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Composite cylinders for breathing apparatus

呼吸器用复合气瓶

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Composite cylinders for breathing apparatus

1 Scope

This standard specifies the types and parameters, technical requirements, test methods and qualification standards, inspection rules and markings, packaging, transportation and storage requirements of fully wrapped carbon-fiber reinforced aluminum liner composite cylinders for breathing apparatus (hereinafter referred to as gas cylinders).

This standard applies to the design and manufacture of gas cylinders which have a nominal working pressure not greater than 30 MPa, a nominal volume of not greater than 12 L, an ambient temperature of use of -40 °C ~ 60 °C, is refillable of breathing gas.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) are applicable to this standard.

GB 191 Packaging - Pictorial marking for handling of goods

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

GB/T 230.1 Metallic materials - Rockwell hardness test - Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)

GB/T 231.1 Metallic materials - Brinell hardness test - Part 1: Test method

GB/T 1458 Test method for mechanical properties of ring of filament - Winding reinforced plastics

GB/T 3191 Extrusion rods and bars of aluminum and aluminum alloys

GB/T 3246.1 Inspection method for structure of wrought aluminum and aluminum alloy products - Part 2: Inspection method for microstructure

GB/T 3246.2 Inspection method for structure of wrought aluminum and aluminum alloy products - Part 2: Inspection method for macrostructure

GB/T 3362 Test methods for tensile properties of carbon-fiber multifilament

GB/T 3880.1 ~ 3880.3 Wrought aluminum and aluminum alloy plates，sheets and strips for general engineering

GB/T 3934 Specification of gauges for general purpose screw threads

GB/T 4437.1 Aluminum and aluminum alloy extruded tubes - Part 1: Seamless tubes

GB/T 4612 Plastics - Epoxy compounds - Determination of epoxy equivalent

GB/T 6519 Process for ultrasonic inspection of wrought aluminum alloy products

GB/T 7690.3 Reinforcements - Test method for yarns - Part 3: Determination of breaking force and breaking elongation for glass fiber

GB/T 9251 Methods for hydrostatic test of gas cylinders

GB/T 9252 Method for pressure cycling test of gas cylinders

GB/T 12137 Method for leakage test of gas cylinders

GB/T 13005 Terminology of gas cylinders

GB/T 15385 Method for hydraulic burst test of gas cylinder

GB/T 20975 (all parts) Methods for chemical analysis of aluminum and aluminum alloys

YS/T 67 Wrought aluminum and aluminum alloy columniform ingots

TSG R7002 Rules for type test of gas cylinder

3 Terms and definitions, symbols

3.1 Terms and definitions

The terms and definitions as established in GB/T 13005 as well as the following terms and definitions apply to this document.

The testing method shall comply with the provisions of GB/T 20975.

5.1.1.2 The material of the liner shall meet the requirements of the corresponding standards. The ingot shall be in accordance with YS/T 67; the extruded bar shall be in accordance with GB/T 3191; the plate shall be in accordance with GB/T 3880.1 ~ 3880.3; the tube shall be in accordance with GB/T 4437.1. The grain size of the ingot shall not be lower than the grade 2. The test method of grain size conforms to the provisions of GB/T 3246.2.

5.1.1.3 The liner material shall have the product quality certificate of the material manufacturer. It can be used only after passing the re-inspection by the gas cylinder manufacturer.

5.1.1.4 The chemical composition re-inspection shall be conducted according to the material's furnace number. The content of Pb and Bi may be confirmed according to the data of the product quality certificate.

5.1.1.5 The ingot shall be ultrasonically tested. The ultrasonic testing shall be carried out according to the ϕ2mm equivalent flat-bottomed hole. The testing method shall meet the requirements of GB/T 6519.

5.1.2 Liner design

5.1.2.1 Shoulder and bottom shall adopt convex structure.

5.1.2.2 The thickness of the shoulder and bottom shall meet the requirements of the hydraulic burst test and fatigue test of the gas cylinder.

5.1.2.3 In order to obtain a reasonable stress distribution, the shoulders and bottom shall use the gradually-changed thickness design; the cylinder and shoulders, cylinder and bottom shall be smoothly transitioned.

5.1.2.4 The designed wall thickness of the liner shall be verified by stress analysis.

5.1.2.5 The thickness of the bottleneck shall ensure that it will not deform when subjected to the additional external force of valve installation. The valve installation torque shall comply with the provisions of Appendix A.

5.1.2.6 The thread of the bottle opening shall be straight thread and penetrate through the opening. The thread length shall be not less than 6 pitches; the safety factor of shear stress under hydraulic test pressure shall be at least 10. The calculation method of the safety factor of the thread's shear stress is as shown in Appendix B.

5.1.3 Manufacturing of liner

5.1.3.1 It shall meet the requirements of design drawings and relevant technical

The strength of the material shall meet the minimum value of the performance requirements of the gas cylinder manufacturer.

The testing method shall comply with the provisions of GB/T 7690.3.

5.2.1.3 Resin matrix

It shall use epoxy resin or modified epoxy resin. The material shall meet the requirements of the corresponding standards and have a quality certificate. The material shall be suitable for the fiber wrapping process and meet the performance requirements of the gas cylinder manufacturer. The determination method of epoxy equivalent shall comply with the provisions of GB/T 4612.

5.2.2 Design of gas cylinder

5.2.2.1 The hydraulic test pressure shall be 5/3 times the nominal working pressure.

5.2.2.2 The minimum burst pressure shall be 3.4 times the nominal working pressure.

5.2.2.3 The design service life of the gas cylinder is 15 years.

5.2.2.4 Stress analysis shall use finite element technology and establish an appropriate model, to calculate the maximum stress in the liner and the wrapping layer and the stress distribution at each point under zero pressure, working pressure, test pressure and minimum burst pressure after auto-frettage. It shall consider the material nonlinearity of the liner, the material anisotropy of the wrapping layer, the geometric nonlinearity of the structure.

5.2.2.5 Stress distribution requirements

a) The compressive stress of the liner barrel part at zero pressure shall be between 60% and 95% of the measured yield strength of the liner;

b) The maximum tensile stress of the liner under working pressure shall not exceed 60% of the measured yield strength of the liner;

c) Under the designed burst pressure, the load carried by the glass fiber shall not exceed 15% of the total pressure load;

d) The maximum stress of carbon-fiber under working pressure shall not exceed 30% of the carbon-fiber stress under design burst pressure;

e) The maximum stress shall be located in the barrel part.

5.2.3 Manufacturing of gas cylinder

barrel's roundness measured on the same cross-section shall not exceed 2% of the average diameter of the cross-section;

d) The straightness of the barrel shall not exceed 0.3% of the length of the barrel.

6.1.2 Inner and outer surfaces

Visual inspection, the inner surface may be inspected by endoscope.

Qualification criteria:

a) There shall be no sharp surface indentations, obvious protrusions, overlaps, cracks and inclusions visible on the inner and outer surfaces; the transition between the neck and shoulders shall not have sharp changes or obvious wrinkles. It may use machining or polishing method to remove the surface defects. After the defects are removed, the corresponding locations shall be smooth and the wall thickness shall not be less than the design wall thickness.

b) The barrel and shoulders, barrel and bottom shall be smoothly transitioned.

6.1.3 Bottle thread

Thread gauges in accordance with GB/T 3934 shall be used for testing.

Qualification criteria:

a) The thread of the bottle mouth shall meet the design requirements; the thread shape, dimensions and manufacturing tolerances shall comply with the relevant requirements of GB/T 192, GB/T 196, GB/T 197.

b) The thread pitch, tooth profile angle, tooth crest, tooth bottom, surface roughness shall meet the requirements of the standard.

c) The effective number of pitches of the thread shall comply with the standards.

6.1.4 Hardness test

The test method shall comply with the provisions of GB/T 230.1 or GB/T 231.1.

Qualification criteria: The hardness value shall not exceed the range specified by the gas cylinder manufacturer.

6.1.5 Tensile test

Cut symmetrically two specimens in the axial direction of the liner barrel. The gauge length of the specimen is not less than 24 times the design wall thickness

Qualification criteria: Under the pressure of the hydrostatic test, the pressure shall be maintained for 1 min. There shall be no leakage or obvious deformation of the cylinder, meanwhile the elastic expansion under the hydraulic test pressure shall not exceed the rejection elastic expansion (REE) of the gas cylinder.

6.2.4 Air tightness test

It shall perform the air tightness test after the hydrostatic test. The test pressure shall be the nominal working pressure; the test method shall comply with the provisions of GB/T 12137.

Qualification criteria: Under the test pressure, hold the pressure for 1 min; there shall be no leakage.

The air tightness test is limited only to the gas cylinders that exit-factory with a cylinder valve.

6.2.5 Hydraulic pressure burst test

Increase pressure at a constant speed to the minimum burst pressure. Hold the pressure for at least 5 s. Then increase pressure until burst. The pressure increase rate does not exceed 1.37 MPa per second. The test method shall comply with the provisions of GB/T 15385.

Qualification criteria: The measured burst pressure is not lower than the minimum burst pressure. The initial position of burst shall be in the cylinder's barrel.

6.2.6 Fatigue test

Under normal temperature conditions, follow the requirements of GB/T 9252 to perform fatigue test. The pressure cycle frequency shall not exceed 10 times per minute. The pressure shall be held for not less than 1.2 s during the period of 90% ~ 100% of the maximum pressure.

The test steps are as follows:

a) The gas cylinder shall be subjected to a pressure cycle of at least 10000 times from less than 10% of the nominal working pressure to the nominal working pressure;

b) Then, perform a pressure cycle for at least 30 times from near zero pressure to hydrostatic test pressure;

c) After completing the above test, perform the hydraulic pressure blast test according to 6.2.5.

cycle test for at least 20 times; it is held at each temperature for at least 10 min;

c) After completing the above test, perform the hydraulic burst test according to 6.2.5.

Qualification criteria: During the pressure cycle test, the gas cylinder shall not show any visible damage, deformation, or leakage. The remaining burst pressure shall not be less than 90% of the minimum burst pressure.

6.2.9 Drop test

Drop the unfilled gas cylinder with valve freely from a height of 3 m to the concrete floor according to the following requirements.

The test steps are as follows:

a) The gas cylinder falls vertically and the bottom of the cylinder touches the ground;

b) The gas cylinder falls horizontally and the side wall of the cylinder touches the ground;

c) The gas cylinder falls horizontally onto the edge of a 38 mm × 4.8 mm angle steel; the two sides of the angle steel are placed at an angle of 45° to the ground; the impact point is near the middle of the side wall of the gas cylinder;

d) After the drop test, the gas cylinder shall be pressure cycled at least 1000 times from less than 10% of the nominal working pressure to the nominal working pressure, the cycle frequency shall not exceed 10 times per minute; the pressure shall be held for not less than 1.2 s during 90% ~ 100% of the maximum cycle pressure. The pressure cycle's test method shall meet the requirements of GB/T 9252;

e) After completing the above test, perform the hydraulic pressure burst test according to 6.2.5.

Qualification criteria: There shall be no visible leaks in the gas cylinder during the pressure cycle test. The remaining burst pressure shall not be less than 90% of the minimum burst pressure.

6.2.10 Shooting test

The test steps are as follows:

a) Fill the gas cylinder with air or nitrogen to the nominal working pressure;

7 Inspection rules

7.1 Exit-factory inspection

7.1.1 Inspection one-by-one

The gas cylinders shall be inspected one by one according to the items specified in Table 3.

7.1.2 Inspection by batch

7.1.2.1 Gas cylinders shall be subject to batch inspection according to the items specified in Table 3.

7.1.2.2 Sampling

7.1.2.2.1 Liner

Randomly take one from each batch of liners for tensile test and metallographic test.

If an item fails during batch inspection, it shall be handled according to the following requirements:

a) If the failure is due to abnormal test operation or measurement error, it shall carry out the test of the same quantity of specimens. If the retest result is qualified, the first test is invalid;

b) If it is confirmed that the disqualification is caused by heat treatment, the batch of liners can be re-heat-treated, but the number of heat treatments shall not be more than two (excluding the number of simple artificial aging treatments). This batch of liners after heat treatment again shall be used as a new batch for batch inspection;

c) If it is confirmed that the disqualification is caused by other reasons, the entire batch of liners will be rejected.

7.1.2.2.2 Gas cylinder

a) Randomly take 1 gas cylinder from each batch to perform the fatigue test;

b) Randomly take 1 gas cylinder from each batch to perform the hydraulic burst test. The gas cylinder used for fatigue test can be used for burst test.

If a certain item fails during batch inspection, it may randomly take another 5 gas cylinders for the test. If all 5 gas cylinders pass the test, then this batch of gas cylinders is qualified. If one of them fails the test, the entire batch of gas

h) Year and month of cylinder manufacturing;

i) Design service life of gas cylinder;

j) Supervision and inspection marking;

k) Manufacturing unit's license number;

l) Product standards;

m) The rejection elastic expansion (REE) of the hydraulic test.

8.2 Packaging

8.2.1 When the gas cylinder is exit-factory without a valve, the opening of the cylinder shall be sealed by reliable measures to prevent contamination.

8.2.2 The gas cylinder shall be properly packed to prevent damage during transportation.

8.2.3 The packaging and transportation marks shall comply with the relevant requirements of GB 191.

8.3 Transport

8.3.1 The transport of gas cylinders shall comply with the relevant requirements of the transportation department.

8.3.2 During the transportation and loading/unloading process, it shall prevent the accessories from being collided, wet, or damaged, especially to prevent scratches on the wrapping layer.

8.4 Storage

Gas cylinders shall not be stored in environments exposed to sunlight and high temperatures, humidity, corrosive media.

9 Product certificate and batch inspection quality certificate

9.1 Product certificate

9.1.1 Each certified gas cylinder shall be accompanied by a product certificate and instruction manual.

9.1.2 The product certificate shall include the following:

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