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Assembly valve on high pressure hydrogen storge cylinder for vehicles

车用高压储氢气瓶组合阀门

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Assembly valve on high pressure hydrogen storge cylinder for vehicles

1 Scope

This document specifies the basic type, technical requirements, test methods, eligibility indicators, inspection rules, marking, packaging, transportation, storage and other requirements of the assembly valve on high-pressure hydrogen storage cylinders for vehicles (hereinafter referred to as assembly valve).

This document is applicable to assembly valve on high-pressure hydrogen storage cylinders for vehicles, which have a nominal working pressure not greater than 70 MPa and a working temperature of -40 °C ~ 85 °C, are fixed on road vehicles AND used as fuel tanks.

The type test of the temperature-driven safety pressure relief device for high-pressure hydrogen storage cylinders, as used in vehicles, can be carried out with reference to this document.

2 Normative references

The contents of the following documents constitute the essential provisions of this document through normative references in the text. Among them, for dated references, only the version corresponding to the date applies to this document; for undated references, the latest version (including all amendments) applies to this document.

GB/T 192 General purpose metric screw threads - Basic profile

GB/T 196 General purpose metric screw threads - Basic dimensions

GB/T 197 General purpose metric screw threads - Tolerances

GB/T 223 (all parts) Methods for chemical analysis of iron, steel and alloy

GB/T 228.1 Metallic materials - Tensile testing - Part 1: Method of test at room temperature

GB/T 229 Metallic materials - Charpy pendulum impact test method

GB/T 528 Rubber, vulcanized or thermoplastic - Determination of tensile stress-strain properties

vehicles, which has a nominal working pressure of 35 MPa, a rated DC voltage of 12 V, a design serial number I, is marked as: CQZF-35-12-I.

5 Technical requirements

5.1 Materials

5.1.1 Metal materials

5.1.1.1 The main parts and materials of assembly valves (valve body, valve stem, other pressure parts) shall have the original quality certificate, which is provided by the material manufacturer, OR a copy of the quality certificate, which was stamped with the official seal of the material management organization and signed/sealed by the person in charge.

5.1.1.2 The main parts and components of assembly valves shall have good compatibility with hydrogen AND meet the requirements of corresponding material standards.

5.1.1.3 The main parts and components of assembly valves should be made of 6061 aluminum alloy or S31603 austenitic stainless steel. The 6061 aluminum alloy extruded bars shall comply with the provisions of GB/T 3191; the forgings shall comply with the provisions of GB/T 32249 or YS/T 479. The S31603 austenitic stainless steel bars shall comply with the provisions of GB/T 1220; the forgings shall comply with the provisions of NB/T 47010. The Ni content of S31603 austenitic stainless steel shall not be less than 12%; the reduction of area shall not be less than 70%. For the component materials which have a stress value more than 25% of the guaranteed value of material tensile strength, at 1.25 times the nominal working pressure, they shall also meet the requirements that the Ni equivalent is not less than 28.5% (calculation formula of Ni equivalent is: Ni_{eq} = 12.6C + 0.35Si + 1.05Mn + Ni + 0.65Cr + 0.98Mo).

5.1.1.4 For assembly valves, which have a nominal working pressure greater than 40 MPa, if the main parts are made of materials other than 6061 aluminum alloy and S31603 austenitic stainless steel, it shall carry out the hydrogen compatibility test and hydrogen embrittlement susceptibility test, according to the provisions of 6.1.3 and 6.1.4.

5.1.2 Non-metallic seal materials

5.1.2.1 The non-metallic seal material shall have the original quality certificate, which is provided by the material manufacturer, OR a copy of the quality certificate, which has the official seal of the material management organization and the signature (seal) of the person in charge. The quality certificate shall include the hardness, tensile strength, elongation at break, etc. of the non-metallic seal material.

5.1.2.2 Non-metallic seals shall be made of materials, which have good compatibility

with high-pressure hydrogen. The properties of the seal materials shall meet the requirements in 6.7.

5.2 Design and manufacture

5.2.1 For the assembly valves on high-pressure hydrogen storage cylinders for vehicles, that cannot be disassembled due to structural design of the vehicle body, they shall have a designed service life of not less than 15 years. For the assembly valves on high-pressure hydrogen storage cylinders for other vehicles, they shall have a designed service life of not less than 6 years.

5.2.2 Assembly valves shall have the following functions:

a) One-way cut-off function: hydrogen can be filled into the cylinder one-way through the assembly valve, when the power is not on; at the same time, it prevents the gas in the cylinder from flowing out in reverse;

b) Safety pressure relief function: In special cases such as fire, the gas in the gas cylinder can be automatically released, through the assembly valve TPRD;

c) Temperature monitoring function: It can monitor the gas temperature inside the cylinder;

d) Manual opening and closing function: The valve can be opened or closed by manual operation;

e) Automatic opening and closing function: The valve can be opened or closed by electric signal.

5.2.3 Assembly valve body shall be subject to the finite element stress analysis. Under 2.5 times the nominal working pressure, the stress of each part of the valve body shall not be greater than the guaranteed value of the yield strength of the valve body material.

5.2.4 The gas inlet and outlet thread specifications of assembly valves shall be straight threads, in accordance with GB/T 192, GB/T 196, GB/T 197 or GB/T 20668, OR other threads in accordance with the corresponding standards.

5.2.5 The thread of assembly valve shall be checked for strength; the shear stress safety factor of the thread, at 1.5 times the nominal working pressure, shall not be less than 4. The calculation method of thread shear stress safety factor shall be carried out, in accordance with Appendix A.

5.2.6 Fusible alloy or glass bubble shall be selected as the safety pressure relief device; the operating temperature is (110 ± 5) °C. The fusible alloy and glass bubble shall comply with the relevant standards on gas cylinder safety pressure relief device. The safety pressure relief channel of the assembly valve shall be independent AND shall not be connected with other functional channels. Only one safety pressure relief device can

Where, β is 273.15 °C, T_{ME} is 85 °C, T_{act} is 110 °C.

b) Place the TPRD in an incubator or a water bath; the allowable temperature deviation during the test is ±1 °C.

c) The pressure of hydrogen or inert gas, at the inlet of TPRD, shall not be lower than 1.25p. The pressure source can be located external to the incubator or water bath. Pressurize the TPRD in a single or branch piping system. If a branch piping system is used, each branch piping shall contain a check valve.

6.5.2.2 Eligibility indicators

The action time of TPRD, which is tested under T_{act}, shall not exceed 10 h. The TPRD, which is tested under T_{life}, shall not act within 500 h. The TPRD after the test shall meet the requirements of 6.5.9 leak test.

6.5.3 Temperature cycle test

6.5.3.1 Test method

The test steps are as follows:

a) Let a TPRD, without internal pressure, stand in a liquid, which has a temperature less than or equal to -40 °C, for at least 2 hours. Then transfer it to a liquid, which has a temperature greater than or equal to 85 °C, within 5 minutes. Let it stand at this temperature for at least 2 hours. Then transfer the TPRD to a liquid, which has a temperature less than or equal to -40 °C, within 5 minutes;

b) Repeat step a), to complete 15 cycles;

c) Put the TPRD in a liquid, which has a temperature less than or equal to -40 °C, for at least 2 hours. Then use hydrogen to perform 100 pressure cycles, on the TPRD at an ambient temperature less than or equal to -40 °C. The lower limit of the pressure cycle shall not exceed 2 MPa. The upper limit of the pressure cycle shall not be less than 0.8p.

6.5.3.2 Eligibility indicators

After the temperature cycle test, the TPRD shall comply with the provisions of 6.5.9 leak test, 6.5.10 action test, 6.5.11 flow test. The temperature of the leak test shall not be higher than -40 °C.

6.5.4 Salt spray corrosion resistance test

6.5.4.1 Test method

The test requirements are as follows.

a) Carry out the salt spray test on 3 TPRDs. Before the test, the corresponding ports of the TPRDs shall be blocked, according to the operating conditions. The test is a cycle test, a total of 100 cycles. A cycle includes a normal environment stage, a wet stage, a dry stage; the single cycle time is 24 h. The test process is as shown in Figure 1.

b) In the normal environment stage, the temperature of the environment box shall be controlled at (25 ± 3) °C and the relative humidity shall be (45 ± 10)%. The test time is 8 h ± 10 min. Salt spray is only applied to TPRD, in the normal environment stage. The first salt spray is applied, at the beginning of the normal environment stage, a total of 4 applications are required. The interval between applying salt spray is about 90 min. Each time the salt spray is applied, the surface of the TPRD shall be wetted and beaded. The amount of spray shall be sufficient, to wash off traces of salt remaining on the TPRD.

c) In the humid stage, the temperature of the control environment box is (49 ± 2) °C, the relative humidity is 100%, the test time is 7 h ± 10 min.

d) In the drying stage, control the temperature of the environmental box at (60 ± 2) °C and the relative humidity not greater than 30%; the test time is 5 h ± 10 min.

e) The transition time, from the normal environment stage to the wet stage, shall be 1 h ± 5 min; the transition time, from the wet stage to the dry stage, shall be 3 h ± 10 min.

f) When the test needs to be suspended, due to special reasons such as weekends or holidays, it shall be suspended after the test cycle is completed. During the suspension period, the temperature of the test chamber shall be kept within the range of (25 ± 3) °C; the relative humidity shall be within the range of (45 ± 10)%.

g) After the cyclic corrosion test, rinse the TPRD with clean water; evaluate it after it dries.

h) The environmental chamber in the test equipment shall meet the requirements of GB/T 13893.2. The test water shall meet the requirements of the grade-3 water, which is specified in GB/T 6682. When spraying the saline solution, avoid direct impact of the spray on the TPRD.

i) The mass fraction requirements of each component of the mixed saline solution are as follows:

1) Sodium chloride (NaCl): 0.9%;

2) Calcium chloride ($CaCl_2$): 0.1%;

3) Sodium bicarbonate ($NaHCO_3$): 0.075%.

1) Sulfuric acid aqueous solution (battery acid), which has a volume fraction of 19%;

2) Ethanol gasoline solution (E10 gasoline), which has a volume fraction of 10%;

3) Aqueous methanol solution, which has a volume fraction of 50% (windshield washer fluid).

b) Use 1 TPRD to complete this test. After soaking in each solution, wipe off the residual solution on the TPRD and rinse it with water. Safety precautions shall be taken during the test to prevent accidents such as fires.

6.5.5.2 Eligibility indicators

After the test, the TPRD shall not have physical damages, such as cracks, softening, swelling, etc., that affect its function (excluding dents, surface discoloration). At the same time, TPRD shall meet the requirements of 6.5.9 leak test, 6.5.10 action test, 6.5.11 flow test.

6.5.6 Stress corrosion resistance test

6.5.6.1 Test method

When the TPRD contains copper alloy (such as brass) parts exposed to the external environment, one TPRD shall be taken for testing. The test requirements are as follows:

a) Remove grease from copper alloy parts;

b) Prepare a desiccating dish. Inject ammonia water (0.9 g/mL), which has a volume of 2% of its volume, into the desiccating dish;

c) Place TPRD on a tray, that does not react with ammonia water at (35 ± 5) mm above the ammonia water level; seal the drying dish;

d) Place the sealed desiccator containing TPRD, in an environmental box for 10 days; the temperature of the environmental box is (35 ± 5) °C.

6.5.6.2 Eligibility indicators

There shall be no cracking or delamination.

6.5.7 Drop test

6.5.7.1 Test method

Freely drop 1 or 6 TPRDs, from a height of 2 m onto a smooth concrete floor, at room temperature. There are 6 directions of falling (positive and negative directions of 3 orthogonal axes). It may choose 1 TPRD to fall in 6 directions or each of 6 TPRDs to

fall in one direction.

6.5.7.2 Eligibility indicators

There shall be no visible external damage, which affects the normal use of the TPRD. Any TPRD, that cannot be installed due to thread damage due to drop, shall not be subjected to the 6.5.8 vibration resistance test. However, this drop test shall not be considered a failure.

6.5.8 Vibration resistance test

6.5.8.1 Test method

Install the TPRD (including 1 untested TPRD and 1 or 6 TPRDs that have been dropped) on a special device. Vibrate for 2 h, at the resonant frequency along the three orthogonal axes. Carry out a 10 min sinusoidal frequency sweep, at an acceleration of 1.5 g, the frequency range is 10 Hz ~ 500 Hz. Determine the resonance frequency of TPRD. If no resonance frequency is found, the test is carried out at a frequency of 40 Hz.

6.5.8.2 Eligibility indicators

The TPRD after the test shall comply with the provisions of 6.5.9 leak test, 6.5.10 action test, 6.5.11 flow test.

6.5.9 Leak test

6.5.9.1 Test method

One untested TPRD is subjected to leak test at room temperature, high temperature, low temperature in turn. Before the start of the test, let the TPRD stand at a specified temperature and a pressure of not less than 2 MPa for at least 1 h, until the temperature stabilized. When pressurizing the TPRD, hydrogen shall be used, to pressurize from the inlet. The test conditions are as follows:

a) Normal temperature: At normal temperature and (2 ± 0.5) MPa, a test pressure not lower than 1.25p;

b) High temperature: At a temperature of not lower than 85 °C and (2 ± 0.5) MPa, a test pressure of not lower than 1.25p;

c) Low temperature: At a temperature of not higher than -40 °C and (2 ± 0.5) MPa, a test pressure of not lower than p.

Under each specified temperature and pressure condition, soak the TPRD in the liquid at the corresponding temperature for 1 min, for observation.

6.5.9.2 Eligibility indicators

c) The air inlet pressure shall be (2 ± 0.5) MPa; the air outlet pressure shall be atmospheric pressure; record the air inlet pressure and temperature;

d) The measurement accuracy of the flow rate shall be ±2%.

6.5.11.2 Eligibility indicators

The minimum value of the eight TPRD's measured flows shall be greater than or equal to 90% of the maximum value.

6.6 Check valve and manual/automatic shut-off valve test

6.6.1 Pressure resistance test

6.6.1.1 Test method

Carry out this test on an untested valve first. Use its burst pressure as the benchmark burst pressure of the valve. The test requirements are as follows:

a) Block the air outlet of the valve; make the inside of the valve in a connected state;

b) Use a non-corrosive liquid, to slowly apply a hydraulic pressure not less than 2.5p to the air inlet of the valve. Keep the pressure for 3 minutes. Then check the valve;

c) Continue to pressurize at a pressure increase rate less than or equal to 1.4 MPa/s, until the valve fails. Record the pressure when the valve fails.

6.6.1.2 Eligibility indicators

After holding the pressure for 3 min, the valve shall not rupture. For valves that have undergone other tests, the measured burst pressure shall not be less than 0.8 times the reference burst pressure, OR greater than 4 times the nominal working pressure p.

6.6.2 Leak test

6.6.2.1 Test method

Use one untested valve, to carry out leak test, under normal temperature, high temperature, low temperature conditions. Before the start of the test, leave the valve at the specified temperature and pressure not lower than 2 MPa, for at least 1 h, until the temperature stabilizes. When pressurizing the valve, it shall block the outlet of the valve; use hydrogen to pressurize the inlet of the valve. The test conditions are as follows:

a) Normal temperature: At normal temperature and (2 ± 0.5) MPa, under the test pressure not less than 1.25p;

b) High temperature: At the temperature of not lower than 85 °C and (2 ± 0.5) MPa, under the test pressure not less than 1.25p;

c) Low temperature: At the temperature of not higher than -40 °C and (2 ± 0.5) MPa, under the test pressure not less than p.

Under each specified temperature and pressure condition, immerse the valve in the corresponding temperature liquid for 1 min, for observation.

6.6.2.2 Eligibility indicators

If no air bubbles are generated within the specified test time, the valve passes the test; if air bubbles are detected, the leak rate shall be measured by an appropriate method. The hydrogen leakage rate shall not exceed 10 mL/h.

6.6.3 Extreme temperature and pressure cycle test

6.6.3.1 Test method

The number of cycles of the check valve is 15000; the number of cycles of the automatic stop valve is 50000; the number of cycles of the manual stop valve is 100. The test procedure is as follows.

a) Install the valve on the special device. Under the specified pressure, the valve is continuously circulated with hydrogen. The definition of a cycle is as follows:

1) For the check valve, install it on the special device for the test. Close the valve outlet. Fill the valve inlet with hydrogen to the specified test pressure, within 6 pressurization steps. Then release the pressure from the valve inlet. Before the next cycle, the pressure at the outlet of the check valve shall be less than 0.6p.

2) For the stop valve, install it on the special device for the test. Continuously pressurize its inlet and outlet.

3) One cycle shall include one operation as mentioned above and one reset.

b) Carry out the following test on one valve:

1) Normal temperature cycle. The test pressure shall not be lower than p; the number of cycles shall be 90% of the total number of cycles; the test temperature shall be normal temperature.

2) High temperature cycle. The test pressure shall not be lower than 1.25p; the number of cycles shall be 5% of the total number of cycles; the test temperature shall be greater than or equal to 85 °C.

3) Low temperature cycle. The test pressure shall not be lower than 0.8p; the number of cycles shall be 5% of the total number of cycles; the test temperature shall be less than or equal to -40 °C.

b) In the normal environment stage, the temperature of the environment box shall be controlled at (25 ± 3) °C and the relative humidity shall be (45 ± 10)%. The test time is 8 h ± 10 min. Only apply salt spray to the valve, in the normal environment stage. Apply the salt spray for the first time, at the beginning of the normal environment stage, a total of 4 applications are required. The interval between applying salt spray is about 90 minutes. Each time the salt spray is applied, the valve surface shall be wetted and beaded. The amount of spray shall be sufficient to clean residual traces of salt from the valve.

c) In the wet stage, the temperature of the control environment box is (49 ± 2) °C; the relative humidity is 100%; the test time is 7 h ± 10 min.

d) In the drying stage, control the temperature of the environmental box at (60 ± 2) °C and the relative humidity not greater than 30%; the test time is 5 h ± 10 min.

e) The transition time -- from the normal environment stage to the wet stage -- shall be 1 h ± 5 min; the transition time -- from the wet stage to the dry stage -- shall be 3 h ± 10 min.

f) When the test needs to be suspended due to special reasons, such as weekends or holidays, it shall be suspended after a test cycle is completed. During the suspension period, the temperature of the test chamber shall be kept within the range of (25 ± 3) °C; the relative humidity shall be within the range of (45 ± 10)%.

g) After the cyclic corrosion test is over, use clean water to rinse the valve; evaluate it after it dries.

h) The environmental box in the test equipment shall meet the requirements of GB/T 13893.2. The test water shall meet the requirements of the grade-3 water specified in GB/T 6682. When spraying saline solution, avoid direct impact of the spray on the valve.

i) The mass fraction requirements of each component of the mixed salt solution are as follows:

1) Sodium chloride (NaCl): 0.9%;

2) Calcium chloride ($CaCl_2$): 0.1%;

3) 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. The water used to prepare the solution shall meet the requirements for grade-3 water, which is specified in GB/T 6682.

6.6.4.2 Eligibility indicators

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