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A.3.3 HYDROGEN STORAGE SYSTEM

The hydrogen storage system consists of all components that form the primary pressure boundary of the stored hydrogen in the system. The primary function of the hydrogen storage system is to contain the hydrogen within the storage system throughout the vehicle life. At present, the most common method of storing and delivering hydrogen fuel on-board is in compressed gas form. Hydrogen can also be stored as liquid (at cryogenic conditions). Both of these types of hydrogen storage systems are described in the following sections. An additional type of hydrogen storage, so-called cryo-compressed is to be covered in future revisions of the GTR (approximately 2015) as it is currently under development. Cryo-Compressed Hydrogen (CcH2) storage is a hybrid between liquid and compressed gas storage which can be fueled with both cryogenic-compressed and compressed hydrogen gas.

A.7.2.1 Rationale for Pressure Relief Device(s) Qualification Requirements (LH2)

The qualification requirements verify that the design shall be such that the device(s) will limit the pressure of the fuel container to the specified values even at the end of the service life when the device has been exposed to fueling/de-fueling pressure and temperature changes and environmental exposures. The adequacy of flow rate for a given application is verified by the hydrogen storage system bonfire test and vacuum loss test requirements (B.5.2.4.1 and B.5.2.3.3).

A.7.2.2 Rationale for Shut-off Valve Qualification Requirements (LH2)

These requirements are not intended to prevent the design and construction of components (e.g. components having multiple functions) that are not specifically prescribed in this standard, provided that such alternatives have been considered in testing the components. In considering alternative designs or construction, the materials or methods used shall be evaluated by the testing facility to ensure equivalent performance and reasonable concepts of safety to that prescribed by this standard. In that case, the number of samples and order of applicable tests shall be mutually agreed upon by the manufacturer and the testing agency. Unless otherwise specified, all tests shall be conducted using pressurised gas such as air or nitrogen containing at least 10 per cent helium (see EC Reg. 406/2010 p.52 4.1.1.). The total number of operational cycles shall be 20,000 (duty cycles) for the automatic shut-off valves.

Fuel flow shut-off by an automatic shut-off valve mounted on a liquid hydrogen storage vessel shall be fail safe. The term “fail safe” shall refer to a device’s ability to revert to a safe mode or a safe complete shutdown for all reasonable failure modes.

The electrical tests for the automatic shut-off valve mounted on the liquid hydrogen storage vessels provide assurance of performance with: (1) over temperature caused by an overvoltage condition, and (2) potential failure of the insulation between the component’s power conductor and the component casing.

UN-GTR PART B INSERTION

B.5.2.5 Labeling.

A label shall be permanently affixed on each container with at least the following information: Name of the Manufacturer, Serial Number, Date of Manufacture, MAWP, Type of Fuel. Any label affixed to the container in compliance with this section shall remain in place. Contracting parties may specify additional labeling requirements.

B.7.2.1.1. Metallic containers

When using metallic containers and/or metallic vacuum jackets the manufacturer must either provide a calculation in order to demonstrate that the tank is designed according to current regional legislation or accepted standards for cryogenic pressure vessels (e.g. in US the ASME Boiler and Pressure Vessel Code, in Europe EN 1251-2 and EN 1252-1 and in all other countries an applicable regulation for the design of metallic pressure vessels) or define and perform suitable tests which prove the same level of safety compared to a design supported by calculation according to accepted standards. The test shall at least include:

- Pressure cycling with a number of cycles at least three times the number of possible full pressure cycles (from the lowest to highest operating pressure) for an expected on-road performance. The number of pressure cycles has to be defined by the manufacturer under consideration of operating pressure range, size of the storage and, respectively, maximum number of refuelings and maximum number of pressure cycles under extreme usage and storage conditions. Pressure cycling should be conducted between atmospheric pressure and MAWP at liquid nitrogen temperatures, e.g. by filling the container with liquid nitrogen to certain level and alternately pressurizing and depressurizing it with (pre-cooled) gaseous nitrogen or helium.

B.7.2.1.2 Non-Metallic containers

In the case that non-metallic materials are used for the container(s) and/or vacuum jacket(s) in addition to the mandatory tests described in chapter B.5.2 suitable tests have to be accomplished, which prove the same level of safety compared to a metallic container design supported by calculation according to accepted standards as described in 7.2.1.1.

B.7.2.2. Qualification Tests for LHSS Components

The entire storage system does not have to be re-qualified (B.5.2) if container shut-off devices and pressure relief devices (components in Figure 4 A.3.3.2.2. excluding the storage container) are exchanged for equivalent components having comparable function, fittings, and dimensions, and qualified for performance using the same qualification tests as the original components.

B.7.2.2.1 Pressure Relief Devices Qualification Requirements (LH2)

Design qualification testing shall be conducted on finished pressure relief devices which are representative of normal production. The pressure relief devices shall meet the following performance qualification requirements:

- Pressure Test (B.8.3.1 test procedure)
- External leakage Test (B.8.3.2 test procedure)
- Operational Test (B.8.3.4 test procedure)
- Corrosion Resistance Test (B.8.3.4 test procedure)
- Temperature cycle Test (B.8.3.8 test procedure)

B.7.2.2.2 Shut-off Valves Qualification Requirements (LH2)

Design qualification testing shall be conducted on finished shut-off valves (in Figure 4 in A.3.3.2.2 named shut-off devices) which are representative for normal production. The valve shall meet the following performance qualification requirements:

- Pressure Test (B.8.3.1 test procedure)
- External leakage Test (B.8.3.2 test procedure)
- Endurance Test (B.8.3.3 test procedure)
- Corrosion Resistance Test (B.8.3.5 test procedure)
- Resistance to dry-heat Test (B.8.3.6 test procedure)
- Ozon ageing Test (B.8.3.7 test procedure)
- Temperature cycle Test (B.8.3.8 test procedure)
- Seat leakage Test (B.8.3.9 test procedure)

B.7.2.3 Flammability

The insulation of the components shall prevent liquefaction of the air in contact with the outer surfaces, unless a system is provided for collecting and vaporizing the liquefied air. Then the materials of the components nearby shall be compatible with an atmosphere enriched with oxygen.

B.8.3 TYPE APPROVAL LHSS Components Qualification Performance Tests

Compare CGH2:
Testing shall be performed with hydrogen gas having gas quality compliant with ISO 14687-2/SAE J2719. All tests shall be performed at ambient temperature $20(\pm 5)^{o}$C unless otherwise specified. The HPRD qualification performance tests are specified as follows:

B.8.3.1 Pressure Test

A hydrogen containing component shall withstand without any visible evidence of leak or deformation a test pressure of 1,5 times its Maximum Allowable Working Pressure (MAWP) with the outlets of the high pressure part plugged. The pressure shall then be increased from 1,5 to 3 times the Maximum Allowable Working Pressure (MAWP). The component shall not show any visible evidence of rupture or cracks.

The pressure supply system shall be equipped with a positive shut-off valve and a pressure gauge, having a pressure range of not less than 1,5 times nor more than 2 times the test pressure and the accuracy of the gauge shall be 1 per cent of the pressure range.

For components requiring a leakage test, this test shall be performed prior to the pressure test.

B.8.3.2 External leakage Test

A component shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting when tested as described in section B.8.3.3.3.
at any gas pressure between zero and its Maximum Allowable Working Pressure (MAWP).
The test shall be performed on the same equipment at the following conditions:

- at ambient temperature;
- at the minimum operating temperature or at liquid nitrogen temperature after sufficient conditioning time at this temperature to ensure thermal stability;
- at the maximum operating temperature after sufficient conditioning time at this temperature to ensure thermal stability.

During this test the equipment under test shall be connected to a source of gas pressure. A positive shut-off valve and a pressure gauge having a pressure range of not less than 1,5 times nor more than 2 times the test pressure shall be installed in the pressure supply piping and the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge shall be installed between the positive shut-off valve and the sample under test.
Throughout the test, the sample shall be tested for leakage, with a surface active agent without formation of bubbles or measured with a leakage rate less than 10 cm3/hour.

B.8.3.3 Endurance Test

B.8.3.3.1
A component shall be capable of conforming to the applicable leakage test requirements of sections B.8.3.2 and B.8.3.9., after being subjected to 20000 operation cycles.
B.8.3.3.2
The appropriate tests for external leakage and seat leakage, as described in sections B.8.3.2 and B.8.3.9 shall be carried out immediately following the endurance test.
B.8.3.3.3.
The shut-off valve shall be securely connected to a pressurised source of dry air or nitrogen and subjected to 20000 operation cycles. A cycle shall consist of one opening and one closing of the component within a period of not less than 10 ± 2 seconds.
B.8.3.3.4
The component shall be operated through 96 per cent of the number of specified cycles at ambient temperature and at the MAWP of the component. During the off cycle the downstream pressure of the test fixture shall be allowed to decay to 50 per cent of the MAWP of the component.
B.8.3.3.5
The component shall be operated through 2 per cent of the total cycles at the maximum material temperature (-40°C to +85°C) after sufficient conditioning time at this temperature to ensure thermal stability and at MAWP. The component shall comply with sections B.8.3.2 and B.8.3.9.

at the appropriate maximum material temperature (-40°C to +85°C) at the completion of the high temperature cycles.
B.8.3.3.6
The component shall be operated through 2 per cent of the total cycles at the minimum material temperature (-40°C to +85°C) but not less than the temperature of liquid nitrogen after sufficient conditioning time at this temperature to ensure thermal stability and at the MAWP of the component. The component shall comply with sections B.8.3.2 and B.8.3.9. at the appropriate minimum material temperature (-40°C to +85°C) at the completion of the low temperature cycles.

B.8.3.4 Operational Test

The operational test shall be carried out in accordance with EN 13648-1 or EN 13648 2. The specific requirements of the standard are applicable.

B.8.3.5 Corrosion Resistance Test

Metallic hydrogen components shall comply with the leakage tests referred to in sections B.8.3.2 and B.8.3.9. after being submitted to 144 hours salt spray test according to ISO 9227 with all connections closed.

A copper or brass hydrogen containing component shall comply with the leakage tests referred to in sections B.8.3.2 and B.8.3.9 and after being submitted to 24 hours immersion in ammonia according to ISO 6957 with all connections closed.

B.8.3.6 Resistance to dry-heat Test

The test shall be carried out in compliance with ISO 188. The test piece shall be exposed to air at a temperature equal to the maximum operating temperature for 168 hours. The change in tensile strength shall not exceed + 25 per cent. The change in ultimate elongation shall not exceed the following values:

- maximum increase 10 per cent, —
- maximum decrease 30 per cent.

B.8.3.7 Ozon ageing Test

The test shall be in compliance with ISO 1431-1. The test piece, which shall be stressed to 20 per cent elongation, shall be exposed to air at + 40 °C with an ozone concentration of 50 parts per hundred million during 120 hours.
No cracking of the test piece is allowed.

B.8.3.8 Temperature cycle Test

A non-metallic part containing hydrogen shall comply with the leakage tests referred to in sections B.8.3.2 and B.8.3.9 after having been submitted to a 96 hours temperature cycle from

the minimum operating temperature up to the maximum operating temperature with a cycle time of 120 minutes, under Maximum Allowable Working Pressure (MAWP).

B.8.3.9 Seat leakage Test

Any flexible fuel line shall be capable of conforming to the applicable leakage test requirements referred to in section B.8.3.2, after being subjected to 6 000 pressure cycles.
The pressure shall change from atmospheric pressure to the Maximum Allowable Working Pressure (MAWP) of the tank within less than five seconds, and after a time of at least five seconds, shall decrease to atmospheric pressure within less than five seconds.
The appropriate test for external leakage, as referred to in section B.8.3.2 shall be carried out immediately following the endurance test.