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NATIONAL STANDARD OF THE
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ICS 23.020.30

CCS J 74

GB/T 24159-2022

Replacing GB/T 24159-2009

Welded insulated cylinders

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Issued on: July 11, 2022

Implemented on: February 01, 2023

**Issued by: State Administration for Market Regulation;
Standardization Administration of the People's Republic of China.**

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Welded insulated cylinders

1 Scope

This document specifies the symbols for welded insulated gas cylinders (hereinafter referred to as "cylinders"). It specifies cylinder model naming methods, basic parameters, materials, design, manufacturing, test methods, inspection rules, type test, marking, packaging, transportation, exit-factory data, data preservation and other requirements.

This document is applicable to the refillable cylinders that are used under normal ambient temperature ($-40^{\circ}\text{C}\sim 60^{\circ}\text{C}$), are used to store liquid oxygen, liquid nitrogen, liquid argon of which the nominal volume range is 10L~1000L, the nominal volume of LNG ranges from 150L to 1000L, that the design temperature is not higher than -196°C , and the nominal working pressure is 0.2MPa~3.5MPa.

For cylinders storing liquid carbon dioxide and liquid nitrous oxide, the manufacture and inspection can be carried out with reference to this document.

NOTE: All pressures not stated in this document refer to gauge pressure.

2 Normative references

The following referenced documents are indispensable for the application 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 229, *Metallic materials - Charpy pendulum impact test method*

GB/T 1804, *General tolerances - Tolerances for linear and angular dimensions without individual tolerance indications*

GB/T 2653, *Bend test methods on welded joints*

GB/T 7144, *Coloured cylinder mark for gases*

GB/T 9251, *Hydrostatic test method for gas cylinders*

GB/T 12137, *Methods for leakage test of gas cylinders*

adiabatic process and the vacuuming process).

3.2 tare of cylinder

The mass of the empty cylinder (for horizontal gas cylinder, it includes frame or support) that meets the basic functions of filling, storage, transportation, use and safety.

3.3 effective volume

The maximum volume of liquid that the cylinder is allowed to fill.

3.4 heat transfer coefficient

The amount of heat that can be transferred between hot and cold fluids in unit area, unit temperature difference, unit time, representing the strength of the heat transfer process.

[Source: GB/T 18517-2012, 2.6.2, modified]

3.5 free air

Air at an absolute pressure of 1.01325×10^5 Pa and a temperature of 15.6°C.

4 Symbols

The following symbols apply to this document.

D_i : Inner diameter of head or cylinder body, mm.

D_0 : Outer diameter of head or cylinder body, mm.

E_0 : Elastic modulus of the material, MPa.

g : Acceleration of gravity, $g=9.81\text{m/s}^2$.

H_i : Inner height of head, equal to the sum of the depth of the inner surface of the head and the height of the straight edge of the head, mm.

h_i : Depth of the inner surface of the head, mm.

h_0 : Total height of the outer surface of the head, $h_0=h_i+S_n$; mm.

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

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

P : Nominal working pressure, MPa.

P_b : Design burst pressure of rupture disc, MPa.

P_{cr} : Critical pressure, MPa.

P_d : Design pressure, MPa.

P_f : Discharge pressure of the safety valve or the design burst pressure of the rupture disc safety device, MPa.

P_t : Pressure of withstand voltage test, MPa.

P_z : Safety valve setting pressure, MPa.

P_1 : External pressure, MPa.

R : Outer radius of the spherical shell of the dish-shaped head and the outer radius of the equivalent spherical shell of the elliptical head, mm.

S : Design wall thickness, mm.

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

S_e : Effective thickness, equal to nominal wall thickness minus corrosion allowance and negative deviation of steel thickness, mm.

S_h : Minimum wall thickness of the head after forming, mm.

S_n : Nominal wall thickness, mm.

σ : Wall stress, MPa.

ΔH_i : Height tolerance inside the head, mm.

$\Delta \pi D_i$: Tolerance of the inner circumference of the head, mm.

5 Model naming methods and basic parameters

5.1 Model naming methods

Vertical type is represented by "DPL". Horizontal type is represented by "DPW". The rest are named according to the method specified in GB/T 15384. When the design is changed, Roman numerals I, II, III, etc. can be added at the end of the model as serial numbers.

5.2 Basic parameters

5.2.1 Nominal volume and inner diameter of inner vessel

The nominal volume and inner diameter of the inner vessel shall be selected according to Table 1. The nominal volume shall be an integer multiple of 5.

7.1.1 Composition

7.1.1.1 A cylinder is mainly composed of an inner vessel, an outer shell, a thermal insulation system, a connecting piece between the inner vessel and the outer shell, a valve piping system, a protection device for protecting the valve piping system, a base and so on. The valve piping system includes valves, instruments, safety relief devices, pipe fittings, pipes and pipe supports. The protective device shall be a protective cover, a protective circle (ring), a frame and so on.

7.1.1.2 The main body of the inner vessel shall not exceed three parts, that is, no more than one longitudinal weld and no more than two circumferential welds.

7.1.2 Connecting piece between inner vessel and outer shell

The stress value of the connecting piece between the inner vessel and the outer shell shall not be greater than $\frac{2}{3}$ of the material's normal temperature yield strength (or specified plastic extension strength) under the following independent loads.

a) Vertical gas cylinders shall meet the following requirements:

- 1) The load perpendicular to the cylinder axis shall not be less than the product of the maximum mass and 2g;
- 2) The load along the vertical direction of the cylinder axis shall not be lower than the product of the maximum mass and 3g.

b) Horizontal cylinders shall meet the following requirements:

- 1) The load perpendicular to the cylinder axis and parallel to the ground shall not be less than the product of the maximum mass and 2g;
- 2) The load along the cylinder axis shall not be less than the product of the maximum mass and 2g;
- 3) The load perpendicular to the cylinder axis and in the vertical direction shall not be less than the product of the maximum mass and 3g.

NOTE: "Maximum mass" is the sum of the total mass of the medium (filling the saturated medium to the effective volume under standard atmospheric pressure), the mass of the inner vessel metal and the mass of the thermal insulation layer.

7.1.3 Performance indicators

The leakage rate of vacuum interspace and the leakage rate of vacuum interspace are as specified in Table 4. The static evaporation rate with the nominal working pressure not greater than 2.4MPa is in accordance with the provisions of Table 4. The static evaporation rate with the nominal working pressure greater than 2.4MPa is in accordance with the requirements of the drawings.

7.4.2.1 The cross-sectional area of the relief pipeline connected to the safety pressure relief device shall not be less than the sum of the inlet area of the safety pressure relief device. It can ensure that the discharge capacity meets the safety discharge requirements of gas cylinders.

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

7.4.3 Safety pressure relief device

7.4.3.1 The main safety pressure relief device and the auxiliary safety pressure relief device shall be arranged in parallel. The main safety pressure relief device shall use safety valves. The auxiliary safety pressure relief device of LNG is only allowed to use safety valves. The auxiliary safety pressure relief device for the rest of the medium shall be safety valve or bursting disc safety device.

7.4.3.2 The set pressure of the main safety relief device (safety valve) shall not be greater than 1.2 times the nominal working pressure ($P_z \leq 1.2P$). The discharge pressure shall meet the following requirements:

- a) In the case of C.1.1, the discharge pressure of liquid oxygen, liquid nitrogen and liquid argon cylinders shall not be greater than 1.1 times the set pressure;
- b) In the case of C.1.2, the discharge pressure of the LNG cylinder shall not be greater than 1.1 times the set pressure.

7.4.3.3 The auxiliary safety pressure relief device is only applicable to the situation of C.1.2. It shall meet the following requirements:

- a) When a safety valve is used, the set pressure is 1.4 times to 1.6 times the nominal working pressure ($1.4P \leq P_z \leq 1.6P$). The discharge pressure shall not be greater than 1.1 times the set pressure;
- b) When the bursting disc safety device is used, the design bursting pressure is 1.54 times to 1.76 times the nominal working pressure ($1.54P \leq P_b \leq 1.76P$).

7.4.3.4 Safety valve shall meet the requirements of GB/T 12243. The reseating pressure is not less than 90% of the set pressure. Except for the screw thread of the bursting disc safety device, the rest shall comply with the provisions of GB/T 16918. The safety valve and bursting disc safety device shall pass the relevant type test verification.

7.5 Pressure relief device of outer shell

The outer shell shall be provided with a pressure relief device to meet the following requirements:

- The relief pressure shall not be greater than 0.1MPa;;

- The minimum discharge area shall not be less than the product of the nominal volume of the liner and $0.34\text{mm}^2/\text{L}$. The minimum inner diameter is not less than 6mm;
- The double closed structure shall not be used;
- Protective measures shall be taken to avoid injury during discharge.

8 Manufacturing

8.1 Responsibilities of manufacturer

8.1.1 Before the official production of the manufacturer, the documents used for manufacturing shall have passed the appraisal and approval. Sample cylinders produced in accordance with this document shall have been verified by type test.

8.1.2 The inspection department of the manufacturer shall conduct inspection and testing in accordance with the requirements specified in this document and the design document. Issue corresponding reports. Be responsible for the correctness and completeness of the report.

8.2 Batching

8.2.1 Manufacture according to inner vessel batches. The material batch number of the same batch of inner vessel shall not exceed two. Product batches are carried out on the basis of inner vessel batches. The same inner vessel batch shall be one product batch, or it can be composed of multiple product batches.

8.2.2 The quantity of a batch of inner vessels shall not be more than 200 (excluding destructive inspection bottles).

8.3 Material re-inspection

The main material of the inner vessel shall be re-inspected for chemical composition according to the furnace number. The mechanical properties shall be re-inspected according to the batch number. The mechanical property test specimens shall be taken along the direction perpendicular to the rolling direction of the steel plate.

8.4 Mark transplant

The material of the pressure components shall be marked with traceability. In the manufacturing process, if the original mark is cut off or the material is divided into several pieces, the manufacturer shall specify the expression of the mark. Before the material is divided, use a chlorine-free and sulfur-free marker to complete the mark transplant. Hard stamping shall not be used.

8.5 Unspecified tolerance

Figure 3 -- Schematic diagram of the height of the axial edge and corner of the girth weld

8.9.3 The components welded on the inner cylinder body shall avoid the longitudinal and circumferential welded joints of the inner cylinder body.

8.9.4 The connection between the base, frame and hoisting accessories and the cylinder body shall avoid the longitudinal and circumferential welds of the outer shell.

8.10 Welding**8.10.1 Welding preparation and welding environment**

8.10.1.1 Repositories for welding materials shall be kept dry. The relative humidity shall not be greater than 60%.

8.10.1.2 Welding (including welding rework) shall be carried out on a clean, dry indoor dedicated site. When any of the following conditions occurs in the welding environment and there is no effective protective measures, welding shall not be applied:

- When gas shielded welding, the wind speed is greater than 2m/s;
- Relative humidity is greater than 90%;
- The temperature of the weldment is lower than -20°C.

8.10.1.3 When the temperature of the weldment is lower than 0°C, but not lower than -20°C, it shall be preheated to about 15°C within 100mm of the initial welding point.

8.10.2 Groove requirements

There shall be no cracks, delamination, inclusions and other defects on the groove surface. Before welding, the groove and other harmful impurities such as oxides, oil stains and other harmful impurities shall be removed within at least 20mm of the surface of the base metal on both sides (calculated by the groove edge).

8.10.3 Qualification of inner vessel welding procedure

8.10.3.1 The longitudinal and annular welded joints of inner vessel as well as welded joints of all components and inner vessel shall be subject to welding procedure qualification. Welding procedure qualification shall comply with the provisions of this document and GB/T 33209.

8.10.3.2 For qualification of welding procedures with nominal volume less than or equal to 100L, sample cylinder can be used for longitudinal seam and circular seam or flat test piece can be used for longitudinal seam; cylindrical specimen is used for circumferential seam. Plate specimens can be used when the nominal volume is greater than 100L.

8.10.3.3 When the thickness of the material is not enough to prepare the impact test specimen for the welding procedure qualification of the inner vessel of which its thickness is 2.5mm, it shall use the materials of which the carbon content (mass fraction) is not less than 0.05% and the thickness is not more than 3.2mm and the same welding process to weld the specimen cylinder or test piece. Then prepare 2.5mm specimens.

8.10.3.4 The requirements for the welding procedure qualification test results of the longitudinal and annular welded joints of the inner vessel are as follows:

- No matter where the tensile specimen breaks, the measured tensile strength shall not be less than the provisions of 6.3 and the requirements of the design documents;
- After the specimen is bent to 180°, there shall be no opening defects in the weld and heat affected zone on the tensile surface. The edge and corner opening defects of the specimen are generally not counted. However, the length of angular opening defects caused by lack of fusion, slag inclusion or other internal defects shall be counted;
- The average value of Charpy impact energy absorbed energy (KV₂) of 10mm×10mm×55mm standard specimen at -192°C shall not be less than 31J. At least one specimen is allowed to be less than 31J, but not less than 21.7J. The KV₂ indexes of the small-size specimens with widths of 7.5mm, 5mm and 2.5mm are 75%, 50% and 25% of the standard specimens, respectively.

8.10.4 Inner vessel welding

8.10.4.1 Welding equipment, welding marks

Longitudinal and annular welded joints shall use mechanized gas shielded welding. After welding, the longitudinal and circumferential welded joints shall have traceable identification and records. The marks shall not be hard-printed.

8.10.4.2 Arc ignition plate and arc quenching plate

When welding, the longitudinal welded joint shall have arc initiation plate and arc quenching plate. Ring weld joints shall not strike arcs at non-welded locations. It shall use cutting method to remove the arc striking plate and the arc quenching plate. The tapping method shall not be used. The cut shall be smoothed after removal.

8.10.4.3 Product welding specimen

8.10.4.3.1 Each batch of inner vessels shall be made according to the material batch number of the inner vessel cylinder body and the following regulations to make specimen cylinders or product welding test pieces for mechanical property test and bending performance test:

- a) When the nominal volume is not more than 100L, the longitudinal and circumferential welded joints shall be made separately;

8.11 Nondestructive testing

8.11.1 The non-destructive testing of the longitudinal and circumferential welded joints of the inner vessel shall be carried out after the shape, size and appearance comply with 8.10.4.4.

8.11.2 The radiographic inspection technology level is level AB. The test result evaluation and quality classification are in accordance with the provisions of NB/T 47013.2. The qualification level is not lower than level II.

8.12 Withstand voltage test of inner vessel

8.12.1 The withstand voltage test of inner vessel shall be carried out one by one after the non-destructive testing is qualified.

8.12.2 The test shall have reliable safety protection measures. It is confirmed and approved by the technical person in charge of the manufacturer or the person in charge of safety production.

8.12.3 The test shall use two pressure test instruments with the same range and within the validity period of the verification. The range is 1.5 times to 3 times the test pressure (shall be 2 times the test pressure). The accuracy is not less than level 1.6. The diameter of the mechanical dial is not less than 100mm.

8.12.4 During the test, welded joints with leakage shall be repaired in accordance with the provisions of 8.10.4.5. After passing the test, perform the withstand voltage test again.

8.12.5 The pressure shall not drop during the pressure holding check. There shall be no leakage, visible macroscopic deformation and abnormal sound.

8.13 Surface quality and cleanliness

8.13.1 There shall be no defects on the surface of the sheet that will affect normal use. For sharp scratches, grinding shall be carried out. The maximum grinding slope shall be 1:3. Grinding shall be smooth and clean. After grinding, the thickness of the inner vessel meets the requirements of 7.2. The thickness of the outer shell meets the requirements of 7.3.

8.13.2 Components forming (or in) a vacuum space shall be cleaned of hydrocarbons (oil, grease and so on), decontaminated. Good protection measures shall be taken after disposal. Residual hydrocarbons shall not exceed 125mg/m² after treatment of parts in direct contact with oxygen.

8.14 Air tightness test

8.14.1 The air tightness test pressure shall not be lower than the nominal working pressure.

test method is in accordance with the provisions of GB/T 2653.

9.4 Nondestructive testing

9.4.1 The inspection of the longitudinal and annular welded joints of the inner vessel shall adopt the radiographic inspection method (film photosensitive, digital imaging, computer-aided imaging). When using film photosensitive, it shall comply with the provisions of NB/T 47013.2. When using digital imaging, it shall comply with the provisions of GB/T 17925 or NB/T 47013.11. When using computer-aided imaging detection, it shall comply with the provisions of NB/T 47013.14.

9.4.2 The longitudinal and ring welded joints of the inner vessel shall be tested in the following methods:

- a) When the withstand voltage test is carried out with air pressure, the longitudinal and annular welded joints are 100% radiographically inspected one by one;
- b) When hydraulic pressure test is used, the proportion of longitudinal welded joints extracted shall not be less than 10% of the total number of each batch. There shall be no less than 2 pieces for 100% radiographic inspection.

9.5 Withstand voltage test of inner vessel

9.5.1 The hydraulic test method is as follows:

- Use clean water with chloride ion content not exceeding 25mg/L;
- The test procedures and steps are carried out in accordance with the provisions of GB/T 9251;
- After the hydraulic test, the water in the inner vessel and the connecting pipe shall be drained in time and dried.

9.5.2 The air pressure test method is as follows:

- Use dry and clean air, nitrogen or other inert gases;
- During the test, first slowly increase the pressure to 10% of the test pressure. Hold the pressure and conduct initial inspection of all welded joints and connections. After confirming that there is no leakage, continue to increase the pressure to 50% of the test pressure. If there is no abnormal phenomenon, then increase the pressure step by step according to 10% of the test pressure until the test pressure is reached. Hold the pressure at least 30s, and it is fully expanded. Then reduce to the nominal working pressure. Hold the pressure to check.

9.6 Surface quality and cleanliness

The treatment method of surface quality and cleanliness shall be in accordance with the

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