordance with ASTM

G154. The inlet and outlet connections of the component shall be connected or capped in accordance with the manufacturer's installation instructions.

5.8.3 Pass criteria

There shall be no evidence of blistering, cracking, chalking, or softening that would negatively affect the function of the component. If the non-metallic material is integral to pressure containment or function of the device, then after this test the device shall meet the leakage requirements of 5.3 and the hydrostatic strength requirements of 5.2.

5.9 Automotive fluid exposure

5.9.1 General

External portions of components shall be able to withstand exposure to the following fluids (see 5.9.3) without mechanical degradation. Resistance may be determined by the test in 5.9.2, by comparable published data, or by known properties (e.g., 300 Series stainless steel).

5.9.2 Test method

The external surfaces of the component shall be exposed to the following test:

a) The inlet and outlet connections of the component shall be connected or capped in accordance with the component manufacturer's installation instructions.

b) The component shall be exposed, at ambient temperature, by spraying the exterior of the component once per hour, 24 times, over a period of up to 3 days (e.g., three 8-h shifts over 3 days or 24 h straight). Alternatively, the component may be immersed in the solution for a period of 24 h. In the immersion method, the fluid shall be replenished as needed to provide complete exposure for the duration of the test.

c) A distinct test shall be performed with each of the three fluids specified in 5.9.3. One component may be used for all three exposures sequentially.

5.9.3 Fluids

The following fluids shall be used:

a) sulfuric acid: 19 % solution by volume in water;

b) ethanol/gasoline: 10/90 % concentration of ethanol fuel (E10); and

c) windshield washer fluid: 50 % by volume solution of methanol and water.

5.9.4 Pass criteria

After exposure to each fluid, the component shall be wiped off, rinsed with water, and examined. The component shall not show signs of mechanical degradation that can impair the function of the component such as cracking, softening, or swelling. Cosmetic changes such as pitting or staining are not considered failures. After all exposures, the component(s) shall meet the leakage requirements of 5.3 and the hydrostatic strength requirements of 5.2.

5.10 Atmospheric exposure

NOTE The atmospheric exposure test applies to qualification of components that have non-metallic materials exposed to the atmosphere during normal operating conditions.

5.10.1 Oxygen aging

All non-metallic materials that provide a fuel-containing seal, that are exposed to atmosphere, and for which a satisfactory declaration of properties is not available from the material manufacturer shall not crack or show visible evidence of deterioration after exposure to oxygen for 96 h at 70 °C and 2 MPa, in accordance with ISO 188 or ASTM D572.

5.10.2 Ozone

All elastomers shall demonstrate resistance to ozone by one or more of the following methods:

a) specification of elastomer compounds with established excellent resistance to ozone;

b) testing in accordance with ISO 1431-1, ASTM D1149, or equivalent test methods; or

c) the test piece shall be stressed to 20 % elongation and exposed to air at 40 °C with an ozone concentration of 50 parts per hundred million during 120 h. The non-metallic materials in the test piece shall not crack or show visible evidence of deterioration after exposure to ozone.

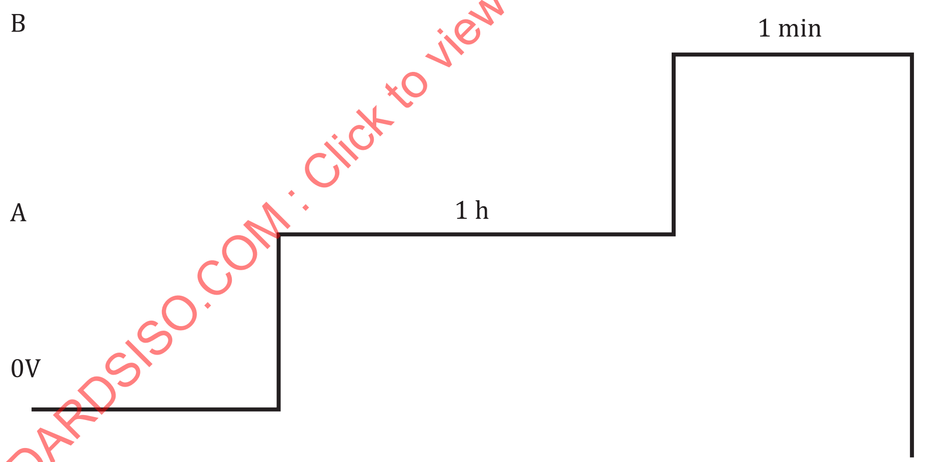
5.11 Abnormal electrical voltages

5.11.1 Overvoltage testing

5.11.1.1 General

This test is only applicable to electrically operated components.

The component shall be connected to a variable DC voltage source. The test shall be conducted at ambient temperature per the cycle in Figure 4.



Key

A 1,5 times rated voltage

B 2 times the rated voltage or 60 V, whichever is less

Figure 4 — Abnormal electrical voltages test cycle

5.11.1.2 Test method

At 1,5 times the rated voltage, establish equilibrium (steady state temperature), and hold for 1 h.

Increase the voltage to 2 times the rated voltage or 60 V, whichever is less, and hold for 1 min.

5.11.1.3 Pass criteria

Any failure shall not result in an open valve, or a similar unsafe condition, and shall comply with the external leakage test at ambient temperature as per 5.3.2.

5.11.2 Minimum opening voltage

The minimum opening voltage at ambient temperature shall be less than or equal to 66 % of the nominal system voltage. The component shall be pressurized to nominal working pressure for components upstream of the first stage of pressure reduction or maximum operating pressure for components downstream of the first stage of pressure reduction while the minimum opening voltage is being applied and measured.

The manufacturer may also consider defining a lower limit voltage below which the component shall not operate to ensure that a valve will not activate unexpectedly due to leakage current.

5.12 Non-metallic material hydrogen compatibility

5.12.1 General

Except where satisfactory declarations of hydrogen compatibility are available from the manufacturer of a non-metallic material used in a component, such materials shall require at least one of the following:

a) documented field experience with successful performance of the material in hydrogen environments with similar service conditions;

b) performance of industry-approved standards for hydrogen compatibility, such as CSA/ANSI CHMC 2;

c) use of hydrogen as the test gas for the continuous operation test specified in 5.6 (and the other component specific clauses); and

d) the hydrogen gas exposure test specified in 5.12.2.

5.12.2 Hydrogen gas exposure

The test shall be conducted as follows.

a) A representative sample(s) of each non-metallic material used in a component shall be prepared, measured, and weighed, and then immersed at ambient temperature in hydrogen gas at nominal working pressure for components upstream of the first stage of pressure reduction, or maximum operating pressure for components downstream of the first stage of pressure reduction, as applicable, for at least 70 h.

b) Following 70 h immersion, the test pressure shall be reduced to atmospheric pressure at a rate of 5 MPa/min or greater without causing shredding or disintegration. The test sample(s) shall be measured and weighed within 1 h of pressure reduction.

Testing may be done at pressures greater than NWP or MOP, if desired for usage of the material at multiple pressure ranges.

The non-metallic material sample in contact with hydrogen gas shall not exhibit swelling greater than 25 % nor shrinkage greater than 1 %, and the weight loss shall not exceed 10 % after the exposure period.

5.13 Vibration resistance

5.13.1 Test method

The component, pressurized to its nominal working pressure for components upstream of the first stage of pressure reduction, or maximum operating pressure for components downstream of the first stage of pressure reduction, with test gas or compressed air and sealed at both ends, shall be vibrated for 30 min along opposing directions of three orthogonal axes (vertical, lateral, longitudinal) at the most severe resonant frequency, determined as follows:

a) by an acceleration of 1,5 *g*;

b) within a sinusoidal frequency range of 10 to 500 Hz; and

c) with a sweep time of 10 min.

If the resonance frequency is not found in this range, the test shall be conducted at 40 Hz.

5.13.2 Pass criteria

At the completion of the vibration test, the component shall not show any indication of fatigue or component damage and shall comply with the leakage test specified in 5.3 and the hydrostatic strength test as specified in 5.2.

5.14 Stress corrosion cracking resistance

5.14.1 General

This test shall only be applicable to components containing copper alloys exposed to the external environment. This test is not applicable to components containing internal copper alloy components (i.e., not exposed to the outside environment).

All fuel-containing copper alloy components or subcomponents for which a satisfactory declaration of properties is not available from the manufacturer shall be tested and evaluated in accordance with 5.14.2.

For pressure-containing components made of a copper alloy containing more than 15 % zinc, one unit shall be tested as an assembly. The copper alloy component shall be subjected to the highest stresses normally imposed on it as a result of assembly. Torque-specified joints shall be assembled to the maximum specified assembly torque.

Tapered threads assembled to a specific number of turns of engagement shall be assembled with no sealant or with sealant per the manufacturers' specification and to the maximum engagement specified for assembly.

The test shall be repeated if there is a change in alloy or if the machining process is changed in such a way that can affect residual stresses. An example would be a change from cut threads to rolled threads.

5.14.2 Test method

All copper alloy components shall be degreased and then continuously exposed for 10 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 litre of chamber volume. The samples shall be positioned 35 mm ± 5 mm above the aqueous ammonia solution and supported in an inert tray. The moist, ammonia-air mixture shall be maintained at atmospheric pressure with the temperature constant at 35 °C ± 5 °C.

5.14.3 Pass criteria

Copper alloy components shall not exhibit cracking or delamination due to this test.

5.15 Insulation resistance

This test is designed to check for a potential failure of the insulation between the component's power conductor and the component casing.

A test voltage of 1 000 V DC shall be applied between the power conductor and the component casing for at least 2 s. The minimum allowable resistance for the component shall be 240 kΩ, unless otherwise specified in the subsequent clauses. Alternatively, compliance may be demonstrated by meeting the requirements of the insulation resistance test from ISO 16750-2.

5.16 Pre-cooled hydrogen exposure

Components in the hydrogen fuelling path will likely be subjected to pre-cooled hydrogen gas in service. Manufacturers of fuelling path components shall consider the effects of pre-cooled hydrogen during fuelling events, where the incoming hydrogen gas may reach temperatures as low as -40 °C, pressures as high as 125 % NWP, and high flow rates per the relevant industry standards. Fuelling path components are intended to remain operational and leak-free (≤ 10 Ncm^3/h) during pre-cooled hydrogen fuelling.

NOTE System level pre-cooled hydrogen performance, which includes the relevant fuelling path components installed as intended for service, is confirmed with fuel system pre-cooled fuelling tests, such as those described in UN GTR No. 13 “Ambient and extreme temperature gas cycle test (pneumatic)” and SAE J2579 “Expected Service (Pneumatic) Performance Test”.

6 Quality assurance

Quality management system programs shall be established and operated to demonstrate that hydrogen fuel system components are produced in accordance with the qualified design.

7 Production inspection and acceptance testing

7.1 Inspection and acceptance testing plan

The component manufacturer shall prepare a plan for production inspection and acceptance testing. Inspections and tests may be conducted by suppliers, the component manufacturer, or an independent agency.

7.2 Inspection of system critical components

System-critical components identified in the FMEA, as described in 4.2, shall have an appropriate control plan developed. The manufacturer shall demonstrate conformance of its component to this document using a suitable quality management system (see Clause 6) before assembly or shipment.

7.3 External leak testing

Unless exempted in the relevant component clauses, all components upstream of the first stage of pressure reduction shall be tested for leakage at ambient temperature and a minimum of 125 % of nominal working pressure.

Unless exempted in the relevant clauses, all components downstream of the first stage of pressure reduction shall be tested for leakage at ambient temperature, and a minimum of 100 % of maximum operating pressure.

Components that leak greater than 10 Ncm^3/h of hydrogen equivalent shall be rejected. Air, hydrogen or other non-reactive gases at any concentration may be used to measure leakage in this test, providing the leak rate of the test gas is converted to an equivalent leak rate for hydrogen gas.

8 Check valves

8.1 Marking

Marking of the check valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the direction of flow for correct installation, if applicable;

b) the serial number, date code, or similar traceability code;

c) the specification for compressed hydrogen gas use and either

   1) nominal working pressure, as indicated by “H25”, “H35”, “H50”, or “H70” if the component is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the component is downstream of the first stage of pressure reduction;

d) the manufacturer’s or agent’s name, trademark, or symbol;

e) the model designation (part number);

f) the temperature range; and

g) the designation of this document “ISO 19887-1:2024”.

8.2 Construction and assembly

Check valves shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 8.3.

8.3 Tests

8.3.1 General

The applicable tests for check valves are listed in Table 3.

Table 3 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 8
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	Yes[a]	X	
Bending moment	Yes[a]	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	No		
Pre-cooled hydrogen exposure	Yes[b]	X	

[a] Not applicable to check valves installed within other components.

[b] Applicable for H70 components in the hydrogen fuelling path between the vehicle’s receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

8.3.2 Continuous operation

8.3.2.1 General

A check valve located upstream of the first stage of pressure reduction shall be capable of withstanding 15 000 cycles of operation in accordance with 8.3.2.2, and 24 h of chatter flow in accordance with 8.3.2.4.

A check valve located downstream of the first stage of pressure reduction shall be capable of withstanding 50 000 cycles of operation in accordance with 8.3.2.3, followed by 24 hours of chatter flow in accordance with 8.3.2.4.

At the completion of the operation cycles and chatter flow tests, the component shall comply with the leakage test specified in 5.3 and the hydrostatic strength test specified in 5.2.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

8.3.2.2 Operation cycle — Filling cycles

The check valve unit shall be installed in a test fixture according to the manufacturer's specifications for installation. The operation of the unit shall be continuously repeated for 15 000 cycles using test gas at the specified temperatures and pressures listed in 5.6.2.

The required test pressure shall be applied in six pulses to the check valve inlet with the outlet closed. The pressure shall then be vented from the check valve inlet. Failure of the check valve to reseat and prevent backflow shall constitute failure of the check valve. The pressure shall be lowered on the check valve outlet side to less than 60 % of nominal working pressure prior to the next cycle.

Following the operation cycles, the check valve shall be subjected to 24 h of chatter flow per 8.3.2.4.

8.3.2.3 Operation cycle – Duty cycles

The check valve unit shall be installed in a test fixture corresponding to the manufacturer's specifications for installation. The operation of the unit shall be continuously repeated for 50 000 cycles using test gas at the specified temperatures and pressures listed in 5.6.2.

The required test pressure shall be applied to the inlet of the check valve with the outlet closed. The pressure shall then be vented from the check valve inlet. Failure of the check valve to reseat and prevent backflow shall constitute failure of the check valve. The pressure shall then be lowered on the check valve outlet side to less than 60 % of maximum operation pressure prior to the next cycle.

Following the operation cycles, the check valve shall be subjected to 24 h of chatter flow per 8.3.2.4.

8.3.2.4 Chatter flow

Following operation cycles (see 8.3.2.2 or 8.3.2.3), the check valve shall be subjected to 24 h of chatter flow at a flow rate that causes the most chatter (valve flutter).

NOTE Valve flutter typical occurs at low flow rates from the opening and closing action of the check valve. If no chatter is induced during normal flow rates, this test is not required.

8.3.3 Pass criteria

At the completion of the test, the check valve shall comply with the leakage requirement specified in 5.3 and the hydrostatic test specified in 5.2.

9 Manual valves

NOTE This Clause does not apply to manual container valves, which are covered in Clause 10.

9.1 Marking

Marking of the manual valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the direction of flow for correct installation, if applicable;

b) the serial number, date code, or similar traceability code;

c) the specification for compressed hydrogen gas use and either

   1) nominal working pressure as indicated by “H25”, “H35”, “H50”, or “H70” if the component is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the component is downstream of the first stage of pressure reduction;

d) the manufacturer’s or agent’s name, trademark, or symbol;

e) the model designation (part number);

f) the temperature range; and

g) the designation of this document “ISO 19887-1:2024”.

9.2 Construction and assembly

9.2.1 General

Manual valves shall comply with applicable provisions of Clauses 1, 4 and 5, and the tests specified in 9.3.

9.2.2 Handles

Manual valves, other than service valves, shall have a handle securely mounted to the valve stem or active member. Service valves shall not have a handle nor be operable in their normal operating condition, either open or closed, without the use of tools.

9.2.3 Emergency manual shut-off valves

An emergency manual shut-off valve shall have approximately 90° rotation (quarter turn) from “on” to “off” positions and shall be provided with rigidly secured stops to limit rotation.

9.2.4 Quarter-turn valves

Valves having 90° of rotation (quarter turn) from “on” to “off” positions shall have the handles perpendicular to the direction of flow at the valve inlet when in the “off” position.

9.2.5 Multi-turn valves

Valves having more than 90° rotation shall move to the “off” position when rotated clockwise to a limit.

9.3 Tests

9.3.1 General

The applicable tests for manual valves are listed in Table 4.

Table 4 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 9
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	No		
Pre-cooled hydrogen exposure	Yes[a]	X	
Operating torque	Yes		X
Valve stem torque	Yes		X

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

9.3.2 Continuous operation

9.3.2.1 General

Service valves shall be capable of withstanding 100 cycles of operation, in accordance with 9.3.2.2. All other manual valves shall be capable of withstanding 7 000 cycles of operation in accordance with 9.3.2.3.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

9.3.2.2 Service valves

The operation of the service valve shall be continuously repeated for 100 cycles at the specified temperatures and pressures listed in 5.6.2.

A cycle shall consist of one full operation and reset (open and close) of the service valve. For each cycle, the downstream pressure of the valve shall be reduced to 0,5 MPa or lower.

If the valve is designed to be used with pressure differential in both directions, the cycle procedure shall be repeated in the opposite direction.

The service valve in its normal operational position shall also be exposed to the total number of pressure cycles appropriate for the component to which it is affixed.

Following the cycle tests, the valve shall meet

a) operating torque requirements (see 9.3.3);

b) valve stem torque requirements (see 9.3.4);

c) internal and external leakage requirements (see 5.3); and

d) hydrostatic strength requirements (see 5.2).

9.3.2.3 All other manual valves

Unless otherwise limited by its design or usage, the manual valve shall be tested using 7 000 duty cycles at the specified temperatures and pressures listed in 5.6.2.

Each duty cycle shall consist of pressurizing the inlet port. The supply to the inlet line shall then be isolated. The manual valve shall be opened and closed. During the off cycle, the downstream pressure shall be reduced to 50 % of the test pressure.

If the valve is designed to be used with pressure differential in both directions, the cycles shall be conducted in each direction.

Following the cycle tests, the valve shall meet

a) operating torque requirements (see 9.3.3);

b) valve stem torque requirements (see 9.3.4);

c) internal and external leakage requirements (see 5.3); and

d) hydrostatic strength requirements (see 5.2).

9.3.3 Operating torque

9.3.3.1 Service valves

Following the test outlined in 9.3.2.2, the service valve shall be capable of completely opening and/or closing when a torque is applied to the valve with the valve pressurized at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or 100 % of maximum operating pressure for components downstream of the first stage of pressure reduction. In the opening portion of the test, the pressure shall be applied to one side of the valve with the other side unpressurized. The test shall be conducted at the appropriate maximum temperature, then repeated at a temperature of −40 °C. The torque required to open and/or close the valve shall be within the manufacturer's specification.

9.3.3.2 All other manual valves

Following the test outlined in 9.3.2.3, the manual valve shall be capable of completely opening and closing when a torque, no greater than the appropriate torque specified in Table 5, is applied to the valve handle in a direction that opens the valve completely and in the opposite direction with the valve pressurized at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or 100 % of maximum operating pressure for components downstream of the first stage of pressure reduction. The test shall be conducted at the appropriate maximum temperature, then repeated at a temperature of −40 °C and with the appropriate maximum torque specified in Table 5.

Table 5 — Torque test

	Maximum Temperature	At −40 °C
Component inlet size, mm	Max. torque, N•m	Max. torque, N•m
< 8	1,7	3,4
≥ 8 to < 12	2,3	4,5
≥ 12	2,8	5,6

9.3.4 Valve stem torque

The manual valve shall be capable of withstanding

a) a torque greater than 16,5 N•m; or

b) a torque applied to the handle of each sample in accordance with the following Formula (1):

$$T = 222,4x\, D(or\ L) \tag{1}$$

where

T	is the torque, in newton metres;
D	is the handwheel diameter, in metres;
L	is the lever length, in metres,

NOTE Choice between use of handwheel diameter (D) or lever length (L) depends on the valve design and whichever is greater, as applicable.

This test shall be conducted with the valve pressurized at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction or maximum operating pressure for components downstream of the first stage of pressure reduction. The valve shall remain functional at the end of test.

10 Manual container valves

10.1 Marking

Marking of the manual container valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the serial number, date code, or similar traceability code;

b) the specification for compressed hydrogen gas use, and nominal working pressure as indicated by “H25”, “H35”, “H50”, or “H70”;

c) the manufacturer’s or agent’s name, trademark, or symbol;

d) the model designation (part number);

e) the temperature range; and

g) the designation of this document “ISO 19887-1:2024”.

10.2 Construction and assembly

10.2.1 General

Manual container valves shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 10.3.

10.2.2 Handle

Manual container valves shall have a handle securely mounted to the valve stem or active member.

10.2.3 Quarter-turn valves

If a manual container valve handle has a 90° rotation (quarter turn) from "on" to "off" position, it shall be provided with rigidly secured stops to limit rotation. The handle or handle marking shall be perpendicular to the direction of flow at the valve inlet when in the "off" position.

10.2.4 Multi-turn valves

Manual container valves having more than 90° rotation should move to the "off" position when rotated clockwise. Any valves that operate in the opposite direction shall be clearly marked.

10.2.5 Internal excess flow valve

Manual container valves incorporating an internal excess flow valve shall have a means for safe venting of the container.

In addition to the general requirements of 4.4 (component literature), valve manufacturers shall provide component literature describing the safe venting of the container contents.

10.3 Tests

10.3.1 General

The applicable tests for manual container valves are listed in Table 6.

Table 6 — Applicable Tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 10
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	No		
Pre-cooled hydrogen exposure	Yes[a]	X	
Operating torque	Yes		X
Valve stem torque	Yes		X

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

10.3.2 Continuous operation

Unless otherwise limited by its design or usage, the manual container valve shall be mounted into a suitable test fixture and tested using 2 000 duty cycles at the specified temperatures and pressures in 5.6.2.

The test fixture shall be pressurized to the required test pressure, and each duty cycle shall consist of opening and closing the manual container valve. During the off (closed) portion of the cycle, the downstream pressure shall be reduced to 50 % of the test pressure or lower.

Following the 2 000 duty cycles, the manual container valve shall then be tested through an additional 13 000 pressure cycles. Each pressure cycle shall consist of filling through the inlet and then depressurizing to 50 % of the test pressure, while the valve remains in an open position.

If the valve is designed to be used with pressure differential in both directions, then the cycle procedure shall be repeated in the opposite direction.

Following the cycle tests, the valve shall meet

a) operating torque requirements (see 10.3.3);

b) valve stem torque requirements (see 10.3.4);

c) internal and external leakage requirements (see 5.3); and

d) hydrostatic strength requirements (see 5.2).

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

10.3.3 Operating torque

Following completion of the test outlined in 10.3.2, the manual container valve shall be capable of completely opening and closing when a torque not greater than the appropriate torque specified in Table 7 is applied to the valve handle in a direction that opens it completely and in the opposite direction.

The test shall be conducted at a temperature of −40 °C and at 125 % of nominal working pressure.

Table 7 — Torque Test

Component inlet size, mm	Max. torque, N•m
< 8	3,4
≥ 8 to < 12	4,5
≥ 12	5,6

10.3.4 Valve stem torque

The manual container valve shall be capable of withstanding

a) a torque greater than 16,5 N•m; or

b) a torque applied to the handle of each sample in accordance with the following Formula (2):

$$T = 222{,}4 \, x \, D(or\ L) \tag{2}$$

where

T is the torque, in newton meters;

D is the handwheel diameter, in meters;

L is the lever length, in meters,

NOTE Choice between use of handwheel diameter (D) or lever length (L) depends on the valve design and whichever is greater, as applicable.

This test shall be conducted with the valve pressurized at 125 % of nominal working pressure. The valve shall remain functional at the end of test.

11 Automatic valves and automatic container valves

11.1 Marking

Marking of the automatic valve and automatic container valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the direction of flow for correct installation, if applicable;

b) the serial number, date code, or similar traceability code;

c) the specification for compressed hydrogen gas use and either

   1) nominal working pressure, as indicated by “H25”, “H35”, “H50”, or “H70” if the component is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the component is downstream of the first stage of pressure reduction;

d) the manufacturer’s or agent’s name, trademark, or symbol;

e) the model designation (part number);

f) the temperature range; and

g) the designation of this document “ISO 19887-1:2024”.

11.2 Construction and assembly

11.2.1 General

Automatic valves and automatic container valves shall comply with applicable provisions of 1, 4, and 5, and the tests specified in 11.3.

11.2.2 De-energized position

Automatic container valves shall be closed when de-energized.

11.2.3 Shut-off valve failure position

Fuel flow shut-off valves shall fail in the closed position or as marked on the valve.

11.2.4 Internal excess flow valve

Automatic container valves incorporating an internal excess flow valve, either the flow-limiter type or the shut-off type, shall have a means for safe venting of the container.

In addition to the general requirements of 4.4, valve manufacturers shall provide component literature describing the safe venting of the container contents.

11.3 Tests

11.3.1 General

The applicable tests for automatic valves and automatic container valves are listed in Table 8.

Table 8 — Applicable Tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 11
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	Yes	X	
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	Yes	X	
Pre-cooled hydrogen exposure	Yes[a]	X	
Automatic valve manual override torque	Yes[b]		X

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

[b] Applicable for automatic valves with manual override only.

11.3.2 Continuous operation

11.3.2.1 General

Automatic valves and automatic container valves shall meet the requirements of 11.3.2.2 or 11.3.2.3, respectively, for 50 000 duty cycles.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

11.3.2.2 Continuous operation — Automatic valve

Unless otherwise limited by its design or usage, the automatic valve shall be tested using 50 000 duty cycles at the specified temperatures and pressures listed in 5.6.2.

The inlet of the component shall be pressurized to the required test pressure, and each duty cycle shall consist of opening and closing the automatic valve. During the off (closed) portion of the cycle, the downstream pressure shall be reduced to 50 % of the test pressure or lower.

Following the continuous operation cycles, the automatic valve shall meet the internal and external leakage requirements in 5.3. and the hydrostatic strength requirements in 5.2.

11.3.2.3 Continuous operation — Automatic container valve

Unless otherwise limited by its design or usage, the automatic container valve shall be mounted into a suitable test fixture and tested using 50 000 duty cycles at the specified temperatures and pressure listed in 5.6.2.

Each duty cycle shall consist of filling through the inlet port to the required test pressure. The automatic container valve shall be opened (energized) and the pressure in the valve/fixture shall be reduced to 50 %

of the filling test pressure. The automatic container valve shall then be closed (de-energized) prior to the next filling cycle.

After continuous operation cycling, a chatter flow test shall also be completed if the automatic container valve functions as a check valve during fuelling. The automatic container valve shall be subjected to 24 h of chatter flow at a flow rate that causes the most chatter (valve flutter) within normal operating conditions.

NOTE If no chatter is induced during normal flow rates, the 24 h chatter flow portion of this test is not required.

At the conclusion of the continuous operation cycling and chatter flow tests (if applicable), the automatic container valve shall meet and the internal and external leakage requirements in 5.3 and the hydrostatic strength requirements in 5.2.

11.3.3 Automatic valve manual override torque

Where applicable, the manual override of the automatic valve or automatic container valve shall be capable of withstanding:

a) a torque greater than 16,5 N•m; or

b) a torque applied to the handle of each sample in accordance with the following Formula (3):

$$T = 222,4\ x\ D(or\ L) \qquad (3)$$

where

T is the torque, in newton meters;

D is the handwheel diameter, in meters;.

L is the lever length, in meters,

NOTE Choice between use of handwheel diameter (D) or lever length (L) depends on the valve design and whichever is greater, as applicable.

This test shall be conducted with the valve pressurized at 125 % of nominal working pressure for components upstream of the first stage of pressure reduction or 100 % of maximum operating pressure for components downstream of the first stage of pressure reduction.

12 Hydrogen injectors

NOTE This Clause specifies performance and general test methods for hydrogen injectors intended for delivery or metering of gaseous hydrogen using high-frequency pulsing. These hydrogen injectors are typically used in an internal combustion engine, but can also be used in fuel cell applications.

12.1 Marking

Marking of the hydrogen injector shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the serial number, date code, or similar traceability code;

b) the specification for compressed hydrogen gas and maximum operating pressure;

c) the manufacturer’s or agent’s name, trademark, or symbol;

d) the model designation (part number);

e) the temperature range; and

f) the designation of this document “ISO 19887-1:2024”.

12.2 Construction and assembly

12.2.1 General

Hydrogen injectors shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 12.3.

12.2.2 De-energized position

Hydrogen injectors should be closed when de-energized.

12.3 Tests

12.3.1 General

The applicable tests for hydrogen injectors, fuel rail assemblies, and fuel rails are listed in Table 9.

Table 9 — Applicable Tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 12
Hydrostatic strength	No		
Leakage	Yes	X	
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	Yes	X	
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	Yes		X
Pre-cooled hydrogen exposure	No		
Pneumatic strength	Yes		X
Extreme temperature cycling	Yes		X

12.3.2 Continuous operation

Six injectors or the fuel rail assembly shall be exposed to 600 x 10^6 cycles at maximum operating pressure. The minimum frequency for the pulses shall be specified by the injector manufacturer. This test may be interrupted periodically to verify criteria.

At the completion of cycling, the injectors shall function per the manufacturer's requirements. If the injectors are normally closed during the engine off condition, then the injectors or the fuel rail assembly shall comply with the internal leakage requirements of 5.3. The hydrogen injectors shall comply with the insulation resistance test specified in 12.3.3.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

12.3.3 Insulation resistance

This test is designed to check for a potential failure of the insulation between the connector pin and the housing.

A test voltage of 500 V DC shall be applied for a duration of at least 2 s between each injector power pin and a metallic surface of the injector housing. For injectors with circuitry of 3,8 mm pitch or below, 100 V DC shall be applied. The minimum allowable resistance between each injector power pin and a metallic surface of the injector housing shall be greater than 240 kΩ after high-voltage exposure.

12.3.4 Pneumatic strength

The pneumatic strength test shall be performed in the sequence as given:

a) At ambient temperature, apply the minimum of 125 % of upstream storage pressure or 200 % of the maximum operating pressure to the inlet and outlet of the gas injector and/or fuel rail for a period of at least 3 min. The gas injector and/or fuel rail shall not leak more than 10 Ncm^3/hour externally during the test.

b) Apply the minimum of 125 % of upstream storage pressure or 400 % of the maximum operating pressure to the inlet of the gas injector and/or fuel rail for a period of at least 3 min. The gas injector and/or fuel rail shall not rupture or burst.

NOTE If the hydrogen injector fails in the closed position due to its construction, it is considered to have passed both parts [Items a) and b)] of this test.

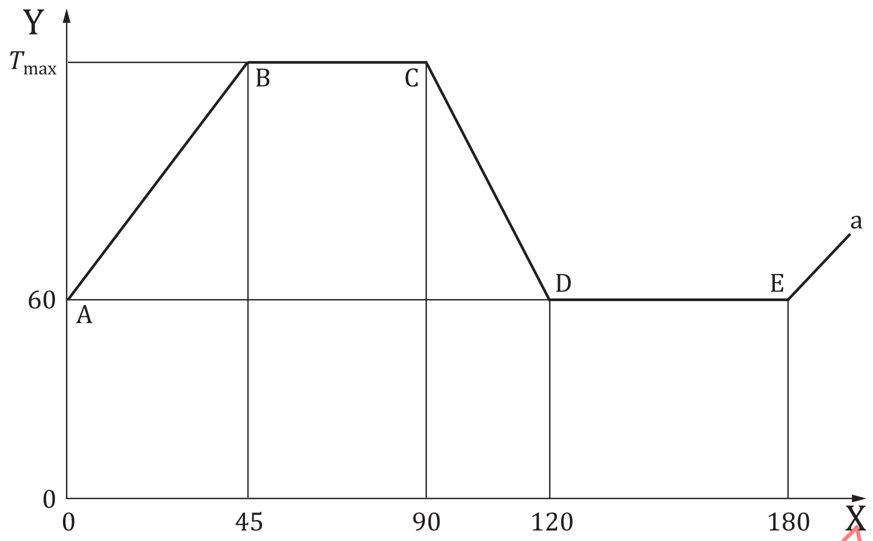
12.3.5 Extreme temperature cycling

Six injectors or the fuel rail assembly shall be exposed to the following, in the order listed:

a) expose the injectors or the fuel rail assembly, without operation, to 140 °C ± 2 °C for air cooled injectors or 120 °C ± 2 °C for liquid cooled injectors for 16 h;

b) expose the injectors or the fuel rail assembly, without operation, to −40 °C or lower for 16 h; and

c) expose the injectors or the fuel rail assembly to 140 thermal cycles according to the thermal cycle specified in Figure 5.



Key

X time, min

Y temperature, °C

[a] Repeat cycle.

T_{max} = 130 °C for air cooled injectors or 110 °C for liquid cooled injectors

Figure 5 — Extreme temperature cycling profile

The injector or the fuel rail assembly shall be operated only from D to E for at least 500 000 cycles and for not less than 1 h at a 50 % injector duty cycle. The time for this phase shall be determined by the manufacturer.

The injectors or the fuel rail assembly shall comply with the internal leakage requirements in 5.3 and the insulation resistance requirements specified in 12.3.3.

13 Pressure sensors, temperature sensors, and pressure gauges

13.1 Marking

Marking of the pressure sensors, temperature sensors, and pressure gauges shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the serial number, date code, or similar traceability code;

b) the specification for compressed hydrogen gas use and either

  1) nominal working pressure, as indicated by "H25", "H35", "H50", or "H70" if the component is upstream of the first stage of pressure reduction; or

  2) maximum operating pressure if the component is downstream of the first stage of pressure reduction;

c) the manufacturer's or agent's name, trademark, or symbol;

d) the model designation (part number);

e) the temperature range; and

f) the designation of this document "ISO 19887-1:2024".

13.2 Construction and assembly

13.2.1 General

Pressure sensors, temperature sensors, and pressure gauges shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 13.3.

13.2.2 Pressure gauge lens

Pressure gauges shall be equipped with a shatter-proof lens.

13.3 Tests

13.3.1 General

The applicable tests for pressure indicators are listed in Table 10.

Table 10 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 13
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	Yes[a]		X
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	Yes[a]		X
Pre-cooled hydrogen exposure	Yes[b]	X	

a Required for pressure sensors and temperature sensors incorporating or using electrical elements.

b Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

13.3.2 Continuous operation

13.3.2.1 Cycles

A pressure sensor, temperature sensor, or pressure gauge that is directly downstream or parallel mounted to an automatic container valve shall be subjected to 15 000 pressure cycles at the specified temperatures and pressures listed in 5.6.2 for components upstream of the first stage of pressure reduction.

All other pressure sensors, temperature sensors, or pressure gauges shall be subjected to 50 000 pressure cycles at the specified temperatures and pressures listed in 5.6.2 for components downstream of the first stage of pressure reduction.

For each pressure cycle, the pressure shall be reduced to 50 % of the required test pressure listed in 5.6.2.

Alternatively, a pressure sensor, temperature sensor, or pressure gauge may be mounted directly to the component that it is intended to be affixed to in service and tested according to the continuous operation test requirements for that specific component. For example, a pressure sensor or temperature sensor attached to an automatic container valve may be tested per 11.3.2.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

13.3.2.2 Pass criteria

At the completion of the test, the pressure sensor, temperature sensor, or the pressure gauge shall function according to the manufacturer's specifications.

At the completion of the test, the pressure sensor, temperature sensor, or pressure gauge shall comply with the leakage requirements specified in 5.3 and the hydrostatic strength requirements in 5.2.

13.3.3 Abnormal electrical voltages

13.3.3.1 General

Pressure sensors and temperature sensors driven by an electronic control unit shall be subjected to the following specified test.

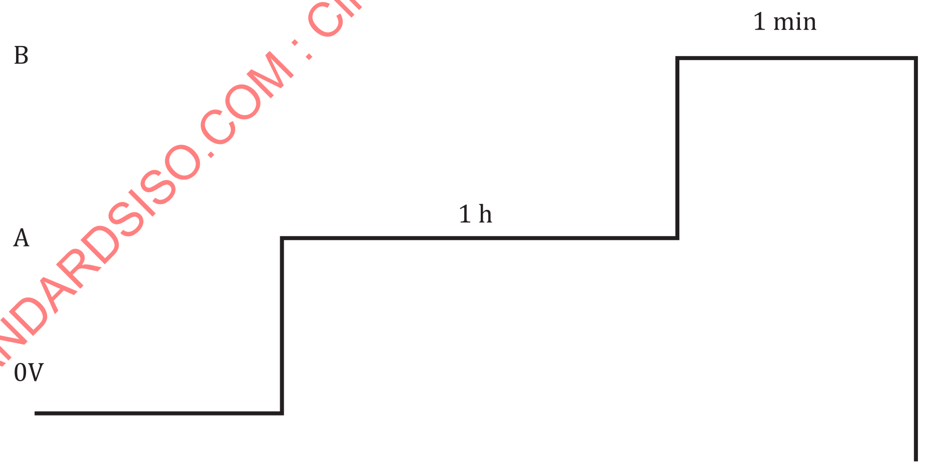
13.3.3.2 Test method

The component shall be connected to a variable DC voltage source. It shall be operated per the cycle illustrated in Figure 6.

At rated voltage +1 V, equilibrium (steady state temperature) shall be established and held for 1 h. The component shall remain functional.

Increase the voltage to 2 times the rated voltage and hold for 1 min.

Any failure shall not result in external leakage, or a similarly unsafe condition.



Key

A rated voltage + 1 V

B 2 times the rated voltage

Figure 6 — Abnormal electrical voltages test cycle

13.3.4 Insulation resistance

A test voltage of 500 V DC shall be applied between the sensor pin and component casing for a duration of at least 2 s. The minimum allowable resistance shall be greater than 240 kΩ.

14 Pressure regulators

14.1 Marking

Marking of the pressure regulator shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the serial number, date code, or similar traceability code;

b) the specification for compressed hydrogen gas use and the following, as applicable:

   1) nominal working pressure, as indicated by “H25”, “H35”, “H50”, or “H70”, if the pressure regulator includes the first stage of pressure reduction in the hydrogen fuel system;

   2) nominal outlet pressure; and

   3) maximum operating pressure for components downstream of the first stage of pressure reduction;

   NOTE MOP marking may be covered by PRV marking, if applicable. See 15.1.

c) the manufacturer’s or agent’s name, trademark, or symbol;

d) the model designation (part number);

e) the temperature range; and

f) the designation of this document “ISO 19887-1:2024”.

14.2 Construction and assembly

14.2.1 General

Pressure regulators shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 14.3.

14.2.2 Nominal outlet pressure

Pressure regulators shall have a factory-set nominal outlet pressure with the adjustor screw, if applicable, locked into position (i.e., not adjustable in the field).

14.2.3 Pressure regulator PRV

A pressure relief valve may be incorporated into a pressure regulator to limit pressure at any stage. If so equipped, the PRV shall be of a type that resets after relieving and shall be in compliance with Clause 15.

14.3 Tests

14.3.1 General

The applicable tests for pressure regulators are listed in Table 11.

Table 11 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 14
Hydrostatic strength	Yes		X
Leakage	Yes		X
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	Yes[a]	X	
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	Yes[a]	X	
Pre-cooled hydrogen exposure	No		
Pressure impulse	Yes		X
Pressure chamber – PRV operation	Yes		X

[a] Required for pressure regulators incorporating or using electrical elements.

14.3.2 Hydrostatic strength

14.3.2.1 Inlet passage

This test applies to the portion of the pressure regulator normally exposed to container pressure.

The outlet openings in the pressure regulator shall be plugged and pressure-regulating components allowed to function normally.

A hydrostatic pressure of 250 % of nominal working pressure of the pressure regulator shall be applied to the inlet for a period of at least 3 min.

The pressure regulator shall not show visible evidence of rupture or fracture.

14.3.2.2 Downstream sections

When performing this test, the upstream chamber should be filled with liquid to atmospheric pressure and capped.

Chambers that are downstream of the first regulating element and not equipped with an integral pressure relief valve shall withstand 200 % of the nominal working pressure, or 200 % of the maximum operating pressure of the upstream chamber, as applicable, for at least 3 min without rupture or fracture.

Chambers downstream of the first regulating element equipped with an integral pressure relief valve shall withstand 200 % of the relief pressure for at least 3 min without rupture or fracture.

14.3.3 Leakage

External leakage tests shall be performed in accordance with 5.3.2. Components downstream of the first regulating element shall be tested at their developed pressure when the inlet is pressurized in accordance with 5.3.

NOTE Internal leakage tests per 5.3.3 are not applicable to pressure regulators unless defined by the manufacturer.

14.3.4 Continuous operation

The pressure regulator shall withstand 50 000 cycles as defined as follows:

a) The pressure regulator shall be cycled for 95 % of the total number of cycles at ambient temperature and at nominal working pressure. Each cycle shall consist of flow, until stable outlet pressure has been obtained, after which the gas flow shall be shut off by the downstream quick closing valve until the lock-up pressure downstream of each pressure regulating device has stabilized. This test may be interrupted, if desired, for intermediate leakage testing.

b) The inlet pressure of the pressure regulator shall be cycled 1 % of the total number of cycles at ambient temperature from nominal working pressure to 50 % of the nominal working pressure. The pressure regulator shall comply with 14.3.3 at ambient temperature at the completion of the ambient temperature cycles.

c) The cycling procedure in Item a) shall be repeated at the applicable maximum temperature and at 125 % of nominal working pressure for 1 % of the total cycles.

d) The cycling procedure in Item b) shall be repeated at the applicable maximum temperature and at 125 % of nominal working pressure for 1 % of the total cycles. The pressure regulator shall comply with 14.3.3, at the applicable maximum temperature at the completion of the applicable maximum temperature cycles.

e) The cycling procedure in Item a) shall be repeated at −40 °C and at 62,5 % of nominal working pressure for 1 % of the total cycles.

f) The cycling procedure in Item b) shall be repeated at −40 °C and at 62,5 % of nominal working pressure for 1 % of the total cycles. The pressure regulator shall comply with 14.3.3, at −40 °C at the completion of the low temperature cycles.

At the completion of the cycles, the lock-up pressure downstream of each pressure regulating device in the regulator system shall not exceed the manufacturer's maximum rated lock-up pressure.

Following the cycle tests, the pressure regulator shall meet the hydrostatic strength requirements of 14.3.2.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

NOTE 1 The leakage tests can be performed at the intervals listed in the procedure above while the components are already conditioned to the appropriate temperatures. Alternatively, all leakage tests at all required temperatures can be performed per 14.3.3 at the completion of all 50 000 cycles.

NOTE 2 The above procedure assumes that the pressure regulator inlet is connected to container pressure. If testing a pressure regulator that is located downstream, then items a), c), and e) are to be tested at 100 % maximum operating pressure, and items b), d), and f) are to be tested between 100 % of maximum operating pressure and 50 % of maximum operating pressure.

14.3.5 Pressure impulse

The pressure regulator shall withstand 100 inlet pressure pulses as follows:

a) If the regulator has an integrated solenoid valve, then it shall be opened by application of the rated voltage.

b) The outlet of the regulator shall be vented until the inlet is at atmospheric pressure and then closed.

c) Test gas at 125 % of nominal working pressure shall be instantaneously applied to the regulator inlet.

The pressure regulator shall contain or vent the pressure without damage. The pressure regulator shall meet the requirements of the external leakage in accordance with 14.3.3 and shall not exceed the manufacturer's rated lock-up pressure.

14.3.6 Pressure chamber – PRV operation

A pressure chamber equipped with an integral pressure relief valve shall withstand the maximum pressure created when the mechanism regulating flow into that chamber is held in the fully open (maximum flow) position. The maximum operating pressure shall be applied to the next upstream chamber, and the PRV shall operate without compromising the pressure-retaining outer body components.

15 Pressure relief valves

15.1 Marking

Marking of the pressure relief valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the direction of flow for correct installation, if applicable;

b) the PRV set pressure;

c) the serial number, date code, or similar traceability code;

d) the manufacturer's or agent's name, trademark, or symbol;

e) the model designation (part number);

f) the temperature range; and

g) the designation of this document "ISO 19887-1:2024".

15.2 Construction and assembly

15.2.1 General

Pressure relief valves shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 15.3.

15.2.2 Venting

Pressure relief valves shall provide a means to allow venting of the contents to the outside of the vehicle.

15.2.3 Inspection and acceptance testing

The external leakage testing per 7.3 shall not be applicable to pressure relief valves.

The pressure relief valve opening pressure and reseating pressure shall be confirmed to be within the manufacturer's specifications.

15.3 Tests

15.3.1 General

The applicable tests for pressure relief valves are listed in Table 12.

Table 12 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 15
Hydrostatic strength	Yes		X
Leakage	Yes		X
Excess torque resistance	Yes	X	
Bending moment	Yes	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	No		
Pre-cooled hydrogen exposure	No		
Opening and reseating characteristics	Yes		X

15.3.2 Hydrostatic strength

The relief mechanism of the pressure relief valve shall be blocked in the closed position. Alternatively, the relief mechanism may be removed and the last orifice of the high-pressure side shall be blocked.

A hydrostatic pressure of 400 % of the maximum set pressure of the pressure relief valve or 600 kPa, whichever is greater, shall be applied to the inlet of the component for a period of at least 3 min.

The pressure relief valve shall not show visible evidence of rupture or fracture.

A hydrostatic pressure of 150 % of the pressure resulting from the activation of the pressure relief valve shall be applied to the outlet of the component for a period of at least 3 min.

The pressure relief valve shall not show visible evidence of rupture or fracture.

15.3.3 Leakage

External leakage testing shall be performed in accordance with 5.3.2, except that the high-pressure test level shall be 80 % of the pressure relief valve set pressure as specified by the manufacturer.

Alternatively, if the pressure relief valve is installed on a multi-function component (e.g., installed on a pressure regulator), then the pressure relief valve may follow the external leakage test requirements listed for the base component on which the pressure relief valve is installed.

NOTE The internal leakage test in 5.3.3 is not required for pressure relief valves. The internal leakage requirements are covered in opening and reseating characteristics test specified in 15.3.5.

15.3.4 Continuous operation

Pressure relief valves shall be capable of withstanding 600 cycles of operation.

A test cycle shall consist of pressurizing the pressure relief valve, with an upstream pressure of at least 125 % of set pressure, until the valve opens. Once the valve is venting, the inlet pressure shall be reduced until the valve reseats.

Components shall be operated through 90 % of the total cycles at ambient temperature. The test shall be continued at the appropriate maximum temperature through 5 % of the total cycles and at the appropriate minimum temperature through 5 % of the total cycles.

At the completion of the test, the component shall comply with the leakage requirements specified in 15.3.3.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

15.3.5 Opening and reseating characteristics

Three pressure relief valves shall be subjected to the following tests in the order listed:

a) Establish the opening and reseating values for the samples at ambient temperature. Slowly pressurize the inlet of the sample up to 110 % of the set pressure, noting the value at which it first opens.

b) Lower the inlet pressure until the pressure relief valve reseats and note that value. The valves shall be considered to have passed if all the following requirements are met:

   1) opening pressures shall be ±5 % of the manufacturer's set pressure; and

   2) reseating pressures shall be not less than 85 % of the manufacturer's set pressure and within 5 % of the average reseating pressure.

c) Repeat Items a) and b) at the minimum and appropriate maximum temperature. In each condition, the following criteria shall be met:

   1) opening pressures shall be within 15 % of the manufacturer's set pressure; and

   2) reseating pressures shall be not less than 75 % of the manufacturer's set pressure and within 15 % of the average reseating pressure.

16 Pressure relief devices

Thermally activated pressure relief devices (TPRD) shall meet the requirements of ISO 19882.

17 Excess flow valves

17.1 Marking

Marking of the excess flow valve shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the direction of flow for correct installation, if applicable;

b) the serial number, date code, or similar traceability code;

c) the specification for compressed hydrogen gas use and either

   1) nominal working pressure, as indicated by "H25", "H35", "H50", or "H70" if the component is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the component is downstream of the first stage of pressure reduction

d) the manufacturer's or agent's name, trademark, or symbol;

e) the model designation (part number);

f) the temperature range; and

g) the designation of this document "ISO 19887-1:2024".

17.2 Construction and assembly

Excess flow valves shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 17.3.

17.3 Tests

17.3.1 General

The applicable tests for excess flow valves are listed in Table 13.

Table 13 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 17
Hydrostatic strength	Yes	X	
Leakage	Yes[a]	X	
Excess torque resistance	Yes[b]	X	
Bending moment	Yes[b]	X	
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	Yes	X	
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		
Non-metallic material hydrogen compatibility	Yes	X	
Vibration resistance	Yes	X	
Stress corrosion cracking resistance	Yes	X	
Insulation resistance	No		
Pre-cooled hydrogen exposure	Yes[c]	X	
Bypass flow	Yes[d]		X

[a] The internal leakage test is applicable for shut-off type excess flow valves only and is not applicable to flow-limiter type excess flow valves.

[b] Applicable for external shut-off type excess flow valves only.

[c] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

[d] Applicable for flow-limiter type excess flow valves only.

17.3.2 Continuous operation

The excess flow valve shall be cycled 20 times at a pressure differential greater than or equal to 125 % of nominal working pressure or 100 % of maximum operating pressure, as applicable. One cycle shall consist of one activation and one resetting. At the completion of all cycling, the excess flow valve shall function according to the manufacturer's specifications and comply with the leakage requirements specified in 5.3.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

17.3.3 Bypass flow

This test is applicable to flow-limiter type excess flow valves only.

The bypass flow of the excess flow valve shall be measured after it activates. The test shall be performed using the activation conditions stated by the manufacturer. The measured flow rate shall meet the manufacturer's specified activation flow range. At pressures between the minimum and maximum inlet pressures, the bypass flow of the excess flow valve shall not exceed the manufacturer's stated value.

NOTE See ASTM F1802 Section 10.4 for guidance on measuring bypass flow.

18 Gastight housing and leakage capture passages

NOTE 1 Gastight housing and leakage capture components are intended to contain permeation gas and allowable leakage from the primary pressure-retaining components from internal compartments and direct them to the atmosphere. This device is intended to cover allowable leakage under normal conditions as well as credible faults.

NOTE 2 The intention is to be able to contain hydrogen while not exceeding 0,05 MPa pressure.

NOTE 3 These leakage capture lines and passages are not intended to handle pressure relief discharge.

18.1 Marking

Marking of the gastight housing and leakage capture passages shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the manufacturer's or agent's name, trademark, or symbol;

b) the model designation (part number); and

c) the designation of this document "ISO 19887-1:2024".

18.2 Construction and assembly

18.2.1 General

Gastight housings and leakage capture passages shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 18.3.

18.2.2 Inspection and acceptance testing

Gastight housings and leakage capture passages shall comply with the requirements in 7.3, except that the test shall be run at 0,05 MPa.

18.3 Tests

18.3.1 General

The gastight housing and leakage capture passages shall be tested as per Table 14.

Table 14 — Applicable tests

Test	Gastight housing	Metallic leak capture hose	Non-metallic leak capture hose	Leakage capture passages
Hydrostatic strength	No	No	No	No
Leakage	Clause 18	Clause 18	Clause 18	Clause 18
Excess torque resistance	Clause 5[a]	Clause 5[a]	Clause 5[a]	Clause 5[a]
Bending moment	Clause 5[a]	Clause 5[a]	Clause 5[a]	Clause 5[a]
Continuous operation	No	No	No	No
Corrosion resistance	Clause 5	Clause 5	Clause 5	Clause 5
Ultraviolet resistance of external surfaces	Yes	No	Clause 5	No
Automotive fluid exposure	Yes	No	Yes	No
Atmospheric exposure	Clause 5[b]	No	Clause 5[b]	Clause 5[b]
Abnormal electrical voltages	No	No	No	No
Non-metallic material hydrogen compatibility	Clause 5	Clause 5	Clause 5	Clause 5
Vibration resistance	Clause 5[c]	Clause 5[c]	Clause 5[c]	Clause 5[c]
Stress corrosion cracking resistance	No	No	No	No
Insulation resistance	No	No	No	No
Pre-cooled hydrogen exposure	No	No	No	No
Venting ability and pressure retention	Clause 18	Clause 18	Clause 18	Clause 18
Pull-off	Clause 18	Clause 18	Clause 18	No

[a] Applies only to components or portions thereof having relevant rigid members.

[b] Only for passages in non-metallic components.

[c] Applies only to rigid components.

18.3.2 Leakage

18.3.2.1 External leakage — Leakage capture hoses and gastight housings

Leakage capture passages and gastight housings shall be leak-free (≤ 10 Ncm^3/h) when pressurized with leak test gas to 0,05 MPa at ambient temperature, −40 °C, and 85 °C. Atmospheric passages and other connections shall be connected as for normal service or plugged for the purpose of the test. The component shall be thermally conditioned at each of the required test temperatures and held for at least 1 h to ensure thermal stability before testing.

18.3.2.2 External leakage — Leakage capture passages of pressure-retaining components

Leakage capture passages of pressure-retaining components shall meet the requirements of the following tests.

The leakage capture passages of pressure-retaining components outlets shall be plugged and the leakage capture passages pressurized to 0,05 MPa. The component shall be leak-free (≤ 10 Ncm^3/h) other than through the intended (plugged) leakage capture passage.

The leakage capture passage shall be allowed to vent normally. Remove or damage the worst-case high-pressure sealing member and pressurize the relevant high-pressure portion of the component to a high enough pressure to create 0,5 g/s test gas leak, but not more than nominal working pressure. The component shall be leak-free (≤ 10 Ncm^3/h) other than through the intended leakage capture passage.

18.3.3 Venting ability and pressure retention

The venting ability and pressure retention test is intended for gastight housings and leakage capture passages.

The component shall be installed as recommended by the manufacturer for normal service, including typical components between the high-pressure component and the final atmosphere port. A 0,5 g/s test gas source shall be applied to the interior or inlet of the component to simulate a pressure-retaining component leak.

The gastight housing or leakage capture passages shall not retain more than 0,05 MPa pressure during leakage of the high-pressure component.

18.3.4 Pull-off

The pull-off test is intended for leakage capture passages and gastight housings.

The leakage capture component shall be mounted as recommended by the manufacturer for normal service. A tensile load shall be applied along the axis of the component at a maximum rate of 100 N/min. The ventilation lines or gastight housing shall not rip, break, or separate from its connecting points at less than 100 N.

19 Rigid fuel lines

19.1 Marking

Marking of the rigid fuel line shall be in accordance with 4.5 and shall include, at a minimum, the following:

a) the lot or heat number, or suitable traceability code; and

b) the manufacturer's or agent's name, trademark, or symbol.

19.2 Construction and assembly

Rigid fuel lines shall comply with the tests specified in 19.3.

NOTE For non-metallic low-pressure rigid fuel lines, see Clause 23.

19.3 Tests

19.3.1 General

The raw tube used for rigid fuel lines shall be tested as per Table 15. When possible, tubing and fittings shall be tested together as a sub-system.

Table 15 — Applicable tests

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 19
Hydrostatic strength	Yes	X	
Leakage	Yes	X	
Excess torque resistance	No		
Bending moment	No		
Continuous operation	Yes		X
Corrosion resistance	Yes	X	
Ultraviolet resistance of external surfaces	No		
Automotive fluid exposure	Yes	X	
Atmospheric exposure	Yes	X	
Abnormal electrical voltages	No		

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

Table 15 *(continued)*

Test	Applicable	Tests required according to Clause 5	Tests required according to Clause 19
Non-metallic material hydrogen compatibility	No		
Vibration resistance	No		
Stress corrosion cracking resistance	No		
Insulation resistance	No		
Pre-cooled hydrogen exposure	Yes[a]	X	
Bending	Yes		X

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

19.3.2 Continuous operation

Rigid fuel lines shall be subjected to 100 000 pressure cycles as follows:

a) Rigid fuel lines shall be capable of withstanding 50 000 cycles from 10 % to 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or 10 % to 100 % of maximum operating pressure for components downstream of the first stage of pressure reduction. The test shall be conducted with hydraulic fluid.

b) Rigid fuel lines shall be capable of withstanding 50 000 cycles of operation from 60 % to 125 % of nominal working pressure for components upstream of the first stage of pressure reduction, or 60 % to 100 % of maximum operating pressure for components downstream of the first stage of pressure reduction. The test shall be conducted using test gas.

Components shall be operated through 90 % of the total cycles at ambient temperature. The test shall be continued at the appropriate maximum temperature for 5 % of the total cycles, and at the minimum temperature for 5 % of the total cycles.

At the completion of the test, the rigid fuel line shall comply with the external leakage requirement specified in 5.3.2 and the hydrostatic strength test specified in 5.2.

Testing with hydrogen gas for the continuous operation test may be used to demonstrate hydrogen compatibility for hydrogen environments as anticipated in service.

19.3.3 Bending

The rigid fuel line shall be tested as follows:

a) Select a mandrel with a diameter according to Table 16.

b) Bend the rigid fuel line over the mandrel once, forming a "U" shape.

c) Close the ends of the rigid fuel line and pressurize it hydraulically to 250 % of nominal working pressure or 250 % of maximum operating pressure without deformation or rupture.

Table 16 — Rigid fuel line outside and mandrel diameters

Outside diameter	Mandrel diameter
≤ 8 mm	3x outside diameter
> 8 mm	5x outside diameter

20 Flexible fuel lines, hoses, and hose assemblies

NOTE This Clause applies to newly manufactured flexible fuel lines, hoses and hose assemblies for use as:

a) part of a vehicle on-board fuel storage system, high pressure, upstream of the first stage of the pressure regulator; or

b) part of a vehicle low-pressure fuel delivery system, downstream of the first stage of the pressure regulator.

20.1 Markings

20.1.1 General

Marking material shall be corrosion-resistant, fade-resistant and permanent.

20.1.2 Bulk hoses

Bulk hoses shall be permanently marked on the hose cover, at intervals not exceeding 0,6 m. Bulk hose shall include, at a minimum, the following:

a) bulk hose manufacturer name;

b) specification for compressed hydrogen gas use and either

   1) nominal working pressure, as indicated by “H25”, “H35”, “H50”, or “H70” if the hose is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the hose is downstream of the first stage of pressure reduction;

c) nominal internal diameter of the hose;

d) a distinctive designation to specifically identify this product;

e) a marking establishing the date and location of its manufacture (e.g., lot number);

f) operating temperature range; and

g) the designation of this document “ISO 19887-1:2024”.

20.1.3 Hose assemblies

Each hose assembly shall bear the applicable markings specified below. These markings shall be permanent, on a non-removable metal ring, a permanent adhesive label, or on a portion of a non-removable end connector not subject to tool usage. If the marking is already on the hose, it need not be duplicated.

Each hose assembly shall include, at a minimum, the following:

a) assembler’s name, trademark, or symbol if different than the bulk hose manufacturer;

b) a distinctive designation to specifically identify this product;

c) a marking establishing the date and location of its assembly (e.g., lot number);

d) specification for compressed hydrogen gas use and either

   1) nominal working pressure, as indicated by “H25”, “H35”, “H50”, or “H70” if the hose assembly is upstream of the first stage of pressure reduction; or

   2) maximum operating pressure if the hose assembly is downstream of the first stage of pressure reduction;

e) operating temperature range; and

f) the designation of this document “ISO 19887-1:2024”.

The hose assembly should be constructed so that all markings required in 20.1.2 for bulk hoses are present on each hose assembly. Markings added by the hose assembler shall not obscure the markings required in 20.1.2 for bulk hose.

Each hose assembly with a minimum free length of 0,6 m shall have all the above information visible. Shorter assemblies shall be marked to show the manufacturer's name, and the model or part number.

20.1.4 Marking surfaces

All markings shall be suitable for application to the surfaces upon which applied.

20.1.5 Date code

The hose assembly supplied by the manufacturer shall bear a separate date code marking, or the manufacturer shall outline a means of establishing the date of manufacture so it is traceable.

This marking shall consist of at least four consecutive digits determined as follows:

a) The first and second digits shall indicate the calendar year in which the component was manufactured (e.g., 23 for 2023).

b) The third and fourth digits shall indicate the week in which the component was manufactured (e.g., 03 for the third week of the year). For purposes of this marking, a week shall begin at 00:01 hours on Sunday and end at 24:00 hours on Saturday.

If additional numbers, letters, or symbols lead or follow the four-digit number specified in Items a) and b), then they shall be separated from the date code.

20.2 Construction, assembly, and installation instructions

20.2.1 General

Flexible fuel lines, hoses, and hose assemblies shall comply with applicable provisions of Clauses 1, 4, and 5, and the tests specified in 20.3.

NOTE Hoses typically consist of three main layers: linings, reinforcement, and cover.

20.2.2 Linings

Linings

a) shall be smooth, of uniform thickness and free from imperfections and defects (e.g., bubbles, thinning, gouging, or discolorations); and

b) may consist of multiple layers of materials.

NOTE Linings are also referred to as liners or interior tubes.

20.2.3 Hose cover

If an outer hose cover is used, it shall be constructed to minimize or prevent fluid penetration into the inner plies, braids, or tube. The hose assembly shall be resistant to the effects of common automotive fluids, as determined by the test method in 20.3.5.

The outer cover shall be of uniform thickness, and free from imperfections.

NOTE The intent of this requirement is not to exclude the use of a braided, woven, corrugated, or perforated cover.

20.2.4 Protection from permeation or leakage

Hoses shall be constructed in such a manner that permeation or leakage from the inner tube does not expand or damage the outer cover, braids, or inner plies, as tested in accordance with 20.3.9.

NOTE Outer hose covering can be pin-pricked to minimize trapped gas between layers.

20.2.5 Static electricity dissipation

Hose assemblies shall be constructed so as to provide an electrically conductive path between couplings at each end of the hose in order to dissipate static electricity, as tested in accordance with 20.3.8.

Hoses shall be constructed so as to provide an electrically conductive liner.

20.2.6 End connections

Hoses for use on vehicles shall not use tapered thread end connections.

Hose assemblies shall have end fittings that comply with Clause 22 and that are permanently attached.

Fittings or threaded end connectors shall be faced or otherwise finished externally to provide a standard wrench flat grip.

20.2.7 Component literature

In addition to the requirements in 4.4, the component literature shall include, at a minimum, the following information:

a) a statement that the hose or hose assembly shall not be kinked, twisted, or torqued;

b) a statement that contact with foreign objects or substances shall be avoided;

c) the manufacturer's specified minimum hose bend radius;

d) appropriate installation instructions with cautionary notes for leak testing;

e) installation instructions that state the hose assembly shall be of adequate length for the intended use and that assemblies shall not be joined together to achieve the required length; and

f) a statement that the hose assembly shall be inspected prior to installation in accordance with the manufacturer's instructions. These shall address such items as:

   1) soft spots, bulges, or blisters in the hose;

   2) excessive abrasion exposing the hose reinforcement;

   3) cuts or cracks in the hose that expose or damage the reinforcement; and

   4) evidence of fitting movement or slippage with respect to the hose.

20.3 Tests

20.3.1 General

Unless otherwise specified within a test protocol, the test specimens shall be hose assemblies with a free hose length between the end fittings of at least 0,5 m.

The applicable tests for flexible fuel lines, hoses, and assemblies are listed in Table 17 below.

Table 17 — Applicable tests

Test	Applicable	Test required according to Clause 5		Test required according to Clause 20	
		Bulk hose	Hose assembly	Bulk hose	Hose assembly
Hydrostatic strength	Yes				X
Leakage	Yes				X
Excess torque resistance	Yes		X		
Bending moment	No				
Continuous operation	No				
Corrosion resistance	Yes				X
Ultraviolet resistance of external surfaces	No				
Automotive fluid exposure	Yes				X
Atmospheric exposure (oxygen aging and ozone)	No				
Abnormal electrical voltages	No				
Non-metallic material hydrogen compatibility	No				
Vibration resistance	Yes				X
Stress corrosion cracking resistance	No				
Insulation resistance	No				
Pre-cooled hydrogen exposure	Yes[a]		X		
Pressure cycle	Yes				X
Electrical conductivity	Yes			X	X
Hose permeation	Yes			X	
Ultraviolet light and water exposure	Yes			X	
Hydrogen impulse	Yes				X
Ozone exposure resistance	Yes			X	

[a] Applicable for H70 components in the hydrogen fuelling path between the vehicle's receptacle and container that are expected to be subjected to pre-cooled hydrogen fuelling in service.

20.3.2 Hydrostatic strength

20.3.2.1 General

A hose assembly shall withstand, without bursting or visible loss of fluid, a hydrostatic pressure of 400 % of the maximum operating pressure or 400 % of the nominal working pressure, as applicable.

NOTE This value can be considered the minimum burst pressure.

20.3.2.2 Test media

The test media for the hydrostatic strength test shall be glycol, oil, water, or a mixture of glycol and water.

20.3.2.3 Test method

The hose assembly shall be connected to a hydraulic pressure test system, which includes a pump, gauge, and fittings that can sustain the desired pressure. Care shall be taken during set-up to free all air from the system.

The test pressure shall be gradually increased at a constant rate so as to obtain the specified minimum burst pressure in a period of 30–60 s for hoses under 50 mm internal diameter. For hoses over 50 mm internal diameter, the time to reach the final burst pressure shall be determined by the manufacturer. If no bursting or visible loss of fluid occurs during this period, this provision shall be deemed met. This test shall be applied to each nominal diameter, type, and material of hose being examined under this requirement.

The hydrostatic pressure at burst shall be recorded, as applicable.

Hose assemblies that show visible leakage, hose burst, or indication of failure below the specified minimum test pressure shall be rejected.

20.3.3 Leakage

20.3.3.1 General

A hose assembly shall not leak more than 20 Ncm^3/h when tested in accordance with the test method in 20.3.3.4.

20.3.3.2 Test medium

The test medium for conducting the leakage test shall be hydrogen supplied at the same temperature at which the test is being conducted.

20.3.3.3 Test apparatus

The test apparatus for conducting the leakage test shall be comprised of

a) a device capable of supplying the test media at the testing pressure and temperature; and

b) a means capable of measuring the leakage rate.

20.3.3.4 Test method

This test shall be conducted at ambient temperature and at a test pressure of 150 % of the nominal working pressure for hoses upstream of the first stage of pressure reduction, and 150 % of the maximum operating pressure for hoses downstream of the first stage of pressure reduction.

The pressure shall be held for at least 10 min, then held for an additional 5 min while collecting the hydrogen leaked. The amount of leaked hydrogen shall not exceed 20 Ncm^3/h.

NOTE 10 min is the time necessary for releasing any trapped air in the reinforcement to the outside of the test specimen through the cover perforations.

The above tests shall be repeated at the maximum service temperature (85 °C or 120 °C, as applicable) and the minimum service temperature (-40 °C). The minimum conditioning time at each temperature shall be 4 hours.

20.3.4 Corrosion resistance

All hose assemblies shall be tested for corrosion resistance in accordance with Clause 5.7, except that all high-pressure hoses upstream of the first stage of pressure reduction shall be exposed to 100 cycles of the accelerated cyclic corrosion test regardless of location in the vehicle.

20.3.5 Automotive fluid exposure

20.3.5.1 General

The outer cover shall be constructed to minimize or prevent fluids penetration into the inner plies, braids, or tube. The inner plies, braids, or tube shall be resistant to the effects of common automotive fluids, as determined by the following test method.

20.3.5.2 Test method

The test shall be conducted at ambient temperature. The hose assembly shall be sealed at one end. The other end should be attached to a pressure cycling source. The hose shall be exposed to air and to the test fluids. Exposure medium and method, and number of pressure cycles shall be as determined by Table 18.

20.3.5.3 Fluid exposure

20.3.5.3.1 Intermittent fluid exposure

During intermittent exposure to the test fluids, the hose assembly shall be depressurized. Test pads of glass wool, 5 cm wide and 1 layer thick (approximately 0,5 mm), shall be wrapped around the hose, with each pad covering a different area of the sample material being tested (see Figure 7). Also, each pad shall cover a minimum of one permeation hole, if applicable. A volume of 5 mL of each test fluid shall be applied to the pads, one fluid for each pad. The pads shall be removed after 30 min. The same section of hose shall be exposed to the same test fluid throughout the test.

The following fluids shall be used:

a) deionized water (ASTM D1193, Grade II);

b) sodium chloride: 2,5 % in water (by weight);

c) calcium chloride: 2,5 % in water (by weight);

d) sulfuric acid: sufficient to achieve a solution pH of 4,0 ± 0,2;

e) 50 % glycol anti-freeze solution;

f) DOT #3 brake fluid; and

g) ammonium nitrate: 28 % by weight in water.

20.3.5.3.2 Continuous fluid exposure

During continuous exposure, the portion of the hose assembly not subjected to the intermittent exposure test shall be subjected to the required number of pressure cycles while immersed in the specified fluid. A minimum of 30 cm of hose including at least one permeation hole, if applicable, shall be immersed, but none of the areas covered by pads during the intermittent exposure shall be immersed (see Figure 7).

The following fluids shall be used:

a) deionized water (ASTM D1193, Grade II);

b) sulfuric acid: 19 % solution by volume in water;

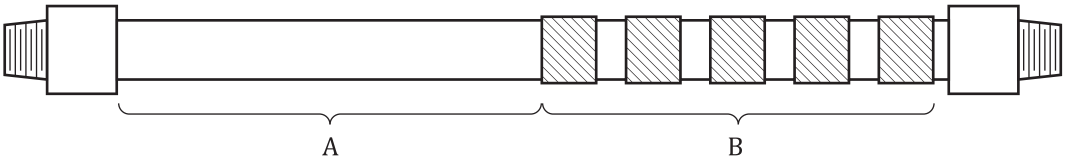
c) sodium hydroxide: 25 % solution by weight in water;

d) methanol/gasoline: 30/70 % concentrations; and

e) windshield washer fluid: 50 % by volume solution of methyl alcohol and water.

The hose may be rinsed with de-ionized water between each exposure to minimize fluid interactions.

The pressure cycling rate shall be no more than 4 cycles/min.



Key

A continuous exposure area

B wool pads (intermittent exposure)

Figure 7 — Automotive fluid exposure test sample

Table 18 — Automotive fluid exposure

Test step	Exposure environment	Number of pressure cycles	Time duration (minimum)
1	Intermittent	0	30 min
2	Continuous – Deionized water	1 875	8 h
3	Air	1 875	16 h
4	Intermittent	0	30 min
5	Continuous – Sulfuric acid	1 875	8 h
6	Air	1 875 @ −40 °C and 1 875 to applicable high temperature 85 °C or 120 °C	16 h
7	Intermittent	0	30 min
8	Continuous – Sodium hydroxide	1 875	8 h
9	Air	1 875	8 h
10	Intermittent	0	30 min
11	Continuous – Methanol/gasoline	1 875	8 h
12	Intermittent	0	30 min
13	Continuous – Windshield washer fluid	1 875	8 h

20.3.5.4 Pass criteria

After exposure to the test fluids, the hose assembly shall comply with the leakage test in 20.3.3. Following the leakage test, a 1 min hydrostatic pressure test shall be done at 200 % of the NWP or MOP, as applicable, with no evident bursting.

At the completion of the test of the hose cover, the inner plies, braids, and tube shall be examined for pitting, delamination, cracking, or breaking.

20.3.6 Vibration resistance

20.3.6.1 Test specimens

Twelve coupled hose assemblies shall be tested. Each assembly shall consist of hose with male and female end fittings having an end-to-end length of 0,6 m.

Six of these assemblies shall be mounted in the test fixture such that the vibration shall be imparted to the assembly through the male fitting. Pressurization of the assembly during the test shall be through the female end.

Six of these assemblies shall be mounted in the test fixture such that the vibration shall be imparted to the assembly through the female fitting. Pressurization of the assembly during the test shall be through the male end.

20.3.6.2 Test method

Each hose assembly shall be subjected to a leak test per 20.3.3 prior to and at the completion of the vibration test.

One end of the hose assembly shall be attached to the fixture to be vibrated. The hose shall be bent horizontally to form a quarter-circle with the axis of the couplings at right angles to each other. The free end of the hose assembly shall be attached to the stationary fixture and pressure source.

The component shall be subjected to the vibration resistance test per 5.13.

20.3.6.3 Pass criteria

The hose assembly shall show no sign of leakage prior to the vibration test.

Upon completion, the hose shall be inspected for damage. All samples shall meet the leakage requirements when tested according to 20.3.3.

20.3.7 Pressure cycle

NOTE This test is not applicable to vent hoses.

20.3.7.1 General

It shall be the decision of the manufacturer to determine which test procedure, Test Procedure A or Test Procedure B (see 20.3.7.3), is used for conducting the pressure cycling test.

A hose assembly shall withstand 100 000 cycles of hydraulic pressure pulses without damage, and shall comply with the leakage requirements of 20.3.3 and the electrical conductivity requirements of 20.3.8.

NOTE Refer to ISO 6803 for pressure pulse guidance.

20.3.7.2 Test specimen lengths

The free length of the test specimens measured between the end fittings shall be the minimum bending radius plus 2 times the outside diameter, calculated in accordance with the following Formula (4):

$$L = \pi \left(r + \frac{d}{2} \right) + 2d \qquad (4)$$

where

L is the free length of the test specimen, in meters;

r is the minimum bending radius, in meters;

d is the outside diameter of the hose, in meters.

In addition:

a) the tolerance on L shall be the greater of:

   1) +1 %, −0 %; or

   2) +8 mm, −0 mm; and

b) when d < 25 mm, 25 mm shall be used in the formula.

20.3.7.3 Test method

20.3.7.3.1 Procedure A

Procedure A of the pressure cycling test shall be conducted as follows:

a) Bend the test specimen 180° with the minimum bending radius specified by the manufacturer.

b) Rigidly attach the test specimen end fittings to a fixture in the bent position, allowing the hose to move freely.

c) Connect the test specimen to the pressure supply, as appropriate.

d) Ensure that the test media or the test chamber is at the testing temperature, as appropriate.

e) Cycle the test specimen between 0,5 MPa ± 0,5 MPa and 125 % of its nominal working pressure for hoses upstream of the first stage of pressure reduction, or 100 % of its maximum operating pressure for hoses downstream of the first stage of pressure reduction, by applying a pulsating pressure to the test specimen at a rate between 0,07 Hz and 0,40 Hz. (See ISO 6803 for pressure pulse wave form).

f) Cycle the test specimen in accordance with Item e) for 50 000 cycles at a temperature of −40 °C. The temperature may be controlled by either of the following methods:

   1) circulate the test media through the test specimen at −40 °C; or

   2) fill the test specimen with the test media and place it inside a chamber at −40 °C.

g) Cycle the test specimen in accordance with Item e) for an additional 50 000 cycles at a temperature of 85 °C or 120 °C, based on the expected service conditions. The temperature may be controlled by either of the following methods:

   1) circulate the test media through the test specimen at 85 °C or 120 °C, as applicable; or

   2) fill the test specimen with the test media and place it inside a chamber at 85 °C or 120 °C, as applicable.

h) Conduct the leakage test specified in 20.3.3.

i) Measure the electrical resistance in accordance with 20.3.8.

20.3.7.3.2 Procedure B

Procedure B of the pressure cycling test shall be conducted as follows:

a) Bend the test specimen 180° with the minimum bending radius specified by the manufacturer.

b) Rigidly attach the test specimen end fittings to a fixture in the bent position, allowing the hose to move freely.

c) Connect the test specimen to the pressure supply, as appropriate.

d) Ensure that the test media or the test chamber is at the testing temperature, as appropriate.

e) Apply a pulsating pressure to the test specimen equivalent to 125 % of its nominal working pressure for hoses upstream of the first stage of pressure reduction, or 100 % of its maximum operating pressure for