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Technical specification of safety valves for liquid hydrogen vessels

液氢容器用安全阀技术规范

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Technical specification of safety valves for liquid hydrogen vessels

1 Scope

This document specifies the technical requirements, test methods, inspection rules, marking, painting, packaging, transportation and storage of safety valves for liquid hydrogen vessels.

This document is applicable to safety valves (including spring-loaded safety valves and pilot operated safety valves) for liquid hydrogen vessels with a nominal size of not greater than DN200, a set pressure of not less than 0.1 MPa, a temperature of not less than -254 °C, and the medium being single-phase liquid hydrogen boil-off gas.

2 Normative references

The provisions of the following documents constitute the essential clauses of this document through normative references in this text. Among them, for referenced documents with dates, only the versions corresponding to the dates are applicable to this document; for referenced documents without dates, the latest versions (including all amendments) are applicable to this document.

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

GB/T 12224 General requirements for industrial steel valves

GB/T 12241 Safety valves - General requirements

GB/T 12242 Pressure relief devices - Performance test code

GB/T 12243 Spring loaded safety valves

GB/T 13305 Method for determining content of the α-phase in stainless steels

GB/T 22652 Overlaying-welding procedure qualification for valves sealing face

GB/T 24499 Technology glossary for gaseous hydrogen, hydrogen energy and hydrogen energy system

GB/T 24921.1 Sizing, selection and installation of pressure relieving valves for petrochemical industries - Part 1: Sizing and selection

rating of the valve body material, the design pressure shall be determined based on the lower value.

4.1.3 The end connection of the safety valve shall comply with the provisions of GB/T 12241. If the purchaser has special requirements, the safety valve can be designed and manufactured in accordance with the procurement technical agreement while ensuring the performance and safety of the safety valve.

4.1.4 Before assembly, all parts shall be cleaned, degreased and dried according to the methods specified in HG 20202, and the results shall comply with the inspection requirements of HG 20202.

4.2 Design requirements

4.2.1 Temperature adaptability

Within the predetermined pressure range, the safety valve shall be able to operate normally within the range from the required minimum temperature to 65 °C.

4.2.2 Set pressure

The set pressure of the safety valve shall be less than or equal to the difference between its design pressure and the overpressure (set pressure ≤ design pressure - overpressure), and should not exceed the specified values in Appendix B and Appendix C of GB/T 24920-2010.

4.2.3 Safety valve shell

4.2.3.1 Safety valves shall be designed to discharge liquid to avoid accumulation of liquid in the valve, unless otherwise specified in the procurement technical agreement.

4.2.3.2 The safety valve shell shall have sufficient strength to ensure that no harmful deformation occurs during strength tests and working conditions. It shall be able to withstand the total load of stress caused by medium pressure and temperature changes, additional stress caused by connecting pipes, and comprehensive stress caused by operating conditions for a long time.

4.2.3.3 When the safety valve is discharging, avoid the accumulation of solid matter in the valve body or at the outlet due to temperature drop, which may cause malfunction.

4.2.3.4 The shell thickness shall comply with the requirements of GB/T 26640.

4.2.4 Guide device

4.2.4.1 The design of the guide device shall ensure the normal operation of the safety valve and avoid the deposition and freezing of moisture in the atmosphere that may

cause malfunction.

4.2.4.2 The structure of the guide device shall be strong enough to ensure its effectiveness during normal handling and operation.

4.2.5 Sealing of valve disc and valve seat

4.2.5.1 The sealing surface of the valve disc and the valve seat shall be designed to be metal-to-metal or metal-to-non-metal. When metal-to-non-metal sealing is used, a secondary metal sealing structure should be designed on the non-metallic sealing side; non-metallic sealing (such as pure PTFE and other materials) shall have sufficient support to prevent sealing failure caused by cold flow deformation of the material.

4.2.5.2 The connection between the non-metallic seal and the valve disc or valve seat shall be mechanically fixed and locked.

4.2.5.3 When the hard alloy is overlaid on the sealing surface of the valve disc and valve seat, the requirements of GB/T 22652 shall be met.

4.2.6 Anti-static

The safety valve shall be designed with an anti-static structure to ensure that the shell, opening and closing parts, valve stem and other components are conductive, and the maximum resistance of the discharge path does not exceed 5 Ω.

4.2.7 Vibration and impact

Safety valves used for mobile vessels shall, if necessary, be designed to be resistant to vibration and impact (drop) according to the requirements of the installed vessel, and their performance shall not change after vibration and impact (drop) tests.

4.3 Performance requirements

4.3.1 Normal temperature performance requirements

4.3.1.1 Shell strength

4.3.1.1.1 The shell strength shall comply with the requirements of GB/T 12241 and GB/T 28778.

NOTE: The design pressure in this document corresponds to the nominal pressure of GB/T 12241 and GB/T 28778.

4.3.1.1.2 The hydraulic static strength shall meet the following requirements:

a) For safety valves with a design pressure not exceeding 10 MPa, the pressure-

seal), each part shall be tested separately according to the sniffing test specified in GB/T 26481. There shall be no visible (or detectable) leakage in each part; when testing according to the total leakage rate test method specified in GB/T 40079, the leakage rate shall not be greater than 1×10^{-7} Pa • m^3/s.

4.3.1.7 Opening and closing cycle life

The opening and closing cycle life of a valve category A is at least 1000 times, and the opening and closing cycle life of a valve category B is at least 20 times. The opening and closing action shall be smooth and without obstruction.

4.3.1.8 Sealing performance after opening and closing cycles

After the opening and closing test, the valve seat sealing performance test is carried out. There shall be no leakage within the same specified time, or the leakage rate shall not exceed twice that before the opening and closing cycle life test.

4.3.2 Low-temperature performance requirements

4.3.2.1 Set pressure

Low-temperature test includes the liquid nitrogen temperature zone and liquid hydrogen temperature zone test. Under the test temperature, for safety valves with set pressure less than or equal to 0.5 MPa, the allowable deviation of set pressure is ±0.015 MPa; for safety valves with set pressure greater than 0.5 MPa, the allowable deviation of set pressure is ±3%.

4.3.2.2 Sealing performance

Under the specified sealing test pressure and test temperature, the leakage rate shall not exceed 0.25 cm^3/(s • DN).

4.4 Materials

4.4.1 General requirements

4.4.1.1 The materials selected shall be compatible with the hydrogen medium.

4.4.1.2 The material shall not be subject to damage caused by physical processes and chemical reactions, such as hydrogen embrittlement, stress corrosion cracking, wear, etc.

4.4.1.3 Materials in direct contact with hydrogen media shall meet normal use requirements within the range from rated minimum temperature to 65°C and under expected operating pressure.

4.4.1.4 The materials used for the safety valve internal parts shall be able to avoid blocking, biting and scratching caused by operation in a liquid hydrogen environment. The corrosion resistance of the materials shall not be lower than that of the pressure-bearing shell.

4.4.1.5 For materials not included in national or industry standards, safety valve manufacturers shall formulate internal standards to control the chemical composition and physical properties to ensure that the material properties meet the requirements; a hydrogen compatibility test report for the material shall be provided and used after approval by the purchaser or evaluation by a third party.

4.4.2 Metal materials

4.4.2.1 The metal material used for pressure-bearing parts shall be austenitic stainless steel. The metallographic structure of the material shall be stable to prevent the deformation of parts due to phase change of the material at liquid hydrogen temperature, thereby affecting the low-temperature performance of the valve. For the recommended metal materials for the main parts, see Appendix B, or refer to Appendix B and Appendix C of GB/T 24920-2010 for selection. The low-temperature performance of the material shall meet the requirements of this document.

4.4.2.2 The chemical composition and mechanical properties of the materials shall comply with the provisions of the relevant standards. The nickel content of austenitic stainless steel in direct contact with hydrogen media shall not be less than 10% or in accordance with the requirements of the procurement technical agreement. The ferrite measurement value of forgings, pipes and bars shall not be greater than 3%, and the ferrite measurement value of castings shall not be greater than 8%. The ferrite content determination shall be carried out in accordance with the provisions of GB/T 13305.

4.4.2.3 Before welding pressure-bearing parts, welding procedure qualification shall be carried out in accordance with the provisions of NB/T 47014.

4.4.2.4 The material samples of pressure-bearing parts and welded samples shall be subjected to low-temperature impact tests, using V-notch test pieces and tested at -196 °C; for cast shells or pressure-bearing forgings, samples shall be cast from the same heat number with castings or shall be taken from forgings, and heat treated together with castings/forgings. The average impact energy absorbed KV_2 of a group (3 pieces) of standard samples shall not be less than 70 J, and the impact energy absorbed of at most one sample is allowed to be lower than the specified value, but shall not be lower than 70% of the specified value, and the lateral expansion value shall not be less than 0.76 mm. The average impact energy absorbed KV_2 of a group (3 pieces) of welded standard samples shall not be less than 47 J, and the lateral expansion value shall not be less than 0.53 mm.

4.4.2.5 Austenitic stainless-steel parts such as valve seats and valve discs shall be

of Level 1 in JB/T 6440-2008.

4.5.2.3 The radiographic testing results of pressure-bearing welds (if applicable) shall not be lower than the requirements of Level I in NB/T 47013.2-2015.

4.5.3 Penetration testing

The outer surface and accessible inner surface of the pressure-bearing shell shall be subjected to liquid penetration testing, and the test results shall comply with the requirements of Level I in NB/T 47013.5-2015. The sealing surface overlaying-welded by hard alloy shall be subjected to 100% liquid penetration testing, and no cracks or other harmful defects are allowed.

4.5.4 Ultrasonic testing

Forged shells, valve discs, valve seats, etc. shall be subjected to ultrasonic testing, and the test results shall comply with the requirements of Level 1 in JB/T 6903-2008.

5 Test methods

5.1 Safety tips

5.1.1 Before a pressure test is conducted, the safety of the test gas or liquid pressure system needs to be evaluated.

5.1.2 Before the low-temperature performance test is conducted, it is necessary to evaluate the safety of the test medium, test system and test environment as well as the safety protection of the test operators.

5.2 Marking inspection

Visually inspect the valve body and nameplate markings (if applicable), including:

a) The content of the markings cast, forged or printed on the shell surface;

b) Nameplate marking content.

5.3 Shell size inspection

Use qualified measuring tools or instruments to measure the valve shell wall thickness and connection port size.

5.4 Chemical composition of materials

Each batch of materials for main pressure-bearing parts (with the same heat number, same manufacturing process, and same heat treatment conditions) shall be inspected at least once, and the inspection results shall comply with the requirements of the corresponding material standards.

5.5 Mechanical properties of materials

5.5.1 Each batch of materials for pressure-bearing parts (with the same heat number, same manufacturing process, and same heat treatment conditions) shall be subjected to at least one mechanical property test.

5.5.2 The mechanical property test methods and results shall comply with the requirements of the relevant material standards.

5.5.3 Low-temperature impact test shall be carried out in accordance with the provisions of GB/T 229.

5.6 Normal temperature performance test

5.6.1 Shell strength and hydrostatic strength test

5.6.1.1 The shell strength test shall be carried out in accordance with the provisions of GB/T 12241.

5.6.1.2 After all valve test items are completed, the shell hydraulic strength test shall be carried out on the inlet side and the discharge side respectively.

5.6.1.3 During the shell strength test and hydraulic strength test, the internal parts of the safety valve shall be disassembled and removed, and the throat of the safety valve shall be blocked.

5.6.2 Operating performance, mechanical performance and discharge capacity test

The test methods for the operating performance, mechanical properties and discharge capacity of the safety valve shall comply with the provisions of GB/T 12242.

5.6.3 Sealing performance test

5.6.3.1 The test method shall be in accordance with the provisions of GB/T 12242.

5.6.3.2 When the test medium is nitrogen, it shall be dry nitrogen with a purity of not

differs from the temperature at the gas phase temperature measuring point by no more than 30 °C, precooling is completed.

NOTE: When testing multiple safety valves continuously, after replacing the safety valve, it is advisable to use helium to replace and purge the relevant parts of the test system, and then pre-cool the tested safety valve after passing the test.

5.7.3.2 Set pressure test

After precooling, release the forced opening state of the safety valve and conduct a set pressure test.

a) Adjust the medium pressure in the test vessel until the safety valve opens, stop pressurizing, and the safety valve closes automatically;

b) The set pressure test shall be carried out continuously for no less than 3 times. The safety valve shall be able to open and close smoothly, and there shall be no visible or audible leakage after closing.

5.7.3.3 Sealing performance test

The sealing performance test shall be carried out after the set pressure test is passed. The test steps are as follows:

a) Use 0.2 MPa helium to purge the inner cavity of the safety valve outlet to remove residual hydrogen medium;

b) Connect a leakage test instrument to the outlet side of the safety valve;

c) Maintain the pressure in the test vessel to conduct leakage rate detection;

d) A flowmeter and bubble counter can be used for leak detection. When using a flowmeter for measurement, the calibration medium of the flowmeter shall be the same as the test medium.

NOTE: When judging the results, consider the influence of temperature on the measurement results.

5.7.4 Treatment and testing after low-temperature test

5.7.4.1 After the low-temperature medium test, the inner cavity of the valve shall be purged with nitrogen. After the valve returns to ambient temperature, it shall be dried in a drying oven for 2 hours at a temperature of 50 °C~55 °C. Other drying methods that can be proven to be effective are not excluded.

5.7.4.2 Repeat the normal temperature set pressure, mechanical property, sealing performance test and fugitive emission test.

5.8 Anti-static test

Take a new, dry safety valve that has passed the pressure and sealing tests, and after performing no less than 5 opening and closing operation cycles, use a DC power supply not exceeding 12 V to measure the resistance between the valve body, opening and closing parts, valve stem and other components.

5.9 Cleanliness inspection

Before assembling parts, a cleanliness inspection shall be carried out according to the method specified in HG 20202.

5.10 Vibration and impact test

5.10.1 Vibration test

5.10.1.1 When the safety valve is subjected to an independent vibration test, the requirements of 6.6 of GB/T 22653-2008 may be referred to. The number of test pieces shall be consistent with the number of type tests. The specific test contents and methods shall refer to the provisions of Appendix A of GB/T 22653-2008.

5.10.1.2 When the safety valve is tested together with the vessel, the requirements and methods in A.2.1 of GB/T 34510-2017 may be referred to.

5.10.1.3 If the user has special requirements, the corresponding technical agreement shall be followed.

5.10.2 Impact test

5.10.2.1 When the safety valve is subjected to an independent impact (drop) test, in principle, the safety valve shall be installed on the testing machine in a similar manner and position to that of the safety valve when it is in normal operation. The impact (drop) test shall be carried out under pressure, which is the working pressure of the safety valve, and the safety valve shall be in a closed state.

5.10.2.2 When the safety valve is subjected to the impact (drop) test together with the vessel, the test may be carried out in accordance with the requirements and methods of A.2.1 of GB/T 34510-2017. If there are special requirements, the corresponding technical agreement shall be followed.

5.10.3 Tests after vibration and impact

After the vibration and impact tests, carry out the normal temperature operating performance, mechanical property, sealing performance and fugitive emission tests in

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