



Guideline No.:B-07(202204)

# **B-07**

# **HYDROGRN CYLINDERS**

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## **Foreword**

China Classification Society (hereinafter referred to as CCS) Product Inspection and Testing Guideline (hereinafter referred to as this Guideline) contains the technical requirements, inspection and testing criteria related to classification and statutory survey of marine products to be applied for CCS approval/inspection.

This Guideline frees the users to adopt other test methods and requirements which are equivalent to or are stricter than this Guideline.

This Guideline is published and updated by CCS, and is released at <http://www.ccs.org.cn>. Your comments or suggestions are welcomed and may be sent to our email addressed [service@ccs.org.cn](mailto:service@ccs.org.cn).

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## HYDROGRN CYLINDERS

### 1 Application

1.1 This Guideline is applicable to the works approval and subsequent unit/batch inspection of refillable all-composite wrapped cylinders with aluminium liners for storing compressed hydrogen. Such cylinders are designed and manufactured with a nominal working pressure not exceeding 70 MPa, a nominal water capacity not more than 450 L, a service temperature ranging from -40°C to 85°C, and are fixed on ships and offshore installations for use as fuel tanks. The cylinders are classified into Type A and Type B. Type A cylinders refer to those with a nominal working pressure of  $\leq 35$  MPa and a nominal water capacity of  $\leq 450$  L; Type B cylinders refer to those with a nominal working pressure of  $> 35$  MPa and a nominal water capacity of  $\leq 230$  L.

1.2 The inspection of the hydrogen cylinders referred to in this guideline during and after the construction of ships and offshore installations shall comply with the requirements of international conventions, national competent authorities and other relevant provisions of the society.

1.3 The hydrogen cylinders referred to in this guideline are applicable to steel ships with a length of 20 m and above. The hydrogen cylinders installed on floating offshore units may be inspected with reference to this guideline.

1.4 This guideline is in principle only applicable to the works approval and subsequent unit/batch inspection of the hydrogen cylinder bodies, and does not cover the head valves.

### 2 Normative references

2.1 CCS Guidelines for Fuel Cell Power Generating Installations for Ship Application

2.2 TSG 23 Technical Regulation for the Safety of Gas Cylinders

2.3 GB/T 35544 Carbon Fiber Fully Wrapped Cylinders with Aluminium Liners for On-Board Compressed Hydrogen

2.4 GB/T 3362 Test Method for Tensile Properties of Carbon Fiber Multifilament Yarns

### 3 Terms and definitions

3.1 Unless otherwise explicitly specified in this guideline, the relevant definitions in CCS guidelines for Fuel Cell Power Generating Installations for Ship Application shall apply to this guideline.

3.2 Aluminium liner: A seamless aluminium alloy vessel with carbon fiber reinforced layers wrapped on its outer surface, used for gas sealing and capable of withstanding part or no pressure loads.

3.3 Full wrapping: A wrapping method in which carbon fibers impregnated with resin matrix are continuously wrapped on the aluminium liner in helical and hoop directions to reinforce the cylinder in both hoop and axial directions.

3.4 Fully wrapped cylinder: A cylinder formed by fully wrapping carbon fiber reinforced layers on the outer surface of an aluminium liner and curing by heating.

3.5 Autofrettage: A pressurization process in which internal pressure is applied to the cylinder to cause plastic deformation of the aluminium liner, so that the aluminium liner bears compressive stress and the carbon fibers bear tensile stress when the cylinder is at zero pressure.

3.6 Autofrettage pressure: The maximum pressure (gauge pressure) applied inside the cylinder during autofrettage.

3.7 Cylinder batch quantity: The specified quantity of cylinders manufactured with the same design conditions, aluminium liners of identical structural dimensions, composite materials of the same specification, and subjected to wrapping and curing by the same process.

3.8 Aluminium liner batch quantity: The specified quantity of aluminium liners manufactured with the same design conditions, identical nominal outer diameter and design wall thickness, steel of the same heat/furnace number, the same manufacturing process, and heat treatment in accordance with the same heat treatment specifications and process parameters.

3.9 Design service life: The allowable service life of a cylinder under the specified service conditions.

3.10 Fiber stress ratio: The ratio of the carbon fiber stress of a cylinder at the minimum burst pressure to that at the nominal working pressure.

3.11 Limit elastic expansion: The allowable upper limit of the elastic expansion of cylinders of each specification and model, specified by the manufacturer during the design finalization stage of the cylinder, in millilitres. This value shall not exceed 1.1 times the average elastic expansion of cylinders of the same specification and model in the design finalization batch at the hydraulic test pressure.

#### **4 Drawings and documentation**

4.1 The following drawings and documentation shall be submitted to CCS for approval:

- (1) Design drawings and documentation of hydrogen cylinders, which shall reflect the product's structural form, main dimensions, material and physicochemical performance indicators (including aluminium liner, carbon fiber, glass fiber, epoxy resin), manufacturing and heat treatment methods, fiber wrapping method, resin heating and curing temperature and method, nominal working pressure, allowable pressure, autofrettage pressure, hydraulic test pressure, minimum burst pressure, fiber stress ratio, nominal water capacity, nominal outer diameter of aluminium liner, design temperature, design cycle number, cylinder type and model, and other special technical requirements (such as galvanic corrosion protection layer, outer surface protection layer of cylinder, etc.).
- (2) Design calculation documents of hydrogen cylinders, including the calculation of design wall thickness, volume, weight, minimum burst pressure of the aluminium liner and wrapping layers, and strength calculation of the cylinder bottom, cylinder mouth and wrapping layers, etc.
- (3) Stress analysis report, which shall calculate the stress and strain in the aluminium liner and wrapping layers under autofrettage pressure, nominal working pressure, allowable pressure, hydraulic test pressure and minimum burst pressure by using the finite element analysis method.

(4) Type test plan.

4.2 The following documentation shall be submitted for review when applying for the initial works approval:

- (1) Factory profile: factory name, address, production history, types and specifications of existing products, types, specifications and delivery conditions of the products for which approval is applied, and information on other certification and qualification certificates obtained, etc.
- (2) Quality system documents and other management documents, in which the organizational structure of the quality system and product quality control points shall be clearly defined.
- (3) List of main production equipment: liner forming equipment, wrapping equipment, autofrettage equipment, resin heating and curing equipment, type and dimensions of heat treatment furnace, temperature control and recording method, and arrangement of temperature measuring points.
- (4) List of main measuring/testing equipment: list of equipment for chemical composition analysis, mechanical properties test, metallographic test, non-destructive testing (NDT), hydraulic test, pressure cycling test, hydrogen cycling test, environmental test, etc. (including product name, model, manufacturer, statutory inspection organization, and valid period of verification/calibration).
- (5) Process documents:
  - ① Production process flow chart (with quality control points indicated).
  - ② Operation instructions for each process in the production process flow chart, including main processes such as forming, liner surface treatment, heat treatment, NDT, wrapping, autofrettage, heating and curing, etc.
- (6) Qualification certificates of testing and inspection personnel.
- (7) Qualifications of test locations and laboratories (if the test is subcontracted, the qualifications of the subcontractor and the subcontract agreement shall be specified).
- (8) List of suppliers of materials and main components.
- (9) Product description and quality certificate (sample).

5 Technical requirements for materials of hydrogen cylinder bodies

5.1 The materials used for manufacturing cylinders shall be accompanied by the original quality certificate provided by the material manufacturer, or a copy of the quality certificate with the official seal of the material dealer and the signature (seal) of the handler.

5.2 Aluminium liner

- (1) The aluminum liner shall be made of 6061 aluminum alloy, whose chemical composition shall comply with the provisions in Table 5.2.

Chemical Composition (Mass fraction, %)

Table 5.2

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Other		Al
											single	total	
Minimum	0.40	—	0.15	—	0.80	0.04	—	—	—	—	—	—	
Maximum	0.80	0.70	0.40	0.15	1.20	0.35	0.25	0.15	0.003	0.003	0.05	0.15	Balance

- (2) The aluminium liner materials shall be re-inspected and qualified by the cylinder manufacturer before use, and the cylinder manufacturer shall conduct re-inspection of the chemical composition by heat/furnace number of the materials.
- (3) The aluminium liner materials shall meet the provisions of the corresponding standards. Ingot castings shall be subjected to ultrasonic testing (UT) with an equivalent flat-bottom hole of  $\phi 2$  mm, and the inspection method shall comply with the provisions of the corresponding standards.

### 5.3 Resin

- (1) The impregnating material shall be thermosetting resins with high heat resistance and good temperature stability, such as epoxy resin or modified epoxy resin. The epoxy equivalent of the resin and the glass transition temperature of the resin material shall be determined in accordance with relevant standards, and the glass transition temperature shall not be lower than 105°C.
- (2) The performance and technical indicators of the impregnating material shall comply with the provisions of the corresponding national or industrial standards.

### 5.4 Carbon fiber

- (1) The load-bearing fibers shall be continuous twistless carbon fibers, and mixed fibers shall not be used.
- (2) The mechanical properties such as tensile breaking strength, breaking elongation and tensile modulus of each batch of carbon fibers shall meet the design requirements of the cylinders.
- (3) The cylinder manufacturer shall conduct batch re-inspection of carbon fiber materials.

### 5.5 Glass fiber

- (1) Glass fiber shall only be used as the outer surface protection layer or galvanic corrosion protection layer of the cylinders.
- (2) Type S or Type E glass fiber shall be adopted, whose mechanical properties shall meet the design requirements of the cylinders.
- (3) The mechanical properties of glass fiber shall be re-inspected in batches; the fiber linear density and impregnated fiber tensile strength shall be determined in accordance with the corresponding national standard (GB/T 3362 Test Method for Tensile Properties of Carbon Fiber Multifilament Yarns).

## 6 Product design and technical requirements

## 6.1 General design provisions

6.1.1 The design of cylinders shall comply with the requirements of standards accepted by the Society (e.g. TSG 23 Technical Regulation for the Safety of Gas Cylinders) and its relevant harmonized standards (e.g. GB/T 35544 Carbon Fiber Fully Wrapped Cylinders with Aluminium Liners for On-Board Compressed Hydrogen).

6.1.2 If materials other than those specified in Clause 5 above are intended to be used for the cylinders, detailed information such as the mechanical properties (including various mechanical property values used for calculating the allowable stress) and chemical composition of the materials shall be submitted to CCS for review.

6.1.3 The design cycle number (Nd) of Type A cylinders is 11,000 cycles, and that of Type B cylinders is 7,500 cycles.

6.1.4 The design service life of Type A cylinders is 15 years, and that of Type B cylinders is 10 years. If the actual service life of a cylinder does not reach the design service life but the filling number reaches the design cycle number, the cylinder shall be scrapped.

6.1.5 The allowable pressure of a cylinder shall not be lower than the maximum working pressure, and the allowable pressure shall be 1.25 times the nominal working pressure.

6.1.6 During filling and use, the temperature of the cylinder shall be maintained between -40°C and 85°C.

6.1.7 Design requirements for the bottom of aluminium liner:

- (1) The end of the aluminium liner shall adopt a convex structure.
- (2) The end of the aluminium liner shall be designed with a gradual thickness, and the cylinder body and the end shall be smoothly transitioned.

6.1.8 The minimum design wall thickness of the aluminium liner shall be verified by stress analysis.

6.1.9 Design requirements for the mouth of aluminium liner:

- (1) The cylinder mouth shall be opened at the end of the cylinder and coaxial with the aluminium liner.
- (2) The outer diameter and thickness of the cylinder mouth shall meet the torque requirements for valve assembly. If necessary, the cylinder mouth may adopt a reinforced structure such as a steel sleeve.
- (3) The thread of the cylinder mouth shall be parallel thread, whose length shall be greater than the effective length of the cylinder valve thread and comply with the requirements of recognized standards.
- (4) The shear stress safety factor of the cylinder mouth thread at the hydraulic test pressure shall not be less than 4. When calculating the thread shear stress safety factor, the shear strength of aluminium alloy shall be taken as 0.6 times the guaranteed value of the material's tensile strength.

6.1.10 Design requirements for cylinders:

- (1) The hydraulic test pressure of a cylinder shall not be lower than 1.5 times the nominal working pressure.
- (2) The fiber stress ratio shall not be lower than 2.25.
- (3) The minimum burst pressure of a cylinder shall not be lower than 2.25 times the nominal working pressure.
- (4) The outer surface of a cylinder may be protected by an appropriate protection layer. If the protection layer is part of the design, environmental testing shall be conducted in accordance with recognized standards and the requirements shall be met.
- (5) The service conditions of the cylinder do not include additional loads caused by external forces, etc.

6.1.11 Stress analysis

A suitable cylinder analysis model shall be established by using the finite element method to calculate the stress and strain in the aluminium liner and wrapping layers under autofrettage pressure, zero pressure after autofrettage, nominal working pressure, allowable pressure, hydraulic test pressure and minimum burst pressure. The analysis model shall consider the material nonlinearity of the aluminium liner, the anisotropy of composite materials and the geometric nonlinearity of the structure.

6.2 General manufacturing requirements

6.2.1 The manufacture of cylinders shall meet the requirements of the approved drawings and relevant standards.

6.2.2 The manufacture of cylinders shall be managed in batches. The batch quantity of finished aluminium liners and finished cylinders shall not exceed 200 pieces plus the number of aluminium liners or cylinders used for destructive tests.

6.2.3 Welding of aluminium liners is not allowed.

6.2.4 The formed aluminium liners shall be subjected to solution and aging heat treatment in accordance with the qualified heat treatment process by evaluation.

6.2.5 Hardness measurement shall be conducted on each aluminium liner after heat treatment.

6.2.6 The thread and sealing surface of the cylinder mouth shall be smooth and flat, without defects such as broken thread, flat thread, double thread, flat thread root, sharp thread peak, wide thread, and obvious waviness on the thread surface. The thread axis shall be coaxial with the cylinder axis.

6.2.7 Fiber wrapping

- (1) Before wrapping carbon fibers, the inner and outer surfaces of the aluminium liner shall be cleaned without impurities such as metal chips, and measures shall be taken to prevent galvanic corrosion between the outer surface of the aluminium liner and the carbon fiber

wrapping layer.

- (2) Wrapping and curing shall be carried out in accordance with the qualified process by evaluation. The curing temperature shall not have an adverse effect on the mechanical properties of the aluminium liner.
- (3) Autofrettage treatment shall be conducted in accordance with the specified autofrettage pressure before the hydraulic test, and the autofrettage pressure, volume expansion and other data of each cylinder shall be recorded in detail.

**7 Type test**

7.1 The quantity of cylinders of the same batch used for type test shall not be less than 30 pieces.

- (1) 1 liner shall be randomly selected for tensile test, metallographic test, and cold bending or flattening test.
- (2) The quantity of cylinders randomly selected for type test shall be as follows:
  - ① For Type A cylinders: 3 pieces for hydraulic burst test; 2 pieces for ambient temperature pressure cycling test; 1 piece for fire test; 1 piece for extreme temperature pressure cycling test; 1 piece for accelerated stress rupture test; 1 piece for crack tolerance test; 1 piece for environmental test; 1 piece for drop test; 1 piece for hydrogen cycling test; 1 piece for projectile test.
  - ② For Type B cylinders: 3 pieces for hydraulic burst test; 3 pieces for ambient temperature pressure cycling test; 1 piece for fire test; 1 or 3 pieces for durability test; 1 piece for service performance test.

7.2 The durability test shall be conducted in accordance with Clause 6.2.15 of GB/T 35544, and the test cylinders shall be those that have passed the drop test in accordance with the provisions of Clause 6.2.12.1 of GB/T 35544 and the ambient temperature pressure cycling test in accordance with Clause 6.2.6 of GB/T 35544.

7.3 All liners and cylinders subjected to type test shall be treated to disable their service function after the test.

7.4 Type test items and requirements (see Table 7.3)

Type test items and requirements

Table 7.3

Test Category		Test Item	Test Quantity
Raw Materials	Aluminium liner	By heat/furnace number	1. Raw materials shall be accompanied by quality certificates; 2. The liner shall be made of 6061 aluminium alloy whose chemical composition meets the requirements of GB/T 35544; 3. Aluminium liner materials shall meet the provisions of the corresponding standards: plates shall comply with GB/T 3880.1, GB/T 3880.2 and GB/T 3880.3; pipes shall comply with GB/T 4437.1; extruded bars shall comply with GB/T 3191; ingot castings shall comply with YS/T 67. Ingot castings shall be subjected to UT with an equivalent flat-bottom hole of $\phi 2$ mm, and the inspection method shall

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			comply with YS/T 1188.	
	Resin	By batch	1. The impregnating material shall be thermosetting resins with high heat resistance and good stability, such as epoxy resin or modified epoxy resin;2. The determination of epoxy equivalent of the resin shall be conducted in accordance with GB/T 4612;3. The glass transition temperature of the resin material shall be determined in accordance with GB/T 19466.2 and shall not be lower than 105°C.	
	Carbon fiber	By batch	1. The load-bearing fibers shall be continuous twistless carbon fibers, and mixed fibers shall not be used;2. The mechanical properties of each batch of carbon fibers shall comply with the provisions of the cylinder design documents;3. The fiber linear density (metric count) shall be determined in accordance with GB/T 3362 or GB/T 30019;4. The impregnated fiber tensile strength shall be determined in accordance with GB/T 3362 or GB/T 26749.	
	Glass fiber	By batch	1. Type S or Type E glass fiber shall be adopted, whose mechanical properties shall comply with the provisions of the cylinder design documents;2. Performance re-inspection shall be conducted in accordance with the method specified in GB/T 7690.3.	
Aluminium Liner	Wall thickness	Each piece	Meet the requirements of Clause 6.1.1 of GB/T 35544 and the approved drawings.	
	Manufacturing tolerance	Each piece	Meet the requirements of Clause 6.1.1 of GB/T 35544.	
	Inner and outer surfaces	Each piece	Meet the requirements of Clause 6.1.2 of GB/T 35544.	
	Cylinder mouth thread	Each piece	Meet the requirements of Clause 6.1.3 of GB/T 35544.	
	Tensile test	1 piece (randomly selected)	1 piece (randomly selected), 3 specimens per piece	Meet the requirements of Clause 6.1.4.2 of GB/T 35544 and the approved drawings.
	Metallographic test	1 piece (randomly selected)	1 specimen per piece	Meet the requirements of Clause 6.1.4.3 of GB/T 35544.
	Cold bending or flattening test		2 bending specimens or 1 flattening specimen per piece	1. One of the tests shall be selected;2. Meet the requirements of Clause 6.1.4.4 or 6.1.4.5 of GB/T 35544.
	Hardness test	Each piece		Meet the requirements of Clause 6.1.5 of GB/T 35544 and the approved drawings.
	Non-destructive testing (NDT)	Each piece		Meet the requirements of Clause 6.1.6 of GB/T 35544 and the approved drawings.
Cylinder	Type A and Type	Tensile test of wrapping layer (Type A & B)	6 specimens per batch	Meet the requirements of Clause 6.2.1.1 of GB/T 35544.

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	B	Appearance of wrapping layer (Type A & B)	6 specimens per batch	Meet the requirements of Clause 6.2.1.2 of GB/T 35544 and the approved drawings.
		Hydraulic test (Type A & B)	Each piece	1. Visual inspection;2. No defects such as fiber exposure, fiber breakage, resin accumulation, delamination and insufficient fiber impregnation.
		Air tightness test (Type A & B)	Each piece	Meet the requirements of Clause 6.2.3 of GB/T 35544.
		Hydraulic burst test (Type A & B)	Each piece	Meet the requirements of Clause 6.2.4 of GB/T 35544.
		Fire test (Type A & B)	3 pieces	Meet the requirements of Clause 6.2.5 of GB/T 35544.
		Ambient temperature pressure cycling test (Type A)	1 piece	Meet the requirements of Clause 6.2.7 of GB/T 35544.
	Type A	Extreme temperature pressure cycling test (Type A)	2 pieces	Meet the requirements of Clause 6.2.6 of GB/T 35544.
		Accelerated stress rupture test (Type A)	1 piece	Meet the requirements of Clause 6.2.8 of GB/T 35544.
		Crack tolerance test (Type A)	1 piece	Meet the requirements of Clause 6.2.9 of GB/T 35544.
		Environmental test (Type A)	1 piece	Meet the requirements of Clause 6.2.10 of GB/T 35544.
		Drop test (Type A)	1 piece	Meet the requirements of Clause 6.2.11 of GB/T 35544.
		Hydrogen cycling test (Type A)	1 piece	Meet the requirements of Clause 6.2.12 of GB/T 35544.
		Projectile test (Type A)	1 piece	Meet the requirements of Clause 6.2.13 of GB/T 35544.
		Drop test (Type B)	1 piece	Meet the requirements of Clause 6.2.14 of GB/T 35544.
	Type B	Ambient temperature pressure cycling test (Type B)	1 or 3 pieces	Meet the requirements of Clause 6.2.12 of GB/T 35544.
		Durability test (Type B)	3 pieces	Meet the requirements of Clause 6.2.6 of GB/T 35544.
		Service performance test (Type B)	1 or 3 pieces	Meet the requirements of Clause 6.2.15 of GB/T 35544.
		Tensile test of wrapping layer (Type A & B)	1 piece	Meet the requirements of Clause 6.2.16 of GB/T 35544.

7.5 Design modification

7.5.1 The type test items may be reduced for design modification, and the type test shall be re-conducted in accordance with the items specified in Table 7.4 based on the modification situation.

Type test items to be re-conducted for design modification

Table 7.4

Design alteration	Test item													
	Type A and Type B					Type A							Type B	
	Interlaminar shear trial	Envelope draw trial	water gauge blow up trial	Ambient temperature and pressure force cycle trial	Burn trial	Ultimate temperature pressure gradient recurrence trial	Acceleration response force rupture trial	Crack capacity limited test	environmental trial	Droptest (A)	Hydrogen Cycling Test (A)	Projectile Test (A)	Durability Test (B)	Service Performance Test (B)
Carbon fiber manufacturer	√	√	√	√		√	√			√		√	√	
New carbon fiber material	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Equivalent carbon fiber material	√	√	√	√										
New resin material	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Equivalent resin material	√	√	√	√										
Liner outer diameter change ≤20%			√	√	√					√		√	√	
Liner outer diameter change > 20%			√	√	√	√				√		√	√	
Length change ≤50%			√	√	√ <sup>a</sup>							√		
Length			√	√	√ <sup>a</sup>	√				√			√	

h chang e > 50%														
Nomi nal worki ng press ure chang e ≤20% b			√	√										
Liner wall thickn ess reduct ion			√	√					√				√	
Liner formi ng proce ss			√	√										
End struct ure			√	√										
Cylin der mout h thread			√	√										
Prote ction layer <sup>c</sup>								√			√	√		
<p>a Test is only required when the length is increased;                  b Applicable only when the wall thickness change is proportional to the pressure change;                  c Refers to the protection layer as part of the design.</p>														

**8 Unit/batch inspection**

8.1 The unit/batch inspection for issuing the product certificate of carbon fiber fully wrapped cylinders with aluminium liners for on-board compressed hydrogen shall be conducted after the manufacturer has obtained the works approval, unless special consideration is given. Unit/batch inspection shall be conducted for such cylinders, and the unit/batch inspection for unapproved cylinders shall be conducted in accordance with the type test requirements.

8.2 The unit/batch inspection of approved carbon fiber fully wrapped cylinders with aluminium liners for on-board compressed hydrogen shall be conducted in accordance with the product inspection plan approved at the time of works approval, which shall specifically include the following test items (see Table 8.2).

Factory inspection items for unit/batch

Table 8.2

Ambient temperature	<b>Ambient temperature pressure cycling test (Type A &amp; B)</b>	<b>Ambient temperature pressure cycling test (Type A &amp; B)</b>	<b>Ambient temperature pressure cycling test (Type A &amp; B)</b>
pressure	Random sampling	Random sampling	Random sampling

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cycling test (Type A & B) Random sampling Random inspection and report review	Random inspection and report review		Random inspection and report review	Random inspection and report review
Ambient temperature pressure cycling test (Type A & B) Random sampling Random inspection and report review	Ambient temperature pressure cycling test (Type A & B)		Ambient temperature pressure cycling test (Type A & B)	Ambient temperature pressure cycling test (Type A & B)
	Random sampling		Random sampling	Random sampling
Random inspection and report review	Random inspection and report review		Random inspection and report review	Random inspection and report review
Random inspection and report review	Ambient temperature pressure cycling test (Type A & B)		Ambient temperature pressure cycling test (Type A & B) Random sampling Random inspection and report review	Ambient temperature pressure cycling test (Type A & B)
	Random sampling		Random sampling	Random sampling
Ambient temperature pressure cycling test (Type A & B) Random sampling Random inspection and report review	Random inspection and report review		Random inspection and report review	Random inspection and report review
Random inspection and report review	Ambient temperature pressure cycling test (Type A & B)		Ambient temperature pressure cycling test (Type A & B)	Ambient temperature pressure cycling test (Type A & B)
Ambient temperature pressure cycling test (Type A & B)	Ambient temperature pressure cycling test (Type A & B)		Ambient temperature pressure cycling test (Type A & B)	Ambient temperature pressure cycling test (Type A & B)
Random sampling Random inspection and report review	Random sampling Random inspection and report review	Random sampling	Random sampling	Random sampling
		Random inspection and report review	Random inspection and report review	Random inspection and report review
	Ambient temperature	Ambient temperature pressure	Ambient temperature pressure cycling test (Type A & B)	Ambient temperature pressure cycling test (Type A & B)

Ambient temperature pressure cycling test (Type A & B)	pressure cycling test (Type A & B)	cycling test (Type A & B)		
	Random sampling	Random sampling	Random sampling	Random sampling
Random inspection and report review	Random inspection and report review	Random inspection and report review	Random inspection and report review	Random inspection and report review

**9. Disposal of non-conforming items**

If non-conforming items are found in the type test and batch inspection, disposal shall be conducted in accordance with the following provisions:

9.1 Aluminium liner

- (1) If the non-conformity is caused by abnormal test operation or measurement error, the test shall be re-conducted; if the re-test result is qualified, the initial test shall be invalidated.
- (2) If the test operation and measurement are correct, the cause of the non-conformity shall be identified first, and then disposal shall be conducted in accordance with the following rules:
  - ① If it is confirmed that the non-conformity of the aluminium liner is caused by improper heat treatment, the batch of aluminium liners may be re-heat treated, but the number of heat treatments shall not exceed 2 times. The batch of aluminium liners after re-heat treatment shall be regarded as a new batch and subject to batch inspection again;
  - ② If the non-conformity of the aluminium liner is caused by other reasons, the entire batch of aluminium liners shall be scrapped.

9.2 Cylinder

If non-conforming items are found in the type test or batch inspection, 5 more cylinders may be randomly selected to conduct the relevant test. If all 5 cylinders pass the test, the batch of cylinders shall be deemed qualified; if one of them fails the test, the entire batch of cylinders shall be scrapped.