ICS 23.020. 30
CCS J74

National Standards of the People's Republic of China

GB/T 24159-2021
Replace GB/T 24159-2009

Welded Insulated Cylinder

(Click here to add the identification in conformity with international standards)

(Draft for Approval)

(Draft Completion Time: August 16, 2021)

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Released on XXXX-XX-XX Implemented on XXXX-XX-XX

Issued by
State Administration for Market Regulation,
State Standardization Administration

Contents

Preface

This document is drafted in accordance with GB/T 1.1-2020 *Directives for Standardization Part One: Structure and Drafting Rules of Standardization Documents*.

This document supersedes GB/T 24159-2009 *Welded Insulated Cylinder*. In addition to structural adjustment and editorial changes, this edition also include main technical changes as follows as compared with GB/T 24159-2009:

——Cylinder volume, medium range and type have been changed:

- Cylinder volume expanded from 450L to 1,000 L;
- Liquefied natural gas added;
- Horizontal type added;

——Deleted the content of welding procedure qualification (WPQ) and replaced it with GB/T 33209;

——Added Appendix A *Provisions on Liquid Carbon Dioxide and Liquid Nitrous Oxide*;

——Added Appendix B *Maximum Allowable filling factor*;

——Added Appendix C *Inlet and Outlet Fittings*;

——Changed Appendix A of GB/T 24159-2009 to Appendix D *Calculation of Safe Relief Volume and Required Safe Pressure Relief Device Area* of this document, and added the calculation method of safe relief volume equal to or greater than critical pressure;

——Added Appendix E *Vibration Test*;

——Added Appendix F *Drop Test*;

——Changed Appendix C of GB/T 24159-2009 to Appendix G *Product Certificate* of this document;

——Changed Appendix D of GB/T 24159-2009 to Appendix H *Quality Certificate of Batch Inspection* of this document;

——Deleted GB/T 24159-2009 Appendix B *Gas Supply Test Method*.

Appendixes A, B, C, D, E and F hereto are normative appendixes, while Appendixes G and H are informative appendixes.

It should be noted that some content hereof may be patent-related. The publisher of this document assumes no liability for identification of patents.

This document is proposed by and is under the jurisdiction of the National Technical Committee for Cylinder Standardization (SAC/TC 31).

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All the previous editions replaced by this standard are:

——GB/T 24159-2009

Welded Insulated Cylinder

1 Scope

This document defines the terms, definitions and symbols of Welded Insulated Cylinder (hereinafter referred to as “cylinders”), and specifies the requirements for type naming method, basic parameters, material regulations, design regulations, manufacturing regulations, test methods, inspection rules, type test, marking, packaging, transportation, ex-factory data, and data retention of cylinders.

This document is applicable to refillable cylinders that are used to store low-temperature liquefied gas at normal ambient temperature (-40 ℃～60 ℃), with the design temperature of not higher than-196 ℃ and the nominal working pressure is 0.2 MPa~3.5 MPa (pressure not indicated herein shall refer to gauge pressure). The nominal volume of liquid oxygen, liquid nitrogen and liquid argon ranges 10L~1,000L, while that of liquefied natural gas (LNG) is 150L~1,000L.

Note: Cylinders used to store liquid carbon dioxide and liquid nitrous oxide shall meet the requirements of Appendix A hereto.

2 Normative References

The following documents are referred to in the text in such a way that some or all their content constitute requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 228.1 Metallic Materials-Tensile Testing Part 1: Method of Test at Room Temperature (GB/T 228.1-2010, ISO 6892-1: 2009, MOD)

GB/T 229 Charpy Pendulum Impact Test Method for Metallic Materials (GB/T 229-2007, ISO 148-1: 2006, MOD)

GB/T 1804 General Tolerances - Tolerances for Linear and Angular Dimensions without Individual Tolerance Indications (GB/T 1804-2000, ISO 2768-1: 1889, EQV)

GB/T 2653 Bending Test Method on Welded Joints (GB/T 2653-2008, ISO 5173: 2000, IDT)

GB/T 7144 Colored Cylinder Mark for Gases

GB/T 9251 Methods for Hydrostatic Test of Gas Cylinders

GB/T 12137 Methods for Leakage Test of Gas Cylinders

GB/T 12241 General Requirements for Safety Valves (GB/T 12241-2005, ISO 4126-1: 1991, MOD)

GB/T 12243 Spring Loaded Safety Valves (GB/T 12243-2005, JIS B 8210: 1994, MOD)

GB/T 13005 Cylinders - Terminology (GB/T 13005-2011, ISO 10286: 2007, NEQ)

GB/T 15384 Designation for Gas Cylinders

GB/T 16804 Precautionary Labels for Gas Cylinders (GB/T 16804-2011, ISO 7225: 2005, MOD)

GB/T 16918 Bursting Disc Safety Devices for Gas Cylinders

GB/T 17925 Standard Practice For X-ray Digital Radioscopic Examination of Cylinder Weld

GB/T 18442.1 Static Vacuum Insulated Cryogenic Pressure Vessels—Part 1: General Requirements

GB/T 18442.3 Static Vacuum Insulated Cryogenic Pressure Vessels—Part 3: Design

GB/T 18443.2 Testing Method of Performance for Vacuum Insulation Cryogenic Equipment. Part 2:Vacuum Degree Measurement

GB/T 18443.3 Testing Method of Performance for Vacuum Insulation Cryogenic Equipment.Part 3:Leak Rate Measurement

GB/T 18443.4 Test Methods of Performance for Vacuum Insulation Cryogenic Equipment-Part 4: Leak-outgassing Rate Measurement

GB/T 18443.5 Testing Method of Performance for Vacuum Insulation Cryogenic Equipment.Part 5:Static Evaporation Rate Measurement

GB/T 18443.8 Testing Method of Performance for Vacuum Insulation Cryogenic Equipment. Part 8:Volume Measurement

GB/T 18517 Terminology of Refrigeration

GB/T 24511 Stainless Steel and Heat Resisting Steel Plate, Sheet and Strip for Pressure Equipments

GB/T 25198 Formed Head for Pressure Vessel

GB/T 31480 Materials for High Vacuum Multilayer Insulation of Cryogenic Vessel

GB/T 31481 Guidance for Gas/Materials Compatibility of Cryogenic Vessels (GB/T 31481-2015, ISO 21010: 2014, IDT)

GB/T 33209 Welding Procedure Qualification for Welded Gas Cylinders

GB/T 33215 Pressure Relief Devices for Gas Cylinders

GB/T 34530.1 Valve for Cryogenic Insulated Cylinder—Part 1：Pressure Regulating Valve

GB/T 34530.2 Valve for Cryogenic Insulated Cylinder—Part 2：Shut-off Valve

JB 4732-1995 Steel Pressure Vessel - Analysis Design Document (2005 Validation)

JB/T 6896 Surface Cleanliness of Air Separation Plants

NB/T 47013.2 Nondestructive Testing of Pressure Equipments. Part 2: Radiographic Testing

NB/T 47013.11 Nondestructive Testing of Pressure Equipments. Part 11: Standard Practice for X-ray Digital Radiography

NB/T 47013.14 Nondestructive Testing of Pressure Equipments. Part 14: X-ray Computed Radiographic Testing

NB/T 47018.1 Technical Permission of Welding Materials for Pressure Equipment.Section 1:General Rule

NB/T 47018.3 Technical permission of welding materials for Pressure Equipment.Section 3:Steel Electrodes and Rods for Gas Shielded arc Welding

3 Terms and Definitions

For the purposes of this document, the following terms and definitions defined in GB/T 12241, GB/T 13005, GB/T 16918, GB/T 18442.1, GB/T 18442.3, GB/T 18443.2, GB/T 18517, GB/T 26929 and GB/T 33209 apply.

3. 1

Lot/batch

A certain number of products (or inner container vessels) composed according to the same rules.

3.1.1

Lot/batch of inner container vessel

The limited number of inner container vessels for gas cylinders continuously produced with the same design, the same brand of materials and the same process (mainly referring to welding process, nondestructive testing process, and pressure test process).

3.1.2

Lot/batch of cylinder

The limited number of gas cylinders continuously produced with the same design, the same batch of inner container vessel and the same process (mainly referring to insulation process and vacuum process).

3.2

Tare of cylinder

The mass of an empty cylinder with the basic functions of filling, storage, transportation, use and safety. A horizontal cylinder shall contain frames (or bearings).

3.3

Effective volume

Maximum liquid volume allowed to be filled in a cylinder.

3.4

Coefficient of heat transfer

Heat transfer between hot and cold fluids per unit area, unit temperature difference and unit time, as a characterizing of the intensity of heat transfer process.

[Source: Section 2.6.2 of GB/T 18517-2012, as amended]

3.5

Free air or gas

Air or gas measured at absolute pressure of 1.01325×10^5 Pa and under the temperature of 15.6 ℃.

4 Symbols

The following symbols apply to this document.

D_i——Inner diameter of the head or cylinder, mm.

D_0——Outer diameter of head or cylinder, mm.

E_0——Elastic modulus of material, MPa.

g——Gravitational acceleration, g=9. 81 m/s^2.

h_i——Height of convex surface in head, mm.

h_0——Total height in head, h0 = hi + Sn;mm.

k_1——Coefficient determined by the ratio of the major and minor axes of the ellipse.

L——Sum of the cylinder length plus 1/3 of the height of the straight side and the height of the inner convex surface of each head, mm.

m——Mass, kg.

P——Nominal working pressure, MPa.

P_b——Design burst pressure of bursting disc, MPa.

P_d——Design pressure, MPa.

P_t—— Proof test pressure, MPa.

P_z——Set-pressure of safety valve, MPa.

P_1——Allowable external pressure, MPa.

R——Spherical outer radius of dished head and equivalent radius of oval head, mm.

S——Design wall thickness, mm.

S_b——Measured minimum wall thickness of the cylinder, mm.

S_e——Effective thickness, by nominal wall thickness minus corrosion allowance and negative deviation of steel thickness, mm.

S_f——Minimum wall thickness of head forming, mm.

S_n——Nominal wall thickness, mm.

σ——Wall stress, MPa.

ΔH_i——Head height tolerance, mm.

$\Delta\pi D_i$——Inner circumference tolerance, mm.

5 Designation for Gas Cylinders and Basic Parameters

5. 2 Designation for Gas Cylinders

Model "DPL" represents vertical cylinders, "DPW" horizontal cylinders, and the rest is designated according to the method in GB/T 15384. Roman numerals I, II and III can be added to the end of the model as sequence numbers in case of any change in the design.

5. 3 Basic Parameters

5.3.1 Nominal volume and nominal diameter of inner container vessel

It is recommended to select nominal volume and nominal diameter of inner container vessel according to Table 1. The nominal volume should be an integer multiple of 5.

Table 1. Nominal Volume and Nominal Diameter of Inner Container Vessel

Nominal volume (L)	10-25	25~50	50~150	150-200	200~500	500~800	800~1,000
Nominal diameter of inner container vessel (mm)	200~300	250~350	300~450	400~550	450~800	600~900	750~1 200

5.3.2 Pressure

5.3.2.1 The pressure used for calculating the internal pressure of the wall thickness of the inner container is the design pressure, which is the proof test pressure of the inner container. The proof test pressure of the inner container vessel should not be twice smaller than the nominal working pressure ($P_d=P_t\geq 2P$).

5.3.2.2 The allowable external pressure P_1 of the cylinder and head of the shell and inner container vessel shall not be less than 0.21 MPa.

5.3.2.3 The leakage test pressure shall not be less than the nominal working pressure.

5.3.3 Effective volume

5.3.3.1 The effective volume of cylinders for liquid oxygen, liquid nitrogen and liquid argon shall not be greater than 95% of the nominal volume.

5.3.3.2 The effective volume of LNG cylinder shall not be greater than 90% of the nominal volume.

6 Materials

6. 1 General Rules

6.1.1 The main body of the inner container vessel (cylinder and head) shall be made of austenitic stainless steel in accordance with the provisions of GB/T 24511 and the requirements of Design Documents. When a foreign brand is used, the materials should be permitted by overseas regulations on pressure vessels or gas cylinders and relevant product standards, and have been actually put in use under similar working conditions abroad. The certificate of quality shall comply with the provisions of Section 6.1.4, and the re-inspection results shall comply with Section 6.1.5 and the requirements of Design Documents.

6.1.2 The parts welded on the inner container vessel shall be made of austenitic stainless steel specified in the corresponding standards for materials and in conformity with the requirements of the Design Documents; other materials in direct contact with the storage medium shall be compatible with the medium and in conformity with the corresponding standards for materials.

6.1.3 The chemical composition and tensile property of welding materials and deposited metals shall conform to the provisions of NB/T 47018.1 and NB/T 47018.3 as well as the requirements of Design Documents.

6.1.4 Manufacturers of pressure components and welding materials shall provide the original of Quality Certificate stamped with the manufacturer's quality inspection seal and printed with the traceable information mark (two-dimensional code, bar code, etc.). The traceable information mark shall at least include the information of the manufacturer, material brand, specifications, furnace batch number, delivery status, issuance date of the Quality Certificate, etc.; when such materials are to be purchased from a non-material manufacturer, the manufacturer is required to present the original of the Quality Certificate provided by the material manufacturer or a copy stamped with the inspection seal of the material supplier and the operator's seal.

6.1.5 Testing of chemical composition on the main material of the inner container vessel shall be re-conducted according to furnace tank numbers, and test results shall conform to the provisions of Section 6.2; mechanical properties shall be re-inspected according to batch number. The samples for mechanical properties shall be cut along the vertical rolling direction of the steel plate, analyzed and tested according to the methods specified in the material standards. The inspection results shall conform to the provisions of Section 6.3.

6.1.6 The shell shall be made of austenitic stainless steel.

6.1.7 When the temperature of loading medium is lower than -182℃, thermal insulation materials causing no hazardous reaction with oxygen or oxygen-enriched atmosphere should be used. The performance of thermal insulation materials shall meet the provisions of GB/T 31480 and the test provisions of GB/T 31481.

6.1.8 Adsorbent materials should be compatible with the stored medium.

6.2 Chemical Composition

The chemical composition and allowable deviation of the main material of the inner container vessel shall comply with the provisions in Table 2.

Table 2 Chemical Composition and Allowable Deviation

Chemical composition	C	Mn	P	S	Si	Ni	Cr
Mass percentage	≤0.08	≤2.00	≤0.035	≤0.015	≤0.75	8.00～10.50	18.00～20.00
Allowable deviation	±0.01	±0.04	+ 0.005	+ 0.005	±0.05	±0.10	±0.20

6.3 Mechanical Properties

The mechanical properties of the main materials of the inner container vessel shall conform to the provisions of Table 3 and the requirements of Design Documents.

Table 3 Mechanical Properties

Tensile strength R_m	Specified plastic elongation strength $R_{P0.2}$	Percentage elongation after fracture A
≥520 MPa	≥220 MPa	≥40%

7 Design

7.1 General Rules

7.1.1 Composition of cylinder

7.1.1.1 The gas cylinder is mainly composed of an inner container vessel, an outer shell, a thermal insulation system, a connector between the inner container vessel and the outer shell, a valve piping system, a protective device for valve piping system, a base, etc. The valve piping system includes valves, instruments, safety pressure relief devices, pipe fittings, pipes and their supports. Protective devices should be protective covers, protective rings (loops), frames, etc.

7.1.1.2 The inner container vessel shall be composed of at most three parts, namely, no more than one longitudinal weld and no more than two circumferential welds.

7.1.2 Connector between inner container vessel and outer shell

The stress on the connector between the inner container vessel and the outer shell shall not be greater than 2/3 of the yield strength (or specified plastic elongation strength) of the material at room temperature under the independent action of the following loads.

——Vertical: The load perpendicular to the cylinder axis should not be less than 2mg, and the load along the cylinder axis should not be less than 3mg;

——Horizontal: The load perpendicular to the cylinder axis and parallel to the ground should not be less than 2mg; the load along the cylinder axis should not be less than 2mg; and the load perpendicular to the cylinder axis and in the vertical direction should not be less than 3mg.

Note: For the purpose of this paragraph, "m" represents the sum of the mass of the medium (saturated medium is filled to its effective volume at standard atmospheric pressure), the metal mass of the inner container vessel, and the mass of the thermal insulation blanket.

7.1.3 Performance indicator

Vacuum-jacketed leakage rate, vacuum-jacketed leak-outgassing rate shall meet the provisions of Table 4. Static evaporation rate under the nominal working pressure of not greater than 2.4 MPa is specified in Table 4. Otherwise, the static evaporation shall meet the requirements of drawings.

Table 4 Static evaporation rate, vacuum-jacketed leakage rate and vacuum-jacketed leak-outgassing rate

Nominal volume	L	10	50	175	300	500	800	1 000
Upper limit of static evaporation rate of liquid nitrogen η	%/d	5.45	4.0	2.5	2.2	1.9	1.7	1.5
Vacuum-jacketed leakage rate	Pa · m^3/s	$\leq 2\times10^{-8}$		$\leq 6\times10^{-8}$				
Vacuum-jacketed leak-outgassing rate	(20℃)	$\leq 2\times10^{-7}$		$\leq 6\times10^{-7}$				

7.1.4 Filling volume

7.1.4.1 When the pressure reaches the set-pressure of the master safety pressure relief device, the liquid phase volume of liquid oxygen, liquid nitrogen, and liquid argon shall not exceed 98% of the nominal volume, while that of LNG shall not exceed 95% of the nominal volume.

7.1.4.2 Maximum filling volume refers to the mass calculated according to Section 8.19, namely the product of the effective volume and the maximum allowable filling factor (Appendix B).

7.1.5 **Design service life**

The design service life shall not exceed 20 years, and shall be included in the Design Documents and the nameplate.

7.1.6 Accessories

7.1.6.1 Accessories such as valves, pressure gauges, safety pressure relief devices and level gauges in contact with oxygen shall comply with Section 8.12.3.

7.1.6.2 Pressure regulating valves shall comply with the provisions of GB/T 34530.1 and shut-off valves shall comply with the provisions of GB/T 34530.2. When the external valve interface of the cylinder is threaded, the valve interface for LNG shall be left-hand threaded while others are right-hand threaded.

7.1.6.3 Pressure gauge should have an accuracy of not be lower than 2.5 grade, and a measuring range 1.5~3 times as much as the nominal working pressure.

7.1.6.4 Electrical capacitance gauge for LNG cylinder should meet explosion-proof requirements.

7.1.6.5 The whole LNG cylinder should be designed as an anti-static structure to ensure that any parts in contact with LNG, such as the cylinder, valve and connector, have conductive continuity, with the total resistance of not more than 10Ω.

7.1.6.6 It is recommended to set up a device that is convenient for directly detecting the vacuum in interlayer space.

7.1.6.7 Inlet and outlet fittings (with one end connected to cylinder valve, and the other to hose and other components) shall comply with the provisions of Appendix C.

7.1.6.8 Valve piping system protective devices should be suitable for transportation, and loading process under static and dynamic loads.

7.1.6.9 The base should ensure the stability of the cylinder. Wheels shall not be installed when the cylinder's nominal volume is higher than 500L. Wheeled cylinders and wheeled frames shall be designed with brake locking devices.

7.1.6.10 When the total mass of the cylinder loaded with the medium exceeds 40kg, hoisting accessories should be installed.

7.1.6.11 Protective cover and protective ring (loop) shall be made of metallic materials, and welded to the cylinder.

7. 2 Design of inner container vessel

7.2.1 The load-carrying position should be the head concave of the inner container vessel, and its shape is hemispherical or standard ellipse with the ratio of long axis to short axis of 2: 1. The minimum wall thickness shall not be less than 0.9 times as much as the design wall thickness of the cylinder calculated according to Formula (1).

7.2.2 The design wall thickness of the inner pressure of the inner container vessel is not less than the value calculated according to Formula (1).

$$S=\frac{D_i}{2}\times\left(\sqrt{\frac{0.4P_d+\sigma}{\sigma-1.3P_d}}-1\right) \qquad (1)$$

In the above formula, the wall stress σ takes the minimum of the following:

——310 MPa;

——50% of the minimum tensile strength R_m of the base metal determined according to Section 6.1.5;

——The specified plastic elongation strength $R_{p0.2}$ of the base metal determined according to Section 6.1.5;

——50% of the minimum tensile strength R_m of welded joints determined according to Section 8.9.4.3;

——The wall stress of the inner container vessel with longitudinal seam shall not exceed 85% of the minimum of the above values.

7.2.3 When necessary, external pressure verification of the inner container vessel shall also be conducted according to the requirements of Section 7.3.

7.2.4 Holes are only allowed in the head. These holes should be circular and welded to pipe joints, pipe sockets or flanges. The opening diameter should be less than or equal to 1/3 of the inner diameter of the head, or 76mm, and the opening edge should be located in the range of 80% of the inner diameter of the head, with the center of the head as the center. When the opening diameter and opening edge exceed the specified standards hereof, the strength check shall be conducted in accordance with the provisions of JB 4732-1995 (confirmed in 2005).

7. 3 **Design of Shell**

7.3.1 The wall thickness of cylinder shell shall be checked according to Formula (2):

$$P_1 \leq \frac{2.6E_0\left(S_e/D_0\right)^{2.5}}{\left[\left(L/D_0\right)-0.45\left(S_e/D_0\right)^{0.5}\right]} \quad (2)$$

7.3.2 For dish-shaped or oval shells, the wall thickness shall be checked according to Formula (3). For a dish-shaped head, R represents the outer radius of the spherical part; for an oval shell, then $R=K_1D_0$, the value of K_1 is selected according to Table 5:

$$P_1 \leq 0.25E_0\left(S_f/R\right)^2 \quad (3)$$

Table 5 Value of Coefficient K_1

D0/2H0	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0
K1	1.18	1.08	0.99	0.90	0.81	0.73	0.65	0.57	0.50
Note 1: The median value is interpolated. Note 2: For standard oval heads, K_1=0.9.									

7. 4 **Pressure Relief System**

7.4.1 **General Requirements**

7.4.1.1 Cylinder should be equipped with the pressure relief system which is composed of master and auxiliary safety pressure relief devices (safety valve or bursting disc safety device), pressure relief valve, and other pressure relief system to ensure the safety of the cylinder.

7.4.1.2 The safety relief volume and the required area of safety pressure relief device shall be calculated according to the provisions of Appendix D.

7.4.1.3 Safety valves should be installed in such a manner that the discharged liquid (gas) does not affect the protective device of shell, valve and valve piping system, etc.

7.4.2 **Relief pipe**

7.4.2.1 The sectional area of the relief pipe connected to the safety pressure relief device shall not be less than the total inlet area of the safety pressure relief device, so as to ensure that the relief volume can meet the safety relief requirements of the gas cylinder.

7.4.2.2 The inlet pipe of the safety pressure relief device shall be located at the top of the inner container vessel, with its lowest point above the liquid level of 98% of the nominal volume.

7.4.3 **Safety Pressure Relief Device**

7.4.3.1 The master safety pressure relief device and the auxiliary safety pressure relief device shall be arranged in parallel. Safety valves shall be used for the master safety pressure relief device; only the auxiliary safety pressure relief devices of LNG can use safety valves, while other media shall use safety valves or bursting disc safety devices.

7.4.3.2 The set-pressure of the master safety pressure relief device (safety valve) shall not be greater than 1.2 times the nominal working pressure ($P_z \leq 1.2P$); the Relief pressure shall be as follows:

a) The Relief pressure of liquid oxygen, liquid nitrogen and liquid argon cylinders shall not be greater than 1.1 times the set-pressure under the condition of D.1.1;

b) The Relief pressure of LNG cylinders shall not be greater than 1.1 times the set-pressure under the condition of D.1.2.

7.4.3.3 The circumstance of D.1.2 is only applicable to the auxiliary safety pressure relief device and shall meet the following provisions:

a) When a safety valve is used, the set-pressure is 1.4~1.6 times the nominal working pressure ($1.4P \leq P_z \leq 1.6P$); the Relief pressure should not be greater than 1.1 times the set-pressure;

b） When a bursting disc safety device is used, the design bursting pressure is 1.54~1.76 times the nominal working pressure ($1.54P \le P_b \le 1.76P$).

7.4.3.4 The safety valve shall meet the requirements of GB/T 12243, with its reseating pressure shall not be less than 90% of the set-pressure; except for screw threads, safety devices for bursting discs shall comply with the provisions of GB/T 16918. It is necessary to conduct relevant type tests to verify safety valves and bursting disc safety devices.

7.5 Shell Pressure Relief Device

The shell shall be provided with a pressure relief device which meets the following requirements:

——The relief pressure should not be greater than 0.1 MPa;;

——The minimum discharge area shall not be less than the product of the nominal volume of the inner container vessel and 0.34^{mm^2}/L, and its minimum diameter is not less than 6mm;

——The reclosed structure should not be adopted;

——Protective measures should be taken to avoid hurting people during discharge.

8 Manufacturing Regulations, Test Methods and Inspection Rules

8.1 Responsibilities of Manufacturer

8.1.1 The manufacture has completed verification and approval of the documents for manufacturing before its formal production, and the cylinders produced according to these documents have passed the type test verification.

8.1.2 The manufacturer’s inspection department shall carry out inspection and test according to the requirements specified in this document and Design Documents, issue corresponding reports, and take responsibility for the correctness and completeness of the issued reports.

8.2 Group Batch

8.2.1 Manufacturing shall be conducted according to the batch of inner container vessel. The batch number of cylinder joint materials of the same batch of inner container vessel should be two at maximum. The group batch of products is carried out on the basis of the inner container vessel batch; the same container vessel batch should be one product batch, and multiple product batches can be formed.

8.2.2 The number of inner container vessel in a batch should not exceed 200 (excluding cylinders for destructive inspection).

8.3 Mark Transplantation

Materials of press parts shall be traceable. If the original mark is cut off or the material is divided into several pieces during the manufacturing process, the manufacturer shall specify how to express the mark. Mark transplantation should be completed with a chlorine-free and sulfur-free marker before material segmentation, and hard printing should not be used.

8.4 Unnoted Tolerance

The class of tolerance for linear and angular dimensions shall be in conformity with the provisions of GB/T 1804, with medium class m for machined surfaces and rough class C for non-machined surfaces.

8.5 Cylinder

8.5.1 The misalignment b (left in Fig.1) of the longitudinal welds of the cylinder should not be greater than 0.1 S_n; the circumferential angular E (Fig.2) formed by the longitudinal welds of the cylinder should be detected with an inner template (or outer template) with a chord length equal to $D_i/2$ but not greater than 300mm and a ruler, and its value should not be greater than $0.1S_n+2^{mm}$.

8.5.2 After the cylinder is finished, the difference between the maximum and minimum inner diameter of the same cross section, e, shall not be greater than 0.01 D_i.

Fig. 1. Misalignment of Longitudinal Seams and Circumferential Seams

Fig.2 Height of Circumferential Corner Angle of Longitudinal Seams

8. 6 Head

8.6.1 The steel plates used to manufacture the head should not be spliced, and the wall stress of the inner container vessel head should not be less than that of the cylinder.

8.6.2 The head should be free from abrupt change, crack, peeling, wrinkle and other defects after it is formed, and its wall thickness meets the requirements of Sections 7.2 and 7.3 as well as the Design Documents.

8.6.3 The shape and dimensional tolerances of the head shall be inspected in accordance with GB/T 25198, with the inspection results as specified in Table 6.

Table 6 Shape and Dimensional Tolerances of the Head

Unit: mm

Internal diameter D_i	Shape and dimensional tolerances of the head						
	Inner circumference tolerance $\Delta\pi D_i$	Gap between curved surface and template, a	Surface convexity, c	Maximum and minimum diameter difference, e	Straight edge gradient		Height tolerance in headΔH_i
					Extroversion	Introvertion	
＜400	±4.0	≤2	≤1	≤2	≤ 1.5	≤ 1.0	$^{+5}_{-3}$
≤400～800	±6.0	≤3	≤2	≤3			
≤800～12 00	±9.0	≤5	≤3	≤5			

8.6.4 For liquid oxygen and LNG cylinders, a raised mark with the font height of not less than 40mm should be pressed at the distinct part of the valve end head of the shell, with the mark “O2” for liquid oxygen and “LNG” for LNG.

8. 7 Connector

8.7.1 Longitudinal and circumferential welded joints shall be fully welded butt joints. Longitudinal welded joints shall not be installed with permanent backing plates; permanent backing plates or lock bottom joints can be used in circumferential welded joints.

8.7.2 Components welded to the inner container vessel head or cylinder shall be welded by fusion welding. The welding of pressure components such as pipe joints, pipe sockets or flanges with the head shall use the welded joints of full penetration.

8.7.3 Brazing and threaded connections are only applicable to the joints that are not directly connected to the inner container vessel.

8.8 Assembling

8.8.1 Parts should pass examination before assembling. It is prohibited to forcibly make pressure parts centered or leveled.

8.8.2 The misalignment of butt joint circumferential welds between head and cylinder, b (right in Fig. 1) should not be greater than $0.25S_n$; axial angular height E (Fig. 3) shall not be greater than $0.1S_n+2^{mm}$, and the length of inspection ruler shall not be less than 150mm.

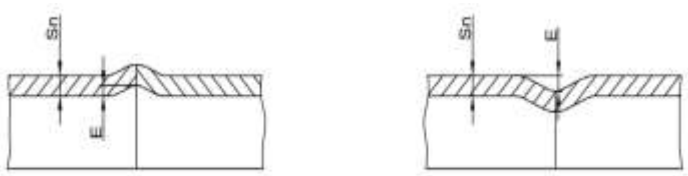


Fig.3 Schematic Diagram of Axial Angular Height of Circumferential Butt Weld

8.8.3 Components welded to the inner cylinder should avoid longitudinal and circumferential welded joints of the inner cylinder.

8.8.4 The connection welds between the base, frame and hoisting accessories and the cylinder should avoid the longitudinal and circumferential welds of the shell.

8.9 Welding

8.9.1 Preparation before welding and welding environment

8.9.1.1 The storage depot of welding materials should be kept dry, with the relative humidity of not higher than 60%.

8.9.1.2 Welding (including welding repair) shall be carried out in a clean and dry indoor welding site. When any of the following conditions occur in the welding environment and in the absence of effective protective measures, it is prohibited to conduct welding:

——The wind speed is over 2m/s for gas shielded welding;

——The relative humidity is over 90%;

——Weldment temperature is lower than-20 ℃.

8.9.1.3 When the weldment temperature is below 0 ℃, but not lower than-20 ℃, it should be heated to above 15℃ within 100mm of the initial welding place.

8.9.2 **Weld Grooves**

Groove surface should be free from cracks, delaminations, inclusions and other defects. Oxides, oil and other harmful impurities within at least 20mm of the surfaces of the groove and base metal on both sides (calculated by the groove edge) shall be removed before welding.

8.9.3 Welding Procedure Qualification of Inner Container Vessel

8.9.3.1 Welding procedure qualification (WPQ) shall be carried out for longitudinal and circumferential welded joints of the inner container vessel and all welded joints between each component and the inner container vessel. WPQ shall be in conformity with the provisions hereof and GB/T 33209.

8.9.3.2 For the WPQ on a weld joint with the nominal volume of less than or equal to 100L, it is allowable to use sample cylinders for conducting WPQ on longitudinal and circumferential welds, or flat specimens for longitudinal welds and cylindrical specimens for circumferential welds; flat specimens can be used in the WPQ on the welds with the nominal volume of greater than100 L.

8.9.3.3 When the material thickness is not enough to prepare the WPQ impact sample for inner container vessel with the thickness of 2.5mm, the material with carbon content (mass fraction) of not less than 0.05% and thickness of not more than 3.2mm shall be used to weld the sample cylinder or sample by using the same welding process, and then prepared into the sample of 2.5mm.

8.9.3.4 The requirements for WPQ test results of longitudinal and circumferential welded joints of the inner container vessel are as follows:

——No matter where the fracture occurs, the measured tensile strength of the tensile sample shall not be less than the value as specified in Section 6.3 and the requirements of the Design Documents;

——After the tensile sample is bent to 180°, there should be no opening defects in the weld and heat affected zone on the tensile surface, and the angular opening defects of the tensile sample are generally ignored; however, the length of angular opening defects caused by incomplete fusion, slag inclusion or other internal defects should be included;

——The average absorbed energy (KV_2) of Charpy impact energy of test sample with the standard dimension of 10 mm×10 mm×55 mm at-192 ℃ should not be less than 31J; the absorbed energy of one test sample at most is allowed to be less than 31 J, but 21.7 J at minimum; the KV2 index of the small sample with the width of 7.5mm, 5mm and 2.5mm is 75%, 50% and 25% of that of the standard sample, respectively.

8.9.4 **Welding of Inner Container Vessel**

8.9.4.1 **Welding Equipment and Identification**

Mechanized gas shielded welding should be adopted for longitudinal and circumferential welded joints of the inner container vessel. After welding, longitudinal and circumferential welded joints shall be indicated and recorded with traceable marks. Hard-printed identification is rejected.

8.9.4.2 **Arc Striking Plate and Arc Extinguishing Plate**

During welding, longitudinal welded joints should be equipped with arc striking plates and arc extinguishing plates. It is not allowed to install art striking plates at non-welded positions of circumferential welded joints. Arc striking plates and arc extinguishing plates should be removed by means of cutting, rather than knocking; after removal, the positions concerened should be smoothed.

8.9.4.3 Welding Samples of Inner Container Vessel Products

8.9.4.3.1 For each batch of inner container vessel, the manufacturer shall produce sample cylinders or welded specimens of products for mechanical property test and bending property test. When the inner container vessel sections of the same batch have different batch numbers, the manufacturer shall produce sample cylinders or welded specimens of products according to different material batch numbers.

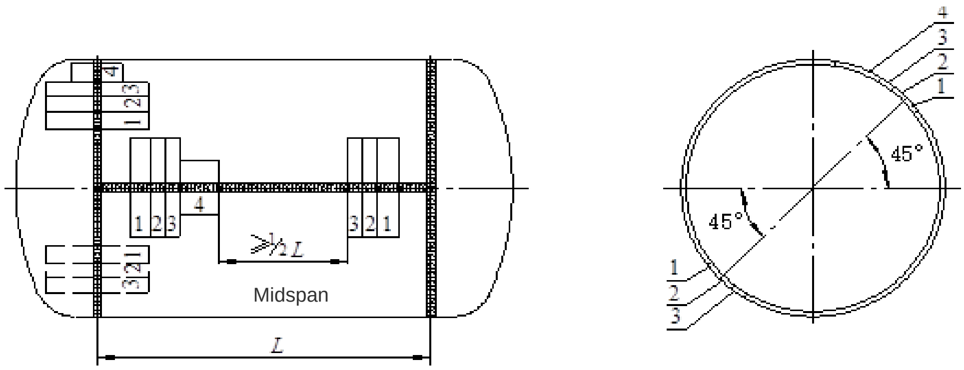
a) When the nominal volume is less than or equal to 100 L, the longitudinal and circumferential welded joints shall be made separately;
b) Longitudinal and circumferential welded joints should be made separately when the welding process is different;

c） When the nominal volume is greater than 100 L and the welding process of longitudinal and circumferential welded joints is the same, longitudinal flat welded specimens can be manufactured only.

8.9.4.3.2 When sample cylinders are used, it is necessary to take samples of longitudinal and circumferential welded joints separately at the sampling positions specified in Fig. 4, after the shape, dimension and appearance of welded joints meet the provisions of Section 8.9.4.4 and their 100% NDT conforms to Section 8.10.4.

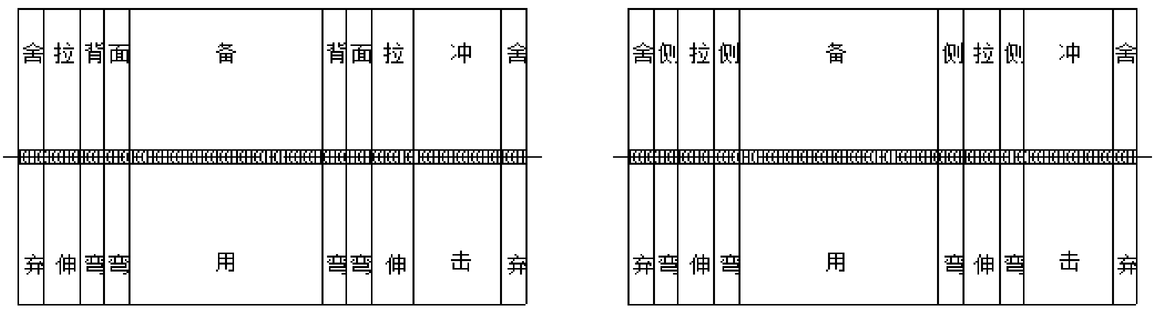
8.9.4.3.3 When flat welding specimens are used, plate-shaped specimens with the same batch number as the inner container cylinder can be placed at the extended part of the cylinder weld and welded together with the represented cylinder; when cylindrical welded specimens are used, their inner diameter should not be greater than the inner diameter of products. Samples shall be taken after the shape, dimension and appearance of welded joints comply with Section 8.9.4.4 and their 100% NDT results comply with Section 8.10.4; the sampling positions of cylindrical and flat welded specimens are respectively specified in Fig. 4 and Fig.5.

8.9.4.3.4 In accordance with Section 8.9. 4.3. 1 a) and Section 8.9. 4.3. 1 b), the manufacturer shall produce one tensile specimen, one horizontal bending specimen, one horizontal back bending specimen and six impact specimens (three welds and three heat affected zones) for longitudinal welded joints and circumferential welded joints. In accordance with Section 8.9. 4.3.1 c), one tensile specimen, one horizontal bend specimen, one horizontal back bend specimen and six impact specimens (three welds and three heat affected zones) shall be prepared for flat welded specimens.



1-Tensile specimen; 2-Surface bending specimen; 3-Back bending specimen; 4-Impact specimen

Fig.4 Sample Position Diagram on Sample Bottle



舍弃 Discarded　拉伸 Stretched　背弯 Back bending　面弯 Surface bending　备用 Stand-by　冲击 Impact　侧弯 Lateral bending

Note: When the width of the discarded part is at least 25mm and the specimen is designed with the arc striking (extinguishing) plates at both ends, it may not be discarded.

Fig. 5 Specimen Position Diagram on Plate-shaped Butt Welded Joint

8.9.4.3.5 Tensile test method, impact test methods (impact temperature is not higher than-192℃), and bending test methods are respectively specified in GB/T 228.1, GB/T 229 and GB/T 2653. Test results shall meet the provisions of Section 8.9.3.4.

8.9.4.3.6 When the actual material thickness of the inner container vessel is not sufficient to make into a 2.5mm weld impact specimen of the product, the specimen is omitted.

8.9.4.4 Shape, Dimension and Appearance of Welded Joints

8.9.4.4.1 The residual height of butt weld of inner container vessel ranges 0mm~2.5mm, and the difference between the widest and narrowest parts of the same weld should not exceed 3mm.

8.9.4.4.2 Welds and base metal should be of smooth transition, and the shape of fillet weld should be of concave smooth transition.

8.9.4.4.3 Welded joints shall be free from undercut, surface cracks, surface porosity, incomplete penetration, incomplete fusion, incomplete filling, arc pit, slag inclusion and spatter.

8.9.4.5 Welding Repair

8.9.4.5.1 Welded joints of inner container vessel and welded specimens of products shall be repaired according to the repair process. The shape, dimension and appearance inspection results of the repaired parts shall conform to the provisions of Section 8.9.4.4, and the nondestructive inspection results of the repaired parts shall meet the provisions of Section 8.10. 4.

8.9.4.5.2 The number of repairs of the same welded part of the inner container vessel should not exceed twice. Otherwise, the repair should be subject to the approval of the manufacturer's Technical Director. Repair times and repaired parts should be recorded in the production inspection records of the product, and indicated in the product's Certificate of Conformity.

8.10 **Nondestructive Test (NDT)**

8.10.1 The longitudinal and circumferential welded joints of inner container vessel can go through non-destructive test after their shapes, dimensions and appearances conform to the provisions of Section 8.9.4.4.

8.10.2 Longitudinal and circumferential welded joints shall be tested by radiographic test methods (film photosensitivity, digital imaging, computer-aided imaging). When the film photosensitivity method is used, the provisions of NB/T 47013.2 shall be observed; for digital imaging, the test shall comply with the provisions of GB/T 17925 or NB/T 47013.11; when the computer-aided imaging is used, the test shall be conducted according to the provisions of NB/T 47013.14.

8.10.3 Longitudinal and circumferential welded joints of the inner container vessel shall be tested by the following ways:

a) When air pressure is used for pressure test, it is necessary to conduct 100% radiographic test on the longitudinal and circumferential welded joints one by one;

b) When hydraulic pressure is used for pressure test, it is necessary to take 10% of the total longitudinal welded joints from each batch, namely, two longitudinal welded joints at minimum, to conduct 100% radiographic test.

8.10.4 The technical grade of radiographic test is AB. Evaluation of test results and quality classification shall be conducted in accordance with the provisions of NB/T 47013.2, and the class of qualification shall be class II or above.

8.11 **Pressure Test of Inner Container Vessel**

8.11.1 Inner container vessels shall go through pressure test one by one after passing the nondestructive test.

8.11.2 During test, reliable safety protection measures shall be taken, and confirmed and approved by the Manufacturer's Technical Director or Safety Director.

8.11.3 The test shall use two pressure test instruments with the same measuring range and within the validity period of verification, additionally with a measuring range of 1.5~3 times the test pressure (preferably twice the test pressure), an accuracy of not less than 1.6, and a mechanical dial diameter of not less than 100mm.

8.11.4 Hydraulic test shall be carried out according to the following requirements:

——Clean water with chloride ion content of not higher than 25 mg/L shall be used;

——The test shall be carried out in accordance with the procedures and steps under GB/T 9251;

——There should be no pressure drop, leakage, visible macro deformation and abnormal sound when the pressure is kept unchanged;

——After the hydraulic test, the operator shall promptly drain the water in the inner container vessel and nozzle, and keep them dry.

8.11.5 The air pressure test shall be carried out according to the following requirements:

——Use dry and clean air, nitrogen or other inert gases;

——During the test, slowly increase the pressure to 10% of the test pressure, conduct primary check on all welded joints and connecting parts by keep the pressure unchanged, and then continue to increase the pressure to 50% of the test pressure after confirming that there is no leakage; if there is no abnormal phenomenon, then increase the pressure step by step according to 10% of the test pressure until it reaches the test pressure, keep that pressure for at least 30s and make it fully expanded; then, decrease the test pressure to the nominal working pressure and conduct inspection by keeping the pressure unchanged;

——There should be no pressure drop, leakage, visible macro deformation and abnormal sound when the pressure is kept unchanged;

8.11.6 If there is leakage in the welded joint during the test, the pressure test shall be carried out again according to Section 8.9.4.5 after the repair is qualified.

8. 12 **Surface Quality and Cleanliness**

8.12.1 The surfaces of plates shall be free from defects which may affect normal use. Sharp scratches shall be grinded with a maximum grinding inclination of 1: 3. Grinded positions should be smooth. The thickness of the inner container vessel should meet the requirements of Section 7.2 and the shell thickness should meet the requirements of Section 7.3.

8.12.2 In accordance with the provisions of JB/T 6896, the parts formed (or in) vacuum space should be treated by appropriate methods, and well-protected after treatment.

8.12.3 Parts in direct contact with oxygen should be treated with hydrocarbons (oil, grease, etc.) according to the methods specified in JB/T 6896, and the recommended methods include oil concentration determination method and mass method. Residual hydrocarbons after treatment should not exceed 125 mg/m^2.

8. 13 **Vacuum-jacketed Leakage Rate**

Before vacuuming, test shall be carried out according to the method specified in GB/T 18443.3 and the frequency specified in Table 8, with test results meeting the requirements of Section 7.1.3.

8. 14 **Vacuum-jacketed Leak-outgassing Rate**

After end of vacuumization, the test shall be carried out according to the method specified in GB/T 18443.4 and the frequency specified in Table 8, with test results meeting the requirements of Section 7.1.3.

8. 15 **Leakage Test**

Once assesmbled, valves, instruments and safety pressure relief devices shall be tested according to the method specified in GB/T 12137 and the frequency specified in Table 8. When the pressure is kept unchanged, there should be no pressure drop and leakage.

8. 16 Low Temperature Vacuum Degree

After the liquid nitrogen is filled and thermal equilibrium is achieved, measurement shall be conducted according to the method specified in GB/T 18443.2 and the frequency specified in Table 8. The interlayer pressure shall not be higher than 2×10^{-2} Pa.

8. 17 Static Evaporation Rate

After manufacture, the test shall be carried out according to the method specified in GB/T 18443.5 and the frequency specified in Table 8, with test results meeting the requirements of Section7.1.3.

8. 18 Volume and Mass

8.18.1 Volume Measurement

The volume of the inner container vessel can be measured according to the method specified in GB/T 18443.8 and the frequency specified in Table 8, and the water volume should not be less than the nominal volume.

8.18.2 Mass Measurement

After manufacture, the tare of gas cylinder shall be measured according to the frequency specified in Table 8 by using a weighing instrument whose weighing range is 1.5~3 times the actual mass and whose accuracy shall meet the requirements for minimum weighing errors.

8. 19 Rounding Rules

For a measured value of volume, ones place higher than five shall be discarded, or it is rounded to five; the number after decimal point should be discarded for the tare and maximum filling volume of the cylinder. Significant digits shall be rounded to single digits. The data is the volume or mass marked on the nameplate. Examples are as follows:

Table 7 Rounding Examples

Measured	Volume (L)	Mass (kg)	
		Tare of cylinder	Maximum filling volume
10.67	10	10	10
104.45	100	104	104
177.78	175	177	177

8. 20 Inspection Rules

8.20.1 Items and Frequency

The items and frequency of product inspection and type test, as well as methods and judgment basis, shall be specified in Table 8.

Table 8 Inspection Items, Frequency, Method and Judgment Basis

No.	Inspection items		Inspection frequency			Inspection method	Judgment basis
			Test one by one	Batch inspection	Type test		
1	Re-inspection of main material of inner container vessel			Δ[a、b]	Δ	6.1.5	6.1.5
2	Cylinder	Longitudinal weld misalignment b	Δ			8.5. 1	8.5. 1
3		Circumferential angular height of longitudinal weld	Δ			8.5. 1	8.5. 1

No.	Inspection items		Inspection frequency			Inspection method	Judgment basis
			Test one by one	Batch inspection	Type test		
		E					
4		Difference between maximum and minimum diameters the same section, e	Δ			8.5. 2	8.5. 2
5		Measured minimum thickness S_b	Δ				Design documents
6	Head C	Appearance		Δ		8.6. 2	8.6. 2
7	Head C	Inner circumference tolerance $\Delta\pi D_i$		Δ		8.6. 3	8.6. 3
8	Head C	Gap between curved surface and template, a		Δ		8.6. 3	8.6. 3
9	Head C	Surface convexity, c		Δ		8.6. 3	8.6. 3
10	Head C	Difference between maximum and minimum diameters, e		Δ		8.6. 3	8.6. 3
11	Head C	Internal height tolerance ΔH_i		Δ		8.6. 3	8.6. 3
12	Head C	Straight gradient		Δ		8.6. 3	8.6. 3
13	Head C	Minimum thickness after forming S_f	Δ				Design documents
14	Circumferential misalignment b		Δ			8.8. 2	8.8. 2
15	Axial angular height E		Δ			8.8. 2	8.8. 2
16	Mechanical properties of welded samples of inner container products			Δ	Δ	8.9. 4.3	8.9. 3.4
17	Shape, dimensions and appearance of welded joints		Δ			8.9. 4.4	8.9. 4.4
18	Nondestructive testing [d]					8.10	8.10
19	Pressure test of inner container vessel		Δ			8.11	8.11
20	Surface quality and cleanliness		Δ			8.12	8.12
21	Vacuum-jacketed leakage rate		Δ e	Δ[e]	Δ	8.13	7.1.3
22	Vacuum-jacketed leak-outgassing rate				Δ	8.14	7.1.3
23	Leakage test		Δ			8.15	8.15
24	Low temperature vacuum degree				Δ	8.16	8.16
25	Static evaporation rate [f]			Δ	Δ	8.17	7.1.3
26	Nominal volume		Δ			8.18. 1	8.18. 1
27	Tare of cylinder		Δ			8.18. 2	
28	Grounding resistance [g]		Δ				7.1.6.5
29	Vibration test				Δ	Appendix E	Appendix E
30	Drop test				Δ	Appendix F	Appendix F

a Δ represents an inspection item;

b The batch inspection means that the chemical composition is inspected according to the furnace number of the materials and the mechanical properties according to the product batch number of the materials;

c The number of heads to be inspection shall be determined by the cylinder manufacturer;

d The frequency of nondestructive testing of welded joints of inner container vessel shall be determined according to Section 8.10.3;

e Cylinder manufacturer chooses “Inspection one by one” or “Batch inspection” according to their own specific conditions;

if The sampling quantity of type test shall not be less than one, while the sampling quantity of each batch of products shall not be less than three during batch inspection;

g This is only applicable to LNG cylinders.

8.20.2 **Re-inspection Rules**

8.20.2.1 In batch inspection, if an inspection item is unqualified and still unqualified after re-inspection, it shall be disposed of according to the provisions of Table 9.

Table 9 Rules for Nonconformity Disposal after Reinspection

Inspection items	Main material of inner container vessel	Shape and appearance of head, etc.	Mechanical properties of welded samples of inner container products	Nondestructive testing of welded joints of inner container vessel	Static evaporation rate
Quantity of re-inspection	According to Section 8.20.2.2	According to 8.20. 2.3	According to Section 8.20.2.4	According to Section 8.20. 2.5	According to Section 8.20. 2.6
Still unqualified after re-inspection	Inspected one by one	Inspected one by one	This batch of products is unqualified	Inspected one by one	Inspected one by one

8.20.2.2 If any chemical composition or mechanical property of the main materials of the inner container vessel is unqualified, the number of re-inspected samples, sampling position, sample preparation, and test method shall be specified in the standards for materials. As each chemical composition is one item, it is only necessary to re-inspect the content of the unqualified composition.

8.20.2.3 If the head is unqualified through inspection, the cylinder manufacturer shall determine the re-inspection quantity according to actual conditions.

8.20.2.4 If there is any nonconformity in the mechanical properties and bending test of welded samples of inner container products, the manufacturer is allowed to take samples from the original sample cylinder or welded samples of original products for re-inspection of unqualified items. Sampling position, sampling quantity, sample preparation, and test method of re-inspected samples shall meet the provisions of Section 8.9.4.3. The results of tensile test, transverse surface bending and transverse back bending shall comply with the provisions of Section 8.9.3.4. The average value of the two groups of impact specimens is not less than 31 J. Two specimens are allowed to be less than 31 J, but only one specimen is allowed to be less than 21.7 J.

8.20.2.5 If there is any nonconformity in the longitudinal welded joints tested in accordance with Section 8.10.3 b), the re-inspection quantity shall not be less than twice as specified in Section 8.10.3 b).

8.20.2.6 If the static evaporation rate is unqualified, at least six samples shall be taken for re-inspection.

8.20.2.7 If there is evidence that nonconformity is attributed to an operational error or test equipment failure, a second test can be carried out. If the second test result is qualified, the results of the first test can be ignored; otherwise, the circumstance shall be handled according to re-inspection rules.

9 Type Test

9.1 Type test shall be carried out under any of the following circumstances:

——Newly developed cylinders;

——Cylinders manufactured for the first time by the manufacturer;

——The first batch of cylinders whose manufacturing was suspended for 12 months and put into manufacturing again;

——Cylinders based on transformation of those conforming to the requirements of Section 9.3.

9.2 The items of type test shall be specified in Table 8; samples shall be taken from the same batch of cylinders (inner container vessels), with the base number specified as follows:

——Not less than 15 cylinder manufactured for the first time;

——The base number of cylinders not manufactured for the first time shall not be less than three times the number of sample cylinders for test;

——At least three inner container vessels shall be provided in case of sampling with sample cylinders.

9.3 In case of any change in designs, the manufacturer shall provide the changed contents to the appraisal institution of design documents. When a change involves any items specified in Table 10, relevant tests shall be carried out according to the type test items specified in Table 10.

Table 10 Items Requiring Type Test after Change

Type test items	Change item					
	Thermal insulation system	Connector between inner container vessel and outer shell	Material type of inner container vessel	Thickness of inner container vessel	Container volume [a]	Frame or protective cover
Chemical composition of materials			Δ [b]	Δ		
Mechanical properties of materials			Δ	Δ		
Mechanical properties of welded samples of products			Δ	Δ [c]		
Vacuum-jacketed					Δ	

Type test items	Change item					
	Thermal insulation system	Connector between inner container vessel and outer shell	Material type of inner container vessel	Thickness of inner container vessel	Container volume [a]	Frame or protective cover
leakage rate						
Vacuum-jacketed leak-outgassing rate	Δ				Δ	
Low temperature vacuum degree					Δ	
Static evaporation rate	Δ	Δ [d]		Δ [e]	Δ	
Vibration test		Δ [f]		Δ	Δ [g, h]	Δ
Drop test		Δ [f]			Δ [g, h]	Δ

[a] If the volume change rate only caused by the change of length does not exceed 100% of the volume of the tested cylinder that has passed the test, the tests except for vibration test and drop test can be omitted;
[b] Δ represents an inspection item;
[c] WPQ shall be conducted on the change of wall thickness according to Table 2 of GB/T 33209-2016;
[d] The test may be omitted when the change rate of sectional area of connectors is not more than 20%;
[e] If the thick-walled gas cylinder with the same nominal diameter and nominal volume has passed the test verification, the test may be omitted when the wall thickness becomes thinner due to the decrease of nominal working pressure;
[f] The test may be omitted if the sectional area of the connector becomes larger;
[g] The test may be omitted when volume changes only along with the change of length under the following situations: the decrease is not more than 100% of the volume of the tested cylinder that has passed the test, while the increase does not exceed 20% of the volume of the tested cylinder that has passed the test;
[h] The test may be omitted when the cylinder's filling mass is less than that of the same type of tested cylinder that has passed the test.

10 Marking, Packaging and Transportation

10.1 The nameplate shall be securely welded or riveted to parts or non-detachable accessories. The contents of nameplate shall be made through mechanical printing, laser printing, etching, engraving and by other methods that can form permanent marks. The nameplate contains at least the following contents:

——Cylinder type;
——Cylinder number;
——Product standard number;
——Name of filling medium (one type allowed);
——Nominal volume;
——Nominal working pressure;
——Proof test pressure of inner container vessel;
——Tare of cylinder;
——Maximum filling volume;
——Name of manufacturer;
——Code of manufacturer;
——Manufacturing license number;
——Date of manufacture;
——Inspection and supervision seals;
——Design service life.

10.2 With the background color and word color as specified in GB/T 7144, a reasonable layout, and a size of not less than 300mm×300mm, labels shall be pasted on the easily observed position of the cylinder and resistant to tearing. A label should contain at least the following:

——The words "welded insulated cylinder";
——Cylinder type;

——Nominal working pressure;
——Proof test pressure of inner container vessel;
——Name of filling medium (one type allowed);
——Main characteristics of medium (including but not limited to low temperature, flammability and asphyxiation);
——Warning label (according to GB/T 16804);
——First aid measures (including but not limited to treatment of low temperature burns and first aid of suffocation);
——Necessary warning contents (e.g., natural gas cylinder should be marked with such words as "Prohibition of Use in Closed or Poorly Ventilated Space" and "No Fire Sources"; vertical cylinders should be marked with such words as "Keep upright" or "No Horizontal Placement").

10.3 Permanent electronic reading marks should be set before the ex-factory of LNG cylinders (recommendable similarly for other types of cylinders). Reading marks should be linked to the product publicity platform established by the manufacturer through mobile phone scanning, and should directly provide the information of each product. Permanent electronic reading marks of LNG cylinders shall be non-replaceable and can be effectively readable during the service life.

10.4 An inner container vessel should be filled with dry nitrogen of not greater than 0.1 MPa upon ex-factory.

10.5 Packaging shall be in accordance with the Design Documents or user requirements.

10.6 Accessories should be prevented from collision, damp and damage during transportation, loading and unloading.

11 Ex-factory Data

11.1 Product Certificate

Each gas cylinder shall have a product certificate in the format as shown in Appendix G.

11.2 Quality Certificate for Batch Inspection

11.2.1 See Appendix H for the content and format of Quality Certificate for Batch Inspection.

11.2.2 Each batch shall be provided with a Quality Certificate for Batch Inspection. When a copy of Quality Certificate for Batch Inspection is to be provided to users, it should be stamped with the inspection seal of the manufacturer.

11.3 Product Manual

The manufacturer shall provide users the Product Manual, which shall at least include product introduction, design standards, structure and performance, product use guidelines (gas properties, filling, transportation, storage, periodic inspection, color marks, basic safety requirements users should observe, etc.), first aid measures, etc.

12 Data Retention

12.1 Technical data such as design appraisal documents, type test reports, various process evaluation reports, and process documents shall be kept as archive information for a long time.

12.2 Product archives include quality certificate of materials, re-inspection reports of materials, welding records, nondestructive test, pressure test, and other quality and record reports generated in the process of manufacturing and inspection. The quality certificate for product batch inspection and the certificate for product supervision and inspection shall be kept for at least 20 years. Product archives can made in paper or electronic forms.

Appendix A

(Normative)

Requirements for Liquid Carbon Dioxide and Liquid Nitrous Oxide

A.1 Overview

Liquid carbon dioxide and liquid nitrous oxide shall be in conformity with the special requirements in this Appendix, while others shall meet the provisions of the text of this Appendix and other appendixes hereto.

A.2 General Requirements

The nominal volume ranges between 10 L～1 000 L.

The design temperature shall not be higher than-196 ℃ when liquid nitrogen is used as test medium.

The effective volume shall not be greater than 95% of the nominal volume.

In any case, the liquid phase volume shall not exceed 98% of the nominal volume when the pressure reaches the set-pressure of the master safety pressure relief device.

A.3 Particular Requirements for Liquid Carbon Dioxide

The nominal working pressure should not be lower than the triple point of liquid carbon dioxide.

The design temperature shall not be higher than-56.7 ℃. If liquid nitrogen is used as the test medium, it shall meet the requirements of A.2.2.

Only safety valves can be used as pressure relief devices. The master safety valve and auxiliary safety valve are respectively specified in Section 7.4. 3.2 a) and Section 7.4. 3.3 a).

The evaporation rate shall meet the requirements of Section 7.1.3, or may be replaced by the following boosting rate test:

a) Use two pressure test instruments with the same measuring range and within the validity period of verification, additionally with a measuring range of 1.5~3 times the test pressure (preferably twice the test pressure), an accuracy of not less than 1.6, and a mechanical dial diameter of not less than 100mm;

b) First confirm that the gas cylinder used for testing has been completely cooled, and then fill it with an effective volume of liquid carbon dioxide, with the pressure of the filled cylinder exceeding 1.5 MPa;;

c) Keep the cylinder still, start to test when the pressure in the cylinder reaches 2.0 MPa, and continue testing for at least 24h;

d) Record cylinder pressure and ambient temperature every two hours;

e) The speed of pressurization should not be greater than 35 kPa/d when the measured value is converted to ambient temperature of 20℃.

A.4 Special Requirements for Liquid Nitrous Oxide

The design temperature shall not be higher than-88 ℃. If liquid nitrogen is used as the test medium, it shall meet the requirements of A.2. 2.

The evaporation rate shall meet the requirements of 7.1.3, or is the evaporation rate of liquid nitrous oxide which is used as the test medium as agreed by the supplier and the buyer.

The head at the valve end shall be marked with an obviously raised medium symbol of “N2O”, whose font height shall not be less than 40mm.

Table A.1 Partial Properties of Liquid Carbon Dioxide and Liquid Nitrous Oxide

Medium	Molar mass kg/kmol	Gas characteristic coefficient C	Gas adiabatic coefficient k	Critical pressure P_{cr} MPa (absolute pressure)	Critical temperature K	Critical density ρ_{cr} kg/m^3	Liquid density kg/m^3
Liquid carbon dioxide	44.01	347	1.30	7.397	304.25	467.60	1 106
Liquid nitrous oxide	44.01	347	1.30	7.265	309.65	452.01	1 237.6
Note 1: The adiabatic index of gas is 1.01325×10^5 Pa (absolute pressure) at the temperature of 15℃; Note 2: The liquid density of liquid carbon dioxide is the boiling point at 1.0MPa, while that of liquid nitrous oxide is the boiling point at 1.01325×10^5 Pa (absolute pressure).							

Appendix B

(Normative)

Maximum Allowable Filling Factor

B.1. **Overview**

Liquefied gas will expand due to the introduction of external heat till it fills the cylinder and causes danger. For purpose of avoiding danger, this Appendix makes restrictions on filling.

B.2. **Description**

B.2.1 For liquid oxygen, liquid nitrogen, liquid argon, liquid carbon dioxide, and liquid nitrous oxide, the maximum allowable filling coefficient is the sum of the product of 0.98 and the saturated liquid density at the set-pressure of the master safety valve plus the product of 0.02 and the saturated vapor density at the set-pressure of the master safety valve; for LNG (methane), the maximum allowable filling coefficient is the sum of the product of 0.95 and the saturated liquid density at the set-pressure of the master safety valve plus the product of 0.05 and the saturated vapor density at the set-pressure of the master safety valve.

B.2.2 Given that LNG is calculated on the basis of methane, the manufacturer should calculate the maximum allowable filling coefficient according to the actual characteristics of LNG.

B.2.3 When the set-pressure is equal to or greater than the critical pressure, the maximum allowable filling coefficient is the critical density.

Table B.1 Maximum Allowable Filling Coefficient Unit: kg/L

Master relief valve set-pressure Pz (MPa)	Liquid oxygen	Liquid nitrogen	Liquid argon	LNG (Methane)	Liquid carbon dioxide	Liquid nitrous oxide
0.24	1.050	0.734	1.284	0.377		
0.48	1.010	0.699	1.233	0.362		
0.72	0.978	0.672	1.194	0.350		
0.96	0.951	0.648	1.160	0.340		
1.20	0.927	0.625	1.130	0.331		
1.44	0.904	0.604	1.101	0.323		
1.68	0.883	0.583	1.075	0.315		
1.92	0.863	0.562	1.049	0.307		
2.16	0.843	0.540	1.024	0.299		
2.40	0.823	0.516	0.999	0.291		
2.64	0.803	0.491	0.974	0.284	0.959	0.915
2.88	0.783	0.461	0.949	0.276	0.943	0.899
3.12	0.763	0.419	0.923	0.268	0.928	0.885
3.36	0.742	0.383*	0.895	0.259	0.912	0.870
3.60	0.720		0.867	0.250	0.897	0.856
3.84	0.696		0.835	0.239	0.882	0.841
4.08	0.671		0.800	0.227	0.867	0.827
4.20	0.657		0.780	0.219	0.860	0.819
Note 1: * Represents a value with the pressure of 3.34MPa. Note 2: The median value is interpolated.						

Appendix C

(Normative)

Inlet and Outlet Fittings

C.1 Overview

This Appendix non-equivalently adopts CGA V-1: 2013 *Inlet and Outlet Fittings for Compressed Gas Cylinder Valves* as the standards for inlet and outlet fittings (hereinafter referred to as "fittings" in this Appendix) to prevent potential safety hazards or accidents caused by incompatible media mixing.

C.2 Basic Requirements

C.2.1 The working pressure shall not be lower than 3.5 MPa and the bursting pressure shall not be lower than 14.0 MPa.

C.2.2 The material shall be compatible with loading medium, additionally in conformity with the requirements for strength and adaptability to the matching valves and external nozzles. The Quality Certificate for Materials shall be obtained.

C.2.3 LNG joints are left-hand threaded, while the rest is right-hand threaded.

C.2.4 The external thread crest with appropriate flattening (passivation) guide threads is permitted as long as it has no effect on the sealing performance and overall strength.

C.2.5 The class of tolerance without an indication of linear dimensions shall be in conformity with the provisions of GB/T 1804, with medium class m for machined surfaces and rough class Ra3.2 for sealed surfaces.

C.2.6 "WP 3.5 MPa" (WP represents working pressure), "CGA ×××" ("×××" as specified in Table C.1) shall be engraved or stamped in the obvious position of any of the six surfaces of the fitting prism, with font height of not be less than 3.5mm.

C.2.7 The number of batches should not be greater than the batch number of materials.

C.3 Test Requirements

C.3.1 Test Conditions

The test shall be carried out under the following conditions:

——Test under ambient atmospheric pressure and ambient temperature;

——Use two pressure test instruments with the same measuring range and within the validity period of verification, additionally with a measuring range of 1.5~3 times the test pressure (preferably twice the test pressure), an accuracy of not less than 1.6, and a mechanical dial diameter of not less than 100mm.

C.3.2 Leakage Rate Test

The leakage rate test shall be carried out and accepted according to the following requirements:

a) Take at least five samples per batch to connect and tighten with test tooling (i.e., matching nuts, gaskets, fitting, and pipes), and test devices;

b) Fill clean inert gas and increase the pressure to 3.5 MPa;;

c) Submerge samples and test tooling into water and keep the pressure unchanged for at least 5min;

d) Keep the total leakage rate of five samples below $1.67mm^3/s$.

C.3.3 Cyclic Test

The cyclic testing shall be conducted and accepted according to the following requirements:

a) Take at least five samples per batch to measure and record data (i.e., threads, hole sizes and other dimensions that may change due to repeated tightening);

b) Measure and record the torque when samples are sealed with the test tooling under the pressure of 3.5 MPa;

c) Continue to screw up to twice the measured torque, and then mark the relative position between samples and the test tooling;

d) Loosen to the extent that the samples can be screwed by hand, and then screw them up to the mark position in c.3. 3 c) for a cycle;

e) Measure and record the data of c.3. 3 a) after the operation every 100 cycles;

f) Conduct the operation of at least 500 cycles per sample;

g) Carry out the leakage test after the cyclic test according to Section C.3. 2, with test results meeting the requirements of Section C.3.2.

C.3.4 Strength Test

Strength test shall be carried out and accepted according to the following requirements:

a) Take at least five samples per batch for strength test;

b) Carry out the pressure test under at least 14.0 MPa for each sample, and keep the pressure unchanged for not less than 5min;

c) Observe that samples have no permanent deformation and rupture after the strength test.

C.4 Connection Mode with Valve

Fittings shall be connected to valves in any of the following ways:

——By silver brazing and welding;

——As a whole (part of the valve seat);

——Connection via an anti-disassembly device which can be disassembled only by special tools.

C.5 Fitting Code and Pairing Nozzle

Filling port, liquid outlet (or both), gas use port, and venting port (or both) shall be equipped with corresponding fittings according to the provisions of Table C.1.

Table C.1 Fitting Code and Pairing Nozzle

Medium	Filling port	Liquid outlet	Gas use port	Vent port (full port)
Liquid oxygen	CGA 440		CGA 540	CGA 440
Liquid nitrogen	CGA 295		CGA 580	CGA 295
Liquid argon	CGA 295		CGA 580	CGA 295
LNG (methane)	CGA 450		CGA 450	CGA 450
Liquid carbon dioxide	CGA 622		CGA 320	CGA 295
Liquid nitrous oxide	CGA 624		CGA 326	CGA 624

Appendix D

(Normative)

Calculation of Safety Relief Volume and Required Safety Pressure Relief Device Area

D.1 Safety Relief Volume

D.1.1 The safe relief volume shall be calculated according to Formula (D.1) in the following conditions: the insulation blanket of the gas cylinder is intact or deteriorated; the interlayer space is filled with gaseous storage medium or air under atmospheric pressure; and the outside is ambient temperature:

$$Q_{a1}=\frac{0.383\,(328-T)G_i U_1 A_r}{922-T} \quad \cdots\cdots 1(D.1)$$

Where:

A_r——The arithmetic mean of heating area, inner and outer surface area of insulation blanket, m^2;

G_i——The gas coefficient of medium under the pressure P_f;

P_f——The Relief pressure of the safety valve or the design burst pressure of the bursting disc safety device (converted into absolute pressure during calculation), MPa;

Q_{a1}——Safe relief volume converted to free air or free gas (volume flow), m^3/h;

T——The temperature of the medium at the inlet of safety device under the pressure P_f, K;

U_1——Heat transfer coefficient, kJ/(h·m^2·℃）, $U_1=\lambda_1/\delta$;

λ_1——Thermal conductivity which should be actually measured by the manufacturer, or can also refer to the value in Table D.1 when there is no data, kJ/(h·m·℃);

δ——Insulation thickness, excluding vacuum space, space occupied by degraded insulation, m.

Here, the value of U_1 is that of the insulation system at the external temperature of 328 K (55 ℃) and the internal temperature at the saturation temperature of the medium at the Relief pressure (or design burst pressure).

D.1.2 The safe relief volume shall be calculated according to Formula (D.2) in the following conditions: The thermal insulation of the gas cylinder is intact or deteriorated; the interlayer space is filled with gaseous storage medium or air under atmospheric pressure; and the outside is in fire or high temperature of 922 K (649 ℃).

$$Q_{a2}=G_i U_2 A_r^{0.82} \quad \cdots\cdots 2(D.2)$$

Where:

Q_{a2}——Safe relief volume converted to free air or free gas (volume flow), m^3/h;

U_2——Heat transfer coefficient, kJ/（h·m^2·℃）, $U_2=\lambda_2/\delta$;

λ_2——Thermal conductivity, preferably measured by the manufacturer, or by referring to the value in Table D.1, kJ/(h·m·℃) if such data is unavailable.

Here, the value of U_2 is measured under the external temperature of the insulation system of 922K and at the saturation temperature of the medium at the Relief pressure (or design burst pressure).

Table D.1 Thermal Conductivity

Medium	Oxygen	Nitrogen	Argon	Methane	Carbon dioxide	Nitrous oxide
λ_1	0.0684	0.0684	0.0468	0.0864	0.0612	0.0504
λ_2	0.1560	0.1447	0.0985	0.2681	0.1421	0.1368
Note 1: The interlayer pressure is 1.01325×10^5 Pa (absolute pressure); Note 2: λ_1 is the average value of liquid saturation temperature and 328 K; Note 3: λ_2 is the average value of liquid saturation temperature and 922 K.						

D.2 Conversion of Mass Flow Rate and Volume Flow Rate

The conversion between mass flow rate and volume flow rate is specified in Formula (D.3).

$$W_s = \frac{Q_a C}{92.34}\sqrt{\frac{M}{ZT}} \quad \text{(D.3)}$$

Where:

C——Gas characteristic coefficient, obtained by referring to Table 1 of GB/T 33215-2016 or the following formula:

$$C = 520 \times \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}};$$

k——Adiabatic exponent of gas;

M——The molar mass of the medium, kg/kmol;

Q_a——The general name of Q_{a1} and Q_{a2};

W_s——Safe relief volume (mass flow), kg/h;

Z——Gas compressibility factor.

D.3 Required Relief Area of Safety Pressure Relief Device

The relief area of safety pressure relief device shall be calculated according to Formula (D.4):

$$A_0 \geq \frac{W_s}{7.6\times10^{-2}CKP_f}\sqrt{\frac{ZT}{M}} \quad \text{(D.4)}$$

Where:

A_0——Relief area of safety pressure relief device, mm^2;

K——Relief coefficient of safety pressure relief device; it depends on the type and structure of the pressure relief device: the bursting disc device should not be greater than 0.6 in general, and the safety valve should be determined by the actual measurement of the pressure relief device manufacturer.

D.4 Gas Compressibility Factor Z

The gas compressibility factor shall be selected in accordance with Table D.2 or by referring to Figure GB/T 33215-2016 Appendix A. When the pressure falls outside the range of Table D.2, the value of Z can be calculated according to Formula (D.5). When it is impossible to determine the gas compressibility factor, Z=1.

$$Z = \frac{10^6 MP_f}{R\rho_g T} \quad \text{(D.5)}$$

Where:

R——General gas constant, R =8 314 N·m/(kmol·K);

ρ_g——Saturated vapor density of medium under the pressure P_f, kg/m^3.

Table D.2 Gas Compressibility Factor Z

Relief pressure of safety pressure relief device P_f (MPa) (absolute pressure)	Liquid oxygen	Liquid nitrogen	Liquid argon	Liquefied natural gas (Methane)	Liquid carbon dioxide	Liquid nitrous oxide
0.364	0.919 6	0.894 2	0.916 2	0.912 2		
0.452	0.906 3	0.877 0	0.902 6	0.898 1		
0.628	0.882 0	0.845 4	0.877 9	0.872 3		
0.804	0.859 8	0.816 3	0.855 2	0.848 7		
0.892	0.849 2	0.802 4	0.844 5	0.837 5		
1.156	0.819 2	0.762 4	0.813 9	0.805 5		
1.420	0.790 9	0.724 0	0.785 1	0.775 4		
1.508	0.781 8	0.711 4	0.775 8	0.765 7		
1.684	0.763 9	0.686 3	0.757 5	0.746 4		
1.860	0.746 4	0.661 2	0.739 5	0.727 6		
1.948	0.737 7	0.648 5	0.730 6	0.718 2		
2.212	0.711 2	0.609 8	0.704 2	0.690 3		
2.476	0.686 5	0.569 1	0.678 0	0.662 5		
2.564	0.678 0	0.554 8	0.669 2	0.653 2		
2.740	0.661 0	0.524 6	0.651 6	0.634 4		
2.916	0.643 9	0.491 3	0.633 9	0.615 3		
3.004	0.635 3	0.472 8	0.624 9	0.605 6	0.724 1	0.718 4
3.268	0.609 1	0.400 9	0.597 4	0.575 8	0.706 3	0.700 5
3.532	0.582 0		0.568 9	0.544 2	0.688 5	0.682 7
3.620	0.572 7		0.559 0	0.533 1	0.682 6	0.676 7
3.796	0.553 6		0.538 6	0.509 9	0.670 7	0.664 9
3.972	0.533 6		0.517 0	0.484 6	0.658 9	0.653 0
4.060	0.523 2		0.505 6	0.470 9	0.652 9	0.647 0
4.324	0.489 7		0.468 1	0.422 1	0.635 0	0.629 0
4.588	0.450 8		0.421 1		0.616 8	0.610 7
4.676	0.435 7		0.400 8		0.610 6	0.604 5
4.720	0.427 5				0.607 6	0.601 4
5.028	0.330 2				0.585 7	0.579 3
5.380					0.559 8	0.553 0
5.732					0.532 4	0.525 0
6.084					0.503 0	0.494 6
6.260					0.487 2	0.478 0

D.5 Gas Coefficient G_i

D.5.1 When $P_f < P_{cr}$, the gas coefficient is calculated by Formula (D.6):

$$G_i = \frac{241\times(922-T)}{qC}\sqrt{\frac{ZT}{M}} \quad \text{(D.6)}$$

Where:

q——Latent heat of vaporization at the pressure P_f, kJ/kg;

P_{cr}——The critical pressure of the medium, MPa.

D.5.2 When $P_f \geq P_{cr}$, the gas coefficient is calculated by Formula (D.7):

$$G_i = \frac{241\times(922-T)}{\theta C}\sqrt{\frac{ZT}{M}} \quad \text{(D.7)}$$

Where:

θ——Heat input $\theta = \upsilon\left(\frac{\partial h}{\partial \upsilon}\right)_P$, the maximum value at the pressure P_f and temperature $\frac{\sqrt{\upsilon}}{\left[\upsilon\left(\frac{\partial h}{\partial \upsilon}\right)_P\right]}$, kg/kJ;

υ——The specific volume of the medium at the pressure P_f and any temperature within the range of operating temperature, m^3/kg.

Table D.3 Gas Coefficient G_i

Relief pressure of safety pressure relief device P_f (MPa) (absolute pressure)	Liquid oxygen	Liquid nitrogen	Liquid argon	Liquefied natural gas (Methane)	Liquid carbon dioxide	Liquid nitrous oxide
0.364	4.865	5.299	5.357	3.156		
0.452	4.976	5.446	5.480	3.225		
0.628	5.168	5.709	5.694	3.345		
0.804	5.377	5.952	5.884	3.453		
0.892	5.417	6.070	5.973	3.504		
1.156	5.645	6.427	6.230	3.652		
1.420	5.865	6.802	6.480	3.797		
1.508	5.939	6.935	6.563	3.847		
1.684	6.087	7.217	6.733	3.974		
1.860	6.239	7.528	6.907	4.052		
1.948	6.317	7.697	6.997	4.106		
2.212	6.560	8.283	7.278	4.278		
2.476	6.822	9.047	7.585	4.469		
2.564	6.916	9.363	7.695	4.539		
2.740	7.112	10.142	7.929	4.688		
2.916	7.326	11.245	8.184	4.854		
3.004	7.440	12.015	8.322	4.945	3.886	4.024
3.268	7.819	17.250	8.786	5.259	3.962	4.128
3.532	8.271		9.352	5.661	4.063	4.228
3.620	8.443		9.573	5.824	4.098	4.264
3.796	8.831		10.079	6.215	4.171	4.340
3.972	9.294		10.704	6.735	4.247	4.419
4.060	9.564		11.079	7.073	4.287	4.461
4.324	10.602		12.628	8.787	4.413	4.593
4.588	12.303		15.712		4.550	4.739
4.676	13.187		17.803		4.602	4.791
4.720	13.741				4.628	4.818
5.028	38.029				4.822	5.024
5.380					5.087	5.306
5.732					5.417	5.662
6.084					5.851	6.141
6.260					6.130	6.457

D.6 Partial Properties of Gas

Table D.4 Partial Properties of Gas

Medium	Molar mass kg/kmol	Gas characteristic coefficient C	Gas adiabatic index k	Critical pressure P_{cr} MPa (absolute pressure)	Critical temperature T_{cr} K	Critical density P_{cr} MPa	Liquid density kg/m^3
Liquid oxygen	31.998 8	356	1.40	5.043	154.35	436.144	1 141.17
Liquid nitrogen	28.0134	356	1.40	3.394	126.05	313.3	806.084
Liquid argon	39.948	378	1.67	4.863	150.69	535.599	1 395.40
LNG(methane)	16.043	348	1.31	4.5992	190.65	162.658	422.356
Note 1: The adiabatic index of gas is 1.01325×10^5 Pa (absolute pressure) at the temperature of 15 ℃.							

D.7 Example of Supercritical Pressure θ Value

For liquid nitrogen with nominal working pressure P=2.8 MPa, the set-pressure of master safety pressure relief device (safety valve) is $P_z\leq1.2\times2.8=3.36$ MPa, then the relief pressure of master safety pressure relief device is $P_f\leq1.1\times3.36=3.696$ MPa, and the absolute pressure is 3.796 MPa; as the maximum value is determined, the value θ is thus determined.

Temperature (K)	128.50	130.50	132.50	132.81	132.82	134.50

Temperature (K)	128.50	130.50	132.50	132.81	132.82	134.50
υ（m^3/kg）	0.003 051 0	0.004 747 4	0.005 521 2	0.005 618 0	0.005 621 0	0.006 086 9
θ	72.049	74.585	79.125	79.801	79.823	83.382
$\sqrt{\upsilon}/\theta$	0.000 766 643	0.000 923 797	0.000 939 082	0.000939 252 max	0.000 939 245	0.000 935 677

Appendix E

(Normative)

Vibration Test

E.1 Purpose of Test

Vibration test is intended to simulate the durability of accessories such as connectors between inner container vessel and shell, valve piping system and horizontal cylinder frame (support) under transportation conditions.

Note: Vibration test should be carried out on liquid oxygen cylinders.

E.2 Test Conditions

E.2.1 Filling Medium and Mass

The cylinder should be filled with liquid nitrogen before vibration test. When thermal equilibrium is reached, the volume of liquid nitrogen is about 50% of the effective volume.

E.2.2 Cylinder Status

Before vibration test, the cylinder should be kept in thermal equilibrium, with the pressure of the inner container vessel at 0 MPa. All valves are closed.

E.2.3 Number of Cylinders Tested

All vibration items shall be carried out on one gas cylinder.

E.3 Test Procedures

The test shall be carried out according to the following steps:

a) First, sweep the frequency in the range of 8Hz~40Hz to determine the resonance frequency. If the resonance frequency falls under range specified in Table E.1, the design should be revised to avoid the resonance frequency;

b) Then conduct vibration according to the vibration acceleration and time as specified in Table E.1 and by following the following vibration directions:
   - Vertical: 2g perpendicular to the cylinder axis direction, 3g along the cylinder axis direction;
   - Horizontal: 2g along the cylinder axis direction, and 3g along the vertical direction.

Table E.1 Vibration Acceleration and Superposed Vibration Time

Vibration frequency (Hz)	8	11	15	20	25	30	35	40
2g superposed virbration time (min)	57	41	40	22	18	15	13	11
3g vibration time (min)	113	81	59	45	36	30	25	23

E.4 Test Evaluation

After vibration, the cylinder should be pressurized to the nominal working pressure, and the test results meet the following requirements at the same time:

——No leakage in any part;

——After the cylinder stands still for more than 12 hours, the shell of gas cylinder should not condense or frost (except for the connector between the inner container vessel and the shell).

Appendix F
(Normative)
Drop Test

F.1 Purpose of Test

Drop test is intended to simulate the protection capacity of the shell and protective device to the gas cylinder and the anti-impact ability of the connector between the inner container vessel and the shell under the impact conditions.

F.2 Test Conditions

F.2.1 Impact Surface Requirements

The impact surface shall be a concrete floor with a thickness of not less than 100mm (or a steel plate with a thickness of not less than 10mm) and shall be hard, flat, smooth and horizontal. Each side of the impact surface shall be at least 200mm wider than the maximum projected surface of the cylinder.

F.2.2 Filling Medium and Mass

Before the drop test, the cylinder should be filled with the medium as specified in the Design Documents; the filling mass is the maximum allowable filling volume.

LNG should be used on the condition that a complete safety plan is well-prepared and confirmed and approved by the Technical Director or Safety Director of the test unit. Otherwise, liquid nitrogen should be used instead.

F.2.3 Drop Height

The height of the lowest point of the cylinder from the impact surface shall not be less than 1.5m.

If only liquid nitrogen is used as the test medium, the drop height shall be corrected according to Formula (F.1).

$$H = \frac{1.5M_0}{M} \quad \cdots\cdots 1(F.1)$$

Where:

H——Drop test height, m;

M_0——The sum of the maximum filling volume and the tare of the cylinder, kg;

M——The sum of the actual filling liquid nitrogen mass and the tare of cylinder, kg.

F.2.4 Cylinder Status

Before the drop test, the cylinder should be kept in thermal equilibrium, and the pressure of its inner container vessel should be 90% of the nominal working pressure. The outer shell should be in vacuum, and all valves should be closed.

F.2.5 Impact Surface of Gas Cylinder

During the test, the lower part of the cylinder should be impacted:

——Vertical: Valve end (cylinder axis perpendicular to the ground), bottom (cylinder axis perpendicular to the ground), and cylinder (cylinder axis parallel to the ground);

——Horizontal: Valve end (cylinder axis perpendicular to the ground), bottom (cylinder axis perpendicular to the ground), cylinder side (cylinder axis parallel to the ground, only one side), and cylinder bottom (cylinder axis parallel to the ground);

——If the protective device does not fully protect the valve piping system, this part of the valve piping system shall go through the drop test.

F.2.6 Number of Cylinders Tested

After the drop test of the previous item is qualified, the test of the next item can be carried out on the same gas cylinder when it is judged by the type test institution that the test results of the next item are not affected. Otherwise, the corresponding number of cylinders tested in the test item shall be provided.

F.3 Test Procedures

The test shall be carried out according to the following steps:

a) Measure the total mass, ambient temperature and wind speed before lifting of the cylinder;

b) Use antifreeze to remove frost and water from the parts to be impacted;

c) Raise the gas cylinder to a height not lower than that specified in F.2. 3, and then release the gas cylinder to enable it drop freely; when the gas cylinder is released, all fixing points should be released at the same time;

d) After the gas cylinder falls to the ground, record the information such as the landing point of the gas cylinder, the direction and position on the impact surface with a camera.

F.4 Test Evaluation

After dropping, the deformation of the shell is allowed; however, no leakage should occur in any part within 1h after dropping. There should be no large-area condensation or frosting on the cylinder shell (except for the connection support between the inner container vessel and the shell, and the impacted part).

Appendix G

(Informative)

Certificate of Conformity

XXXX Company
Welded Insulated Gas Cylinder
Certificate of Conformity

Cylinder model

Filling medium

Drawing number

Product No.

Product batch No.

Inner container vessel No.

Batch number of inner container No.

Date of production

Manufacturing license

Valve manufacturer name/manufacturing license No.

This product meets the requirements of GB/T 24159-2021 *Welded Insulated Gas Cylinder*. Certified upon inspection.

Inspected by　　　　Quality Inspection Seal

MM/DD/YY　　　　MM/DD/YY

1. Main technical data

Nominal volume ___L Nominal working pressure______MPa Inner diameter of inner container vessel______mm

Filling medium_____Design wall thickness of cylinder/head for inner container vessel ___/___mm Tare of cylinder___kg

Maximum filling volume___kg Leakage test pressure___MPa Inner container vessel test pressure__MPa (□pneumatic □hydraulic)

2. Data of materials

Steel plate grade of inner container cylinder____ Material standard code____ Material batch number

Steel plate grade of inner container head____ Material standard code____ Material batch number

Standard chemical composition of materials (%):

Inner container cylinder C_____ S _____ P _____ Mn ______ Si _______ Ni ______ Cr

Inner container head C_____ S _____ P _____ Mn ______ Si _______ Ni ______ Cr

Chemical composition of material re-inspection (%):

Inner container cylinder C_____ S _____ P _____ Mn ______ Si _______ Ni ______ Cr

Inner container head C_____ S _____ P _____ Mn ______ Si _______ Ni ______ Cr

Standard strength of material: R_m______________MPa $R_{p0.2}$______________MPa

Strength of material required in design document: R_m______________MPa $R_{p0.2}$______________MPa

Re-inspection strength of materials:

Inner container cylinder R_m____MPa $R_{p0.2}$____MPa Inner container head R_m____MPa $R_{p0.2}$____MPa

3. Non-destructive testing

Standard for nondestructive testing of welded joints of inner container vessel

Non-destructive testing inner container vessel number

Longitudinal welded joint Circumferential welded joint

Detection ratio:

Qualification level/test results _____/_____ _________/

Repair times of welded joints: __joints for once, __joints for twice, and __joints for three 3 times

4. Expanded drawing of repaired part of welded joint of inner container (if any, marked on the sketch)

Instructions for Filling:

1. When there are two batches of materials in the inner container section, the data of materials should be filled in separately.
2. When samples go through non-destructive testing one by one (including one-by-one test after re-inspection result is unqualified), the inner container vessel number and product number shall correspond one by one.
3. When non-destructive testing is a random test, the inner container vessel number can be provided in a serparate page; when re-inspection is needed after sampling inspection, the re-inspection results and repair conditions can be provided in a serparate page.

Appendix H

(Informative)

Quality Certificate of Batch Inspection

XXXX Company
Welded Insulated Cylinder
Quality Certificate of Batch Inspection

Cylinder model

Filling medium

Drawing No.

Product batch No.

Inner container vessel lot No.

Delivery date

Manufacturing license No.

Totally gas cylinders in this batch, with numbers from to

Totally inner container vessels in this batch, with numbers from to

Excluding

This product batch meets the requirements of GB/T 24159-2021 *Welded Insulated Cylinder*.

Certified upon inspection.

Special Seal of Supervision and Inspection Unit Inspection Seal for the Manufacturer

Supervisor Inspected by

MM/DD/YY MM/DD/YY

Address of manufacturer: Postal code:

1. Main technical data

Nominal volume ________L Nominal working pressure______MPa Inner diameter of inner container vessel______________mm

Filling medium____________Design wall thickness of cylinder/head for inner container vessel __________/_____mm

Leakage test pressure__________MPa Inner container vessel test pressure____________MPa (□pneumatic □hydraulic)

2. Data of materials

Steel plate grade of inner container cylinder____Material standard code____ Material batch number

Steel plate grade of inner container head____ Material standard code____ Material batch number

3. Chemical composition of material re-inspection (%):

Inner container cylinder C_______ S _________ P _________ Mn __________ Si __________ Ni ____________ Cr

Inner container head C_______ S _________ P _________ Mn __________ Si __________ Ni ____________ Cr

4. Welding materials:

Standards for materials_______Welding wire (bar) grade_______ Welding wire (bar) diameter_______ mm

5. Re-inspection data of mechanical properties of materials

Test sample		Mechanical properties and bending test					
Category	Material batch number/ inner container cylinder number	Stretch			Shock KV_2 (J) at-192 ℃	Transverse bending	
		Tensile strength R_m (MPa)	Specified plastic elongation strength $R_{P0.2}$ (MPa)	Elongation after fracture A (%)		Surface bending	Back bending
Re-inspection of main materials					-	-	-
Deposited metal of welding materials					-	-	-
Welding samples of products							

6. Data of inner container vessel

Sampling cylinder product number	Measured volume (L)	Measured thickness (mm)			
		Inner container cylinder	Inner container head	Shell cylinder	Shell head

7. Test data of static evaporation rate

Sampled cylinder product number			
Static evaporation rate (LN_2)%/d			

8. NDT data

Sampled inner container vessel number	Test method	NDT							
		Test length (mm)		Test ratio				Test result	
		Longitudinal welded joint	Circumferential welded joint	Longitudinal welded joint		Circumferential welded joint		Longitudinal welded joint	Circumferential welded joint
				-100%	-10% and not less than 2 pieces	-100%	-	Grade	Grade

9. NDT results of sampled inner container vessels for repairs: ____positions once, __positions twice, __positions for three times. Expanded drawing of repaired parts of welded joints of inner container vessel (if any, marked on the sketch)

Instructions for Filling:

1. When there are two batches of materials in the inner container section, the data of materials should be filled in separately.