GB

NATIONAL STANDARD

OF THE PEOPLE'S REPUBLIC OF CHINA

ICS 23.020.30

J 74

GB 11640-2011

Replacing GB/T 11640-2001

Seamless aluminum alloy gas cylinders

Issued on: December 30, 2011 **Implemented on: December 01, 2012**

Issued by: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China;

Standardization Administration of the People's Republic of China.

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Foreword

All technical contents of this part of GB 21551 are mandatory.

This standard was drafted in accordance with the rules given in GB/T 1.1-2009 “Directives for standardization – Part 1: Rules for the structure and drafting of standards”.

This standard replaces GB/T 11640-2001 “Seamless aluminum alloy gas cylinders”.

As compared with GB/T 11640-2001, the main changes of this standard are as follows:

- In the provisions on the scope, DELETE the lower limit of nominal working pressure and the lower limit of nominal capacity (SEE Chapter 1 of 2001 version);
- In the technical requirements, DELETE the 6351 aluminum alloy material (SEE 5.1.1 of 2001 version);
- ADD the requirements for lead and bismuth elements in aluminum alloys (SEE 5.1.1 and 5.1.6);
- MODIFY the requirement for the inner bottom radius (SEE 5.2.2.4);
- MODIFY the requirements for the collar design (SEE 5.2.5);
- MODIFY the requirements for the measured burst pressure (SEE 6.12);
- ADD Appendix B (normative) Anti-constant load crack test (SEE 5.1.2);
- ADD Appendix D (informative) Calculation method of thread shear stress safety factor (SEE 5.2.3);
- ADD Appendix F (informative) Description and determination of aluminum cylinder manufacture defects (SEE 6.2);
- ADD Appendix G (normative) Flattening test method (SEE 6.9).

This standard was proposed by the National Gas Cylinder Standardization Technical Committee (SAC/TC 31).

The drafting organizations of this standard: Shenyang Gas Cylinder Safety Technology Co., Ltd., Heilongjiang Huaan Machinery Co., Ltd., Shanghai High Pressure Containers Co., Ltd.

The main drafters of this standard: Jiang Jiang, Liu Shouzheng, Deng Hong, Wang Shuxian, Chen Weiming.

Seamless aluminum alloy gas cylinders

1 Scope

This standard specifies the type and parameters, technical requirements, test methods and qualification criteria, inspection rules and marking, coating, packaging, transportation and storage requirements of seamless aluminum alloy gas cylinders (hereinafter referred to as aluminum cylinders).

This standard applies to the design and manufacture of aluminum cylinders which have a nominal working pressure of not more than 30 MPa, the nominal volume of not more than 50 L, the use temperature is -40 °C ~ 60 °C, AND can be re-filled with permanent gas or liquefied 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/T 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 228.1-2010 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 232 Metallic materials – Bend test

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

GB/T 3246.1 Inspection method for structure of wrought aluminum and aluminum alloy products – Part 1: 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 3880.1 ~ 3880.3 Wrought aluminum and aluminum alloy plates, sheets and strips for general engineering

3.2 symbols

The following symbols apply to this document.

A: elongation at fracture, %;

C: Thickness from bottom grounding point to the inner wall, mm;

d: Circumferential tear length of rupture opening, mm;

D_0: Nominal outer diameter of cylinder, mm;

D_f: Indenter diameter of bending test, mm;

H: External height of spherical part (cylinder shoulder and bottom), mm;

L: Length of cylinder part, mm;

n: The ratio of the indenter diameter to the average thickness of sample;

p_h: Pressure of hydraulic test, MPa;

p_b: Pressure of hydraulic blasting test, MPa;

r: Inner bottom corner radius, mm;

r_1: Inner bottom radius, mm;

R: Indenter cutting edge radius of flattening test, mm;

R_m: Measured tensile strength, MPa;

$R_{p0.2}$: Specified non-proportional extension strength, MPa;

S: Designed wall thickness of cylinder, mm;

S_{a0}: Measured average wall thickness of cylinder, mm;

S_1: Cylinder bottom center wall thickness, mm;

T: Indenter spacing of flattening test, mm.

4 Type and parameters

4.1 Type

The typical structure of aluminum cylinders shall generally comply with the type as shown in Figure 1.

5.1.5 The cylinder material must have the product quality certificate from the material manufacturing unit, AND it can only be used after passing the re-testing by the aluminum cylinder manufacturing unit.

5.1.6 The chemical composition shall be re-tested in accordance with the material furnace number. The Pb and Bi contents can be confirmed in accordance with the data of the product quality certificate.

5.1.7 The casting ingot shall be subjected to ultrasonic test in accordance with Φ2 mm equivalent flat bottom hole, AND the inspection method shall comply with the provisions of GB/T 6519.

5.2 Design

5.2.1 Wall thickness design

5.2.1.1 In the wall thickness calculation for cylinder body design, it shall use the specified non-proportional extension strength guaranteed value after material heat treatment, AND such value shall not exceed 85% of the tensile strength guaranteed value.

5.2.1.2 It shall be based on pressure of the hydraulic pressure test, AND such pressure is 1.5 times the nominal working pressure.

5.2.1.3 The design wall thickness of the cylinder shall not be less than the calculated values of the formula (1) and formula (2), AND shall not be less than 1.5 mm.

$$S=\frac{p_h \cdot D_0}{\frac{2R_{p0.2}}{1.3}+p_h} \qquad \cdots\cdots(1)$$

$$S \geqslant \frac{D_0}{100}+1 \qquad \cdots\cdots(2)$$

5.2.2 End design

5.2.2.1 The thickness and shape of the bottom and shoulders shall comply with the requirements of hydraulic rupture tests and fatigue tests.

5.2.2.2 In order to make the stress distribution evenly, the wall thickness from the cylinder body to the shoulder and from the cylinder body to the bottom shall be gradually increased, AND the typical structure of the shoulder and the bottom is as shown in Figure 2.

5.2.2.3 The thickness of any part of the bottom shall not be less than the design wall thickness of the cylinder.

5.2.2.4 The inner bottom radius (r_1) shall not be more than 1.2 times the inner diameter of the cylinder, AND the inner bottom corner radius (r) shall not be less than 10% of the inner diameter of the cylinder.

6 Test methods and qualification criteria

6.1 Wall thickness

It shall use the ultrasonic thickness gauge OR special measurement tools for testing.

Qualification criteria: the wall thickness of the cylinder at any point shall not be less than the designed wall thickness.

6.2 Inner and outer surfaces

PERFORM visual inspection, AND the inner surface may be checked by the endoscope or endoscopic lamp.

Qualification criteria: the inner and outer surface shall not have visible cracks, pits, sandwiches, scratches, or other local defects visible to naked eyes which may affect the strength. It may use the grinding method to remove the surface defects, the part from which the defect is removed shall be smoothly transited, the wall thickness shall be not less than the design wall thickness, AND the description and judgement of the aluminum cylinder manufacturing defects are as shown in Appendix F.

6.3 Manufacturing tolerances

It shall use standard or special tools to perform testing.

Qualification criteria:

a) The roundness tolerance of the cylinder on the same section shall not exceed 2% of the average outer diameter of the section;

b) The straightness tolerance of the cylinder shall not exceed 0.2% of the length of the cylinder;

c) The outer diameter tolerance of the cylinder shall comply with the provisions of Table 1.

6.4 Cylinder opening thread

The taper thread shall be tested using the thread gauge complying with the provisions of GB/T 8336. The straight thread shall be tested using the thread gauge complying with the provisions of GB/T 3934.

Qualification criteria:

a) The type, size and tolerance of thread shall comply with GB 8335 or the relevant standards;

b) The thread pitch, tooth angle, crest, tooth bottom and surface roughness shall comply with the relevant standards;

7.1.1 Inspection one-by-one

Aluminum cylinders shall be tested one-by-one in accordance with the inspection items as specified in Table 5.

7.1.2 Batch inspection

7.1.2.1 Aluminum cylinders shall be subject to batch inspection in accordance with the inspection items as specified in Table 5.

7.1.2.2 Sampling

a) One sample is randomly taken from each batch of aluminum cylinder to perform tensile test, metallographic test, and bending test in accordance with clause 6.6, 6.7 and 6.8, respectively;

b) One sample is randomly taken from each batch of aluminum cylinder to perform flattening test (either bending test or flattening test) in accordance with clause 6.9;

c) One sample is randomly taken from each batch of aluminum cylinder to perform hydraulic rupture test in accordance with clause 6.12.

7.1.2.3 Re-inspection

If the test results are not qualified, FOLLOW the requirements below to process it:

a) If the test results are disqualified due to equipment abnormalities or measurement errors, it shall perform re-testing; AND if possible, the secondary sampling test is performed from the same aluminum cylinder; AND if the second test is qualified, the first test may be ignored;

b) If the test results do not comply with the requirements due to heat treatment, it may perform heat treatment again, AND the aluminum cylinders after re-heat treatment shall be subjected to batch inspection. However, the number of heat treatment shall be not more than 2 times (excluding the number of pure artificial aging treatment).

If one item of the batch inspection of the aluminum cylinder after heat treatment again is disqualified, the entire batch of aluminum cylinders will be discarded.

7.2 Type test

7.2.1 Newly designed aluminum cylinders shall be tested in accordance with the items specified in Table 5.

7.2.2 Complying with any one of the following conditions is deemed as new design:

8.1.1.3 The stamp for the volume and weight (excluding accessories) shall be retained with three significant figures, AND the fourth digit is rounded off for volume and carried for cylinder weight.

8.1.2 Color marking

The paint color, words form, words color, and color ring of the gas filling aluminum cylinder shall comply with the relevant provisions of GB 7144.

8.2 Packaging

8.2.1 When the aluminum cylinder is exit-factory, if the valve is not equipped, it may take effective measures at the cylinder opening to seal it to avoid contamination.

8.2.2 Aluminum cylinders shall be properly packed to prevent damage during transportation.

8.2.3 Packaging and transport markings shall comply with the relevant provisions of GB/T 191.

8.3 Transportation

The transport of aluminum cylinders shall comply with the relevant provisions of the transport sector.

8.4 Storage

Aluminum cylinders shall not be stored in an environment having sun exposure and high temperature, humid and corrosive media.

9 Product certificate and batch inspection quality certificate

9.1 Product certificate

9.1.1 Each aluminum cylinder passing inspection shall be accompanied by product certificate and instruction manual.

9.1.2 The certificate shall include the following:

a) Aluminum cylinder model;

b) Aluminum cylinder number;

c) Measured volume;

d) Measured weight;

e) Filling media;

The solution consisted of 57 g/L sodium chloride and 3 g/L hydrogen peroxide.

A.2.4.2 Preparation of corrosion solution

A.2.4.2.1 Reagent

A.2.4.2.1.1 Sodium chloride NaCl crystals: analytical pure.

A.2.4.2.1.2 Hydrogen peroxide H_2O_2, (100 ~ 110) volume.

A.2.4.2.1.3 Potassium permanganate $KMnO_4$: analytical pure.

A.2.4.2.1.4 Sulfuric acid H_2SO_4: analytical pure, concentration of 1.83 g/mL.

A.2.4.2.1.5 Deionized or distilled water.

A.2.4.2.2 Calibration of hydrogen peroxide

As the hydrogen peroxide is not stable, it shall be calibrated of titration before use. PIPETTE 10 mL of hydrogen peroxide (A.2.4.2.1.2) in a graduated flask; USE deionized water or distilled water to dilute it to 1000 mL, to obtain the hydrogen peroxide solution C. PIPETTE the following solution into a triangular cup: 10 mL of hydrogen peroxide solution C; about 2 mL of sulfuric acid (A.2.4.2.1.4) solution.

USE the potassium permanganate solution (A.2.4.2.1.3) having a concentration of 1.859 g/L; AND the potassium permanganate works as the role of indicator.

A.2.4.2.3 Titration instructions

In the sulfuric acid solution, the chemical reaction formula of potassium permanganate and hydrogen peroxide is:

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

As shown from the above reaction formula, 316 g of $KMnO_4$ need 170 g of H_2O_2 for reaction.

Therefore, 1 g of pure hydrogen peroxide reacts with 1.859 g of potassium permanganate, i.e., 1.859 g/L potassium permanganate solution (saturated) requires equivalent volume of 1 g/L hydrogen peroxide solution for reaction. Since the hydrogen peroxide used is diluted 100 times in the titration process, the 10 mL of reagent represents only 0.1 mL of the initial hydrogen peroxide.

The millimeter of potassium permanganate used for titration is multiplied by 10 to obtain the titer T (in g/L) of the initial hydrogen peroxide.

A.2.4.2.4 Preparation of corrosive solutions

Method for preparing 10 L solution: DISSOLVE 570 g of NaCl (A.2.4.2.1.1) in deionized water or distilled water (A.2.4.2.1.5) to obtain the solution having a total volume of about 9 L; ADD the required amount of hydrogen peroxide; MIX it and ADD deionized water or distilled water to 10 L. The amount of hydrogen peroxide added to the solution is calculated as follows:

$$(1000 \times 30) / T \text{ mL}$$

Where:

30 – Amount of hydrogen peroxide consumed by 10 L of corrosion solution;

T - Hydrogen peroxide titer, that is, the content of the hydrogen peroxide per each liter of corrosion solution.

A.2.4.3 Corrosion process

A.2.4.3.1 PLACE the corrosion solution in a crystal pan which is immersed in the water tank (or as large a beaker as possible); USE a magnetic stirrer to stir the water tank; USE the contact thermometer to control the temperature. The sample may be suspended in the corrosion solution by means of an aluminum wire (or other inert material), or otherwise MAKE the sample edge in direct contact with the container and PLACE it in the corrosion solution, AND the latter method is better. The corrosion time is 6 h AND the temperature is controlled at 30 °C ± 1 °C. PAY special attention to ensuring that there is at least 10 mL of solution per square centimeter at the sample surface. After corrosion, USE water to rinse the sample; then IMMERSE it into the 50% diluted nitric acid for about 30 seconds; USE water to rinse it; USE compressed air to dry it.

A.2.4.3.2 If the samples are of the same type of alloys AND are not in contact with each other, it may corrode several samples at the same time, BUT it shall ensure the minimum amount of the required reagent per unit surface of the sample.

A.2.5 Preparation before sample inspection

A.2.5.1 Devices

A.2.5.1.1 Molds

Outer diameter: 40 mm;

Height: 27 mm;

Wall thickness: 2.5 mm.

A.2.5.1.2 Mold material is an epoxy curing agent or the like.

A.2.5.2 Method

A.3.5 Test results

If the ring under force is free from crack by inspection of naked eyes or low-power magnification (× 10 times to × 30 times) after 30 days of test, then this alloy can be used to produce gas cylinder.

A.3.6 Metallographic examination

A.3.6.1 If there is a suspected crack (for example, a rust line), the metallographic test shall be made, that is, an observation plane is taken perpendicular to the axial direction of the ring from the suspicious area for inspection to eliminate the suspicious points. The surface corrosion penetration depth and shape (intergranular or trans-granular) on the tensioned ring and the compressed ring are compared.

A.3.6.2 If the corrosion of each face of the test ring is similar, the alloy may be considered to be qualified. However, if the intergranular crack of the tensioned surface of the test ring is more obvious than that of the compressed surface, this ring does not pass this test.

A.3.7 Test report

The test report includes the following:

a) Material designation;

b) Chemical composition of materials;

c) Measured chemical composition of materials;

d) Measured mechanical performance and heat treatment guarantee value of material;

e) Test results.

Appendix B

(Normative)

Anti-constant load crack test

B.1 Overview

This Appendix specifies the methods and criteria for the determination of anti-constant load cracking tests on aluminum cylinder materials.

B.2 Terms and symbols

The terms and symbols as established in GB/T 15970.6-2007 AND the following terms and symbols apply to this Appendix.

SLC: Constant load crack;

K_{IAPP}: Applied elastic stress strength, MPa • $m^{1/2}$;

V: Crack opening displacement (CMOD), mm, which refers to the composition of the mode 1 (also known as opening mode) that the crack displacement is caused by elastic and plastic deformation, AND is measured from the cracking plane having maximum unit load elastic displacement;

E: Elastic modulus, MPa;

R_{eSLC}: The average value of the yield stress of two samples taken from the test aluminum cylinder which represents the SLC sample location, MPa;

a: Fatigue crack length, mm.

B.3 Brief description of test

USE the constant load or constant displacement method to apply the load to the fatigue pre-crack sample to the specified stress intensity K_{IAPP}, AND the sample is maintained for the load state of this stress strength at the specified time and temperature. After the test, CHECK the sample to determine the growth of the original fatigue crack.

If the crack growth of the sample is less than or equal to the specified size, it can be considered that the alloy is suitable for the manufacture of cylinders.

The gas cylinders having a nominal thickness of cylinder neck and cylinder shoulder ≤ 7 mm do not need to be subjected to the anti-constant load crack test. It shall follow the Figure B.1 to measure the wall thickness of the cylinder neck and shoulder.

B.6 Test procedure

B.6.1 It shall comply with all requirements of Chapter 7 of GB/T 15970.6-2007 (except for 7.2, 7.3, 7.4, 7.5.1, 7.5.2, 7.5.4, 7.5.5).

B.6.2 Stress strength of fatigue pre-crack sample:

$$K_{IAPP} = 0.056\ R_{eSLC}$$

It shall use appropriate constant displacement method or constant load method to apply load to the sample.

B.6.3 It shall use the non-monitoring load method or a monitoring load method to determine the sample which is loaded by the constant displacement method, AND it shall comply with the following requirements:

a) Through the non-monitoring load method

1) RECORD the crack opening displacement (CMOD) before unloading at the end of the test;

2) UNLOAD the sample;

3) USE a suitable load measurement device to reload the sample, BUT the load value shall not exceed the measured CMOD value. RECORD the load value and USE this value to calculate the K_{IAPP}. The calculated K_{IAPP} value shall be equal to or greater than the K_{IAPP} value calculated in B.6.2.

b) Through the monitoring load method

1) APPLY the final load at the end of the test to the K_{IAPP} calculation;

2) The calculated K_{IAPP} value shall be greater than or equal to the K_{IAPP} value calculated in B.6.2.

B.6.4 Test using the constant displacement method

a) If the CTS sample is tested at constant displacement load, USE the following equation to determine the V value:

$$V = \frac{K_{IAPP}(\sqrt{W})}{(0.032)(E)(f(x))(\sqrt{B/B_n})}$$

$$f(x) = \frac{2.24(1.72 - 0.9x + x^2)(\sqrt{1-x})}{(9.85 - 0.17x + 11x^2)}$$

$$x = \frac{a}{w}$$

b) If the C-shaped sample is tested under constant displacement load, USE the following equation to determine the V value:

$$a, B, B_n, (W-a) \geqslant 1.27\left(\frac{K_{IAPP}}{R_{eSLC}}\right)^2 \times 1\ 000$$

B.6.8 For additional tests in B.7.4, REPEAT the entire test procedure. PLACE it at room temperature for 180 days at the constant load conditions as specified in B.6.5.

B.7 crack growth inspection

B.7.1 UNLOAD the sample after the specified test time; MAKE the sample fatigue at the maximum stress strength of not exceeding 0.6 K_{IAPP}, until the crack increases by at least 1 mm. SMASH the sample after fatigue.

B.7.2 USE the scanning electron microscopy (SEM) to measure the crack distance before and after fatigue. MAKE measurement perpendicular to the cracks before and after the fatigue at the positions of 25%B, 50%B, and 75%B. CALCULATRE the average value of these three values.

B.7.3 If the average distance between the two fatigue cracks does not exceed 0.16 mm, the sample passes the test. If all the samples pass the test, the material complies with the requirements.

B.7.4 If the average value as measured in B.7.3 exceeds 0.16 mm, it shall repeat the test in accordance with B.6.8; after the test, PROCEED in accordance with B.7.1 and B.7.2. If the average distance between the two fatigue cracks does not exceed 0.3 mm, then the material complies with the requirements.

B.8 Quality assessment of cylinder thickness

If the effectiveness requirements of B.6.7 cannot be met, if the sample complies with the other requirements of this test method, it is considered that the sampling material of the aluminum cylinder is appropriate in the maximum thickness range. If the sample complies with the effectiveness requirements of B.6.7 and the other requirements of this test method, the material is suitable for all thicknesses.

B.9 Report

It shall make record and report in accordance with the information as specified in Chapter 8 (except for 8.5) of GB/T 15970.6-2007. The report shall state whether it complies with the effectiveness criteria, AND include the SEM micrographs in B.7.2. The report shall be kept permanently.

Appendix D

(Informative)

Calculation method of stress safety factor for thread shear stress

D.1 Overview

This Appendix specifies the calculation method for the shear stress safety factor of the aluminum cylinder opening thread.

D.2 Calculation method of stress safety factor for thread shear stress

D.2.1 Calculation formula

The shear stress safety factor of the thread is the ratio of the shear strength (τ_m) of the material to the shear stress of the thread. Aluminum alloy material shear strength (τ_m) is taken as 0.6 times the tensile strength of the material. The thread shear stress formula is as follows:

$$\tau_n = \frac{F_w}{zA_n} \qquad \text{(D.1)}$$

$$\tau_w = \frac{F_w}{zA_w} \qquad \text{(D.2)}$$

Where:

τ_n - Shear stress of internal thread, in Megapascal (MPa);

Fw - Maximum axial external load, in Newton (N);

z - Number of threads engaged;

A_n – Shear area of internal thread teeth, in square millimeters (mm^2);

τ_w - Shear stress of external thread, in Megapascal (MPa);

Aw - Shear area of the external thread teeth, in square millimeters (mm^2).

Maximum axial external load:

$$F_w = P_{internal} A \qquad \text{(D.3)}$$

Where:

$P_{internal}$ - Cylinder internal pressure, in Megapascal (MPa);

A - Cylinder opening internal thread hole pressure area (take the large diameter of the internal thread), in square millimeter (mm^2).

Appendix F

(Informative)

Description and judgment of defects in aluminum cylinder manufacturing

F.1 Overview

This Appendix specifies the description and determination criteria of the defects in the manufacture of aluminum cylinders. It is applicable to the inspection and assessment of the inner and outer surface defects of aluminum cylinders.

This Appendix provides a means of resolving common defects when inspectors perform internal and external surface inspections.

F.2 General requirements

F.2.1 Internal and external surface visual inspection

Aluminum cylinder internal and external surface shall be clean, dry, and free from oxide, corrosion or rust, AND it shall use appropriate method before inspection to clean the internal surface and the external surface.

It shall use the illumination source having sufficient intensity.

After the aluminum cylinder has been machined, it shall use an endoscope or other suitable device to check the inside of the cylinder neck.

F.2.2 Local defects can be removed by grinding, AND it shall make wall thickness inspection again after grinding.

F.3 Manufacturing defects

The common internal and external surface defects of aluminum cylinders and their descriptions are as shown in Table F.1.

The judgment of the defects that can be repaired in Table F.1 is determined in accordance with the experience, AND it is applicable to the aluminum cylinders of all sizes and types as well as the conditions of use. When the user requirement is higher than the requirements in Table F.1, the user and the manufacturing unit will make decision otherwise through negotiation.

Table F.1 -- Common manufacturing defects and determination criteria

No.	Defects	Descriptions	Determination criteria	Determination conclusions
1	Swelling	Visible surface swelling	All aluminium cylinders having such defects	Discarded
2	Depression	Visible depression	The depression depth exceeds 2%	Discarded

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