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Periodic Inspection and Evaluation of Fully Wrapped Fiber Reinforced Composite Gas Cylinders of Compressed Hydrogen Gas for Automotive Vehicles

车用压缩氢气纤维全缠绕气瓶定期检验与评定

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Periodic Inspection and Evaluation of Fully Wrapped Fiber Reinforced Composite Gas Cylinders of Compressed Hydrogen Gas for Automotive Vehicles

1 Scope

This document specifies the basic method and technical requirements for the periodic inspection and evaluation of fully wrapped fiber reinforced composite gas cylinders of compressed hydrogen gas for automotive vehicles (hereinafter referred to as "gas cylinders").

This document is applicable to gas cylinders designed and manufactured in accordance with GB/T 35544 and GB/T 42612, whose nominal working pressure does not exceed 70 MPa, nominal water capacity is not greater than 450 L, and the storage medium is compressed hydrogen gas, and operating temperature is not lower than –40 °C and not higher than 85 °C.

This document is not applicable to gas cylinders installed on passenger vehicles with a length of not more than 8 m and a seating capacity of not more than 19, and cannot be disassembled for periodic inspection.

The periodic inspection and evaluation of gas cylinders for hydrogen supply, such as: hydrogen fuel cell urban rail transits, hydrogen energy ships sand hydrogen energy power generation devices, etc. may take this document as a reference.

2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 3464.1 Machine and Hand Taps - Part 1: Plain Parallel Shank Machine and Hand Taps

GB/T 3836.1 Explosive Atmospheres - Part 1: Equipment - General Requirements

GB/T 3934 Specification of Gauges for General Purpose Screw Threads

GB/T 8979 Pure Nitrogen and High Purity Nitrogen and Ultra Pure Nitrogen

GB/T 9251 Methods for Hydrostatic Test of Gas Cylinders

GB/T 13005 Terminology of Gas Cylinders

Resin refers to a material used to bond fibers and transmit loads.

NOTE: it is usually thermoset.

3.8 stress corrosion cracking

Stress corrosion cracking refers to cracks or fractures of composite materials caused by a combined action of load and harsh environments.

3.9 thermally-activated pressure relief device (TPRD) end plug

Thermally-activated pressure relief device (TPRD) end plug refers to an end plug installed at one end of the double-port structure gas cylinder, and equipped with a thermally-activated pressure relief device (TPRD) and the function of blind plugging.

3.10 rejection elastic expansion; REE

Rejection elastic expansion refers to the allowable upper limit of elastic expansion of gas cylinder specified by the manufacturing organization in the design and finalization stage of each specification and model of gas cylinder, and it is expressed in milliliters.

3.11 bulge

Bulge refers to visible partial bulging of the gas cylinder.

3.12 buckling

Buckling refers to the failure caused by the plastic liner losing its original regular geometric shape under the action of compressive stress.

3.13 blister

Blister refers to a local defect in the plastic liner that that looks like a bubble.

3.14 hydrogen storage system

Hydrogen storage system refers to a collection of components related to on-board hydrogen storage and transmission.

NOTE: it usually consists of gas cylinders (including cylinder valves), valves and connecting pipelines, etc. For a single gas cylinder, it refers to gas cylinder and cylinder valve; for a cylinder group consisting of two or more gas cylinders, it refers to gas cylinders (including cylinder valves), and connecting pipelines and valves within the frame, etc.

4 Technical Requirements

4.1 Types and Descriptions of Gas Cylinder

4.1.1 Type 3 gas cylinder

Fully-wrapped carbon fiber reinforced cylinder with an aluminum alloy liner.

4.1.2 Type 4 gas cylinder

Fully-wrapped carbon fiber reinforced cylinder with a plastic liner.

4.2 Inspection Tools and Devices

The inspection institution shall be equipped with at least the following tools and devices:

a) Explosion-proof lamp: used to inspect the inner and outer surfaces of gas cylinders and the surface of accessories. The voltage shall not exceed 12 V, and shall satisfy the requirements of explosion-proof level II class C and group T1 in GB/T 3836.1;

b) Inspectoscope and endoscope: used to inspect the surface of gas cylinder and the inner surface of gas cylinder (including the inner surface of the neck) that are partially obscured due to installation. The endoscope shall be in high-definition color and have the function of storage;

c) Special tools, for example, torque wrench: used for the disassembly and installation of gas cylinders, cylinder valves or TPRD end plugs;

d) Depth gauge: used to measure the depth of damages, such as: scratches, dents and abrasions, etc.;

e) Length measurement tools: including rulers, squares and tape measures, which are used to measure the length of damages, etc.;

f) Hydrostatic test device: used for hydrostatic test of gas cylinders;

g) Air-tightness test device: used for air-tightness test of gas cylinders;

h) Air-tightness helium leak detection device: used for helium leak detection of gas cylinders;

i) Hydrogen venting / recovery device: used for the discharge or recovery of hydrogen gas;

j) Cleaning device: used for the cleaning of contaminants and corrosion products on the inner and outer surfaces of gas cylinders;

k) Portable pumping-type hydrogen leak detection device: used to detect hydrogen

4.4.3 If the results of the pre-inspection satisfy the relevant stipulations of 5.1, the inspection institution may complete the inspection without disassembling the gas cylinder. The inspection items without disassembling the gas cylinder are only visual inspection.

4.4.4 If the results of the pre-inspection do not satisfy the relevant stipulations of 5.1, or the cylinder valve needs to be replaced, then, the gas cylinder shall be disassembled, then, be inspected for all the items.

4.4.5 For gas cylinders with a nominal working pressure of 35 MPa in GB/T 35544 and Class A2 gas cylinders in GB/T 42612, during the 2nd, 4th and the subsequent inspections, the gas cylinders shall be inspected for all the items; the 3rd inspection may adopt the same judgment mode as the first inspection to determine whether to conduct disassembly inspection. For gas cylinders with a nominal working pressure of 70 MPa in GB/T 35544 and Class B2 gas cylinders in GB/T 42612, during the 2nd and the subsequent inspections, the gas cylinders shall be inspected for all the items.

5 Inspection Preparation

5.1 Pre-inspection of Hydrogen Storage System

5.1.1 Overview

The pre-inspection of the hydrogen storage system includes appearance patrol inspection and hydrogen leak detection.

5.1.2 Appearance patrol inspection

Before the appearance patrol inspection, it shall be confirmed that the on-board hydrogen system has been powered off. In the appearance patrol inspection, the gas cylinders, cylinder valves, connecting pipelines, fixing brackets or fastening belts shall be inspected. If the following conditions are satisfied, the inspection result is qualified:

a) The fixing bracket or fastening belt of the gas cylinder is intact, and not loosening or deformed;

b) The cylinder valves and hydrogen pipelines of the cylinder group or a single cylinder are not loosening or damaged, and there are no obvious signs of gas leakage;

c) There is no abnormality on the surface of the gas cylinder and cylinder valve.

5.1.3 Hydrogen leak detection

5.1.3.1 After the appearance patrol inspection, hydrogen leak detection shall be carried out one by one on the gas cylinders, cylinder valves / TPRD end plugs, connecting pipeline joints on the hydrogen storage system and other parts where leaks may occur.

5.1.3.2 The detection pressure of hydrogen leakage shall not be lower than 20% of the nominal

working pressure.

5.1.3.3 A portable pumping-type hydrogen leak detection device shall be used for detection. The resolution of the instrument shall not be lower than 1 mL/m^3, and the minimum detection concentration shall not be greater than 100 mL/m^3.

5.1.3.4 Thoroughly rotate the end of the detection head of the instrument in the site to be detected to find the maximum leakage point, and read the hydrogen concentration value at that location. When there may be condensation water dripping from the detection area, it is advisable to install a detection head shield with a lateral opening on the detection head of the instrument.

5.1.3.5 If leakage is found through detection, the actual measured hydrogen concentration shall not be greater than 300 mL/m^3.

5.1.3.6 The hydrogen leak detection device shall be regularly verified or calibrated, and the verification or calibration cycle shall comply with the relevant stipulations.

5.2 Information Query and Recording

5.2.1 Before the inspection of the gas cylinder, the following information shall be consulted:

a) Relevant information provided by the gas cylinder manufacturing organization, including gas cylinder supervision and inspection certificate, instructions for use and certificate of conformity, etc.;

b) Relevant information provided by the vehicle manufacturing organization (when the on-board hydrogen system is installed by the vehicle manufacturing organization) or on-board hydrogen system integration organization (when the on-board hydrogen system is installed by an organization other than the vehicle manufacturing organization);

c) Registration certificate for gas cylinders for automotive vehicles;

d) Previous inspection reports;

e) Filling records of gas cylinders after the last inspection, daily maintenance records, emergency measures and handling records of accidents or abnormal situations, etc.

5.2.2 Check and record the manufacturing mark and inspection mark of gas cylinders. The recorded content shall at least include license number or organization code of the manufacturing organization, gas cylinder manufacturing standard, gas cylinder serial No., manufacturing year and month, nominal working pressure, hydrostatic test pressure, nominal water capacity, design service life, design cycle times, REE, manufacturing organization and model of cylinder valve and TPRD end plug (if present, the same below), the date of the last inspection and the name or code of the inspection institution, etc. For imported gas cylinders, the nationality shall be recorded.

5.2.3 Gas cylinders manufactured by manufacturing organizations that have not obtained

When it is confirmed that the known chemicals, by which, the gas cylinder is contaminated, will not cause damage to the gas cylinder, it shall be determined as level 1 damage; spots, blistering, softening, resin falling-off, fiber breakage or looseness caused by chemical erosion of the gas cylinder shall be determined as level 3 damage; when the type of chemical cannot be determined, or the impact on the gas cylinder material cannot be confirmed, it shall also be determined as level 3 damage.

6.3.5 Ageing

When a gas cylinder is exposed to sunlight and atmospheric environment for a long time, the glass fiber protective layer on the outer surface of the gas cylinder will be damaged and aged, which may cause discoloration or degradation of the outer surface material. If only the surface layer of resin is pulverized, and no fiber in the wrapping layer is broken or loosened, it shall be determined as level 1 or level 2 damage; otherwise, it shall be determined as level 3 damage.

6.3.6 Impact damage

Impact damage is caused by a strong impact on the surface of the gas cylinder. Impact damage may cause permanent deformation and dents on the surface of the gas cylinder, and may also cause delamination of the wrapping layer and fiber breakage. Surface damage related to impact damage includes: scratch, scuffing, bruise, fiber breakage or looseness, resin cracking, discoloration, dent or cylinder body deformation. When the above-mentioned damage exists, the surface of the gas cylinder shall be meticulously inspected, and the impact damage to the gas cylinder can be tested by tapping. If a small metal hammer is used to gently tap the surface of the wrapping layer to test the impact-damaged area, the sound emitted by the impact-damaged area will be significantly different from the sound emitted by the undamaged area. Meanwhile, an emphasis shall be placed on the following aspects.

a) Inner wall damage: the known impact area, surface damage area and inner wall of the gas cylinder shall be inspected to determine whether the inner wall has been damaged. If there is permanent deformation on the surface of the gas cylinder or any inward bulge on the inner wall, it shall be determined as level 3 damage.

b) Gas cylinder color: there may be local color changes on the surface of the impacted gas cylinder. Such changes are caused by delamination, cracking or cracks of the wrapping layer material, and bruises on the outer surface. Delamination of the wrapping layer shall be determined as level 3 damage.

c) Surface cracks: the impacted gas cylinder may manifest circular, oval or linear local surface cracks on the surface of the wrapping layer material. Cracks as deep as the carbon fiber layer shall be determined as level 3 damage.

6.3.7 Stress corrosion cracking

The stress corrosion cracking of the gas cylinder may be caused by erosion by the environment (for example, carbonic acid or other acidic materials leaking from vehicle components).

The stress corrosion cracking on the wrapping layer usually appears as cracking or collective cracking perpendicular to the fiber direction. Gas cylinders with cracking or collective cracking shall be determined as level 3 damage.

6.3.8 Crazing

Crazing is generally linear and usually occurs along the fiber direction, or in multi-directional cracks on the resin on the surface of the wrapping layer. Crazing may occur after the gas cylinder has been pressurized for several times.

The crack width along the fiber direction is less than 1.0 mm, and there is no foreign matter at the crack, the crazing direction may be spirally wrapped or cross the circumferential wrapping direction (especially the head area), and if the fiber does not break, it shall be determined as level 1 damage; if the crack width on the resin surface is greater than or equal to 1.0 mm, or there is foreign matter at the crack, it shall be determined as level 3 damage.

6.3.9 Metal corrosion under the wrapping layer of type 3 gas cylinders

If there is metal corrosion at the boundary between the wrapping layer and the metal, or corrosion products are found from the surface of the wrapping layer material back to the surface, it shall be determined as level 3 damage. Pay attention not to confuse gas cylinder corrosion products with corrosion deposits resulting from automotive components.

6.3.10 Galvanic corrosion

When the cylinder valve seat comes into contact with other conductive materials (for example, carbon fiber in contact with metal), galvanic corrosion may occur. If there are features of corrosion dents, it shall be determined as level 3 damage.

7 Treatment of Outer Surface Damage

7.1 It is allowed to adopt the method of resin coating to restore the damage to the outer surface of the glass fiber protective layer of the gas cylinder. The resin coating shall be carried out before the hydrostatic test.

7.2 Use room-temperature cured bi-component epoxy resin for treatment. Before applying the resin, the area to be treated shall be cleaned. If it is necessary to use other types of resin, consult the gas cylinder manufacturing organization for suggestions.

7.3 After the hydrostatic test, the resin-coated part shall be inspected for defects, such as: expansion, peeling or delamination.

7.4 For each damaged area, coating with resin is only allowed to be performed once. Appendix C provides illustrations of the typical method of resin coating treatment.

or other mechanical damage.

9.2 The threads of the cylinder neck of Class A gas cylinders shall not have cracking defects, but minor damage to the threads of the cylinder neck that does not affect the use is allowed. In other words, notches of no more than 2 teeth are allowed, and the length of the notch does not exceed 1/6 of the circumference, and the depth of the notch does not exceed 1/3 of the tooth height.

9.3 Mild corrosion, abrasion or other damage to the threads of the cylinder neck of Class A gas cylinders can be repaired with a screw tap that complies with GB/T 3464.1 or the corresponding standards. After the repair, use a gauge that complies with GB/T 3934 or the corresponding standards to inspect it, and when the inspection result does not comply with the relevant requirements of the standards, the gas cylinder shall be deemed scrapped.

9.4 Class B gas cylinders that are found to have cracking defects, deformation, corrosion or other mechanical damage on the threads of the cylinder neck shall be deemed scrapped.

9.5 Gas cylinders with cracking defects or damage found on the contact surface of the cylinder neck sealing ring shall be deemed scrapped.

10 Hydrostatic Test

10.1 Type 3 gas cylinders shall be subject to external hydrostatic test one by one in accordance with GB/T 9251. Type 4 gas cylinders shall be subject to internal hydrostatic test one by one in accordance with the relevant requirements of GB/T 42612.

10.2 The test pressure is the hydrostatic test pressure in the mark of the gas cylinders.

10.3 The pressure retention time of the gas cylinders under the hydrostatic test pressure shall be no less than 2 min.

10.4 During the hydrostatic test, gas cylinders that have defect expansion in the wrapping layer, leakage and obvious deformation of the cylinder body, or pressure drop during the pressure retention time (not caused by the test device or leakage of cylinder neck) shall be deemed scrapped.

10.5 During the hydrostatic test of the gas cylinders, Type 3 gas cylinders shall be simultaneously determined for the elastic expansion amount and the ratio of permanent volumetric expansion. Gas cylinders whose elastic expansion amount exceeds REE or whose ratio of permanent volumetric expansion exceeds 5% shall be deemed scrapped. For Type 4 gas cylinders, only the elastic expansion amount is determined, and if the elastic expansion amount exceeds REE, the gas cylinders shall be deemed scrapped.

10.6 During the hydrostatic test, when the pressure rises to more than 90% of the test pressure, if the test cannot be continued for certain reason, the test pressure shall be raised by 0.7 MPa when testing again, but it shall not exceed the self-tightening pressure. At this moment, the

calculation of the elastic expansion amount and the ratio of permanent volumetric expansion of the gas cylinders shall be performed in accordance with the pressure after the raise. The re-test is only allowed to be performed once.

11 Internal Drying

11.1 Method and Requirements for Drying

11.1.1 Gas cylinders that have passed the hydrostatic test shall be internally dried one by one.

11.1.2 Turn the cylinder upside down for a period of time or use special water drainage equipment to drain the remaining water in the cylinder, then, use dry air or nitrogen to blow it, or adopt other appropriate methods to dry the interior.

11.1.3 During internal drying, the temperature shall not exceed 70 °C; the time shall be long enough to ensure that the inside of the gas cylinder is completely dry.

11.2 Inspection of Drying Condition

With the help of an endoscope, observe the drying condition and cleanliness inside the gas cylinders. The inside of the gas cylinders shall be free of visible particulates, metal shavings and other impurities. The inner wall shall be completely dry and have no particulate impurities ≥ 100 μm. Instruments, such as: particle detectors or particle size detectors can be used to detect the particulate impurities.

12 Inspection and Assembly of Cylinder Valve

12.1 The cylinder valve and TPRD end plug shall be subject to appearance inspection.

12.2 All components of the cylinder valve and TPRD end plug (including TPRD, solenoid valve and manual valve, etc.) shall be complete, and shall not be deformed, damaged, corroded, or have loose components, otherwise, they shall be replaced. The thread inspection shall comply with the stipulations of Chapter 9.

12.3 Before the cylinder valve and TPRD end plug are assembled, there shall be no visually visible particulates, metal shavings or other impurities on the cylinder neck end face, cylinder valve sealing surface and thread root. Cylinder valves and TPRD end plugs with the sealing structure of O-shaped sealing ring shall be replaced with new O-shaped sealing rings of the same model.

12.4 The cylinder valve and TPRD end plug shall be firmly assembled, and the installation torque shall comply with the stipulations of the cylinder valve manufacturing organization or the gas cylinder manufacturing organization.

12.5 When the cylinder valve or TPRD end plug does not satisfy the stipulations of 12.2 and cannot be guaranteed to be safely used until the next inspection cycle, or the next inspection

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