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B-05 SEAMLESS STEEL GAS CYLINDERS

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Foreword:

This Guide is a part of CCS Rules, which contains technical requirements, inspection and testing criteria related to classification and statutory survey of marine products.

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SEAMLESS STEEL GAS CYLINDERS

1 Application

1.1 This guideline is applicable to the works approval and post-approval unit/path inspection of refillable and portable seamless steel gas cylinders which are used for containing permanent gases such as oxygen, nitrogen, hydrogen, etc. or high-pressure liquefied gases such as carbon dioxide, etc., and have a nominal working pressure of8 MPa~30MPa, a nominal capacity of 0.5L~150L and a service environment temperature of -40 ℃~60 ℃.

1.2 This guideline is not applicable to the seamless steel gas cylinders used for containing dissolved gases and adsorbed gases and cylinder pressure vessels mounted as accessory on transport vehicles and machinery installations. Seamless steel gas cylinders are not to be used for containing the media having stress corrosion tendency.

1.3 Reference may be made to This guideline for seamless steel gas cylinders having a nominal capacity of 150L~500L.

1.4 Seamless steel gas cylinders having a working pressure greater than 30MPa are to be surveyed in accordance with the recognized standards (e.g. ISO 9809-2) and/or relevant technical protocols.

1.5 This guideline is in principle only applicable to the approval inspection of the body of seamless steel gas cylinders, exclusive of head valves.

1.6 This guideline is applicable to the seamless steel gas cylinders used on ships classed with CCS and reference may be made to This guideline for the seamless steel gas cylinders used on offshore installations.

1.7 This guideline is applicable to the initial approval and post-approval manufacturing inspection of seamless steel gas cylinders. The seamless steel gas cylinders in service are to be surveyed in compliance with the requirements of applicable international conventions and the competent state administration.

1.8 Upon the approval of CCS, seamless steel gas cylinders may be approved and surveyed in accordance with the standards acceptable to the state administration.

2 Normative references

Chapter 2, PART SIX of CCS Rules for Classification of Sea-going Steel Ships

ISO 9809-1:2010 Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction and Testing-Part 1: Quenched and Tempered Steel Cylinders with Tensile Strength Less Than 1100MPa.

3 Definitions

3.1 For the purpose of This guideline, the following definitions are used:

(1) Permanent gas: gas of a critical temperature less than -10 ℃.

(2) High-pressure liquefied gas: gas of a critical temperature greater than or equal to -10 ℃ and less than or equal to 70 ℃.

(3) Nominal working pressure: the restricted filling pressure of the contained gas at reference temperature (normally 15 ℃) for steel cylinders containing permanent gases; and the upper limit value of the pressure of the gas contained in the cylinder at 60 ℃ for steel cylinders containing high-pressure liquefied gases.

(4) Hydraulic test pressure Ph: the pressure to be reached during hydraulic test.

(5) Yield strength: the upper yield strength is to be taken where the material test specimen exhibits apparent yielding during the tensile test; where the test specimen does not exhibit apparent yielding, the specified non-proportional elongation strength under the test force, Rp0.2, is to be taken as the yield strength of the material.

(6) Batch quantity: the specified quantity of steel cylinders which adopt the same design conditions, have the same nominal diameter and design wall thickness, are made of steel of the same heat/furnace number by the same manufacturing process, and are continuously heat treated in accordance with the same heat treatment specifications. For quenched and tempered steel cylinders, a batch corresponds to a quantity of not less than 200 plus the number of steel cylinders used for destructive test.

(7) Filling ratio: the maximum allowable weight of gas to be filled per unit water capacity of the steel cylinder specified in the applicable standards for various filled media.

(8)Burst pressure Pb: the maximum pressure of gas cylinders reached during burst test.

4 Drawings and documentation to be submitted

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

(1) Seamless steel gas cylinder drawings. Drawings are to reflect the products' structural form, main dimensions, materials, mechanical and chemical parameters, manufacturing and heat treatment methods, nominal working pressure, hydraulic test pressure and other special technical requirements;

(2) Seamless steel gas cylinder design calculations. Relevant calculations, including strength calculations of cylinder body, base and head, are to be made in accordance with the design standard;

(3) Type test plan.

4.2 The following drawings and documentation to be submitted are to be submitted for review when the initial works approval is being applied for:

(1) Basic information of the manufacturer: name, address and production history of the manufacturer, types and specifications of current products, the types, specifications and delivery conditions of the products for which approval is being applied, information on other certification or qualification certificates obtained, etc.;

(2) Quality system documents and other management documents. The organizations of the quality system and product quality control points are to be clearly defined in these documents;

(3) Main production, measuring/testing equipment.

List of main production equipment:

Forming equipment;

Heat treatment furnace's type, dimensions, heating method, temperature controlling and recording method, arrangement of temperature measuring points.

List of main measuring/testing equipment

List of equipment for chemical components analysis, mechanical properties, mechanical test, metallographic test, NDT, hydraulic test, etc. (including the product name, type, manufacturer, statutory inspection organization and valid period of verification/calibration)

(4) Process documents:

Production process flow chart (quality control points are to be indicated);

Operation guidance books with various work procedures indicated in production process flow chart, including the main work procedures such as forming, heat treatment, NDT, etc.;

(5) Qualification certificates of testing and inspection personnel;

(6) Test location and laboratory qualifications (where the test is subcontracted, the qualification of the subcontractor and subcontract agreement are to be described).

(7) List of suppliers of materials and main parts;

(8) Product description and quality certificates (sample).

5 Technical requirements for the materials of seamless steel gas cylinders

5.1The material of cylinder body must be non-aging killed steel smelted by basic open-hearth furnace, electric furnace or basic oxygen converter.

5.2 The material of cylinder body is to be compatible with the gas intended to be filled. Refer to ISO 11114-1 for compatibility of cylinder material with the gas;

5.3 The S element content (mass fraction) of the cylinder body material obtained through heat analysis is not to exceed 0.010% and the P element content (mass fraction) thereof obtained through heat analysis is not to exceed 0.020%. And the sum of S+P content percentages is not to exceed 0.025%;

5.4 The limit values (the difference between the maximum content and the minimum content) of the chemical composition of cylinder body material are not to exceed the values listed in the table 5.4 below:

Chemical Composition Table **Table 5.4**

Element	Maximum content (mass fraction), %	Limit value (mass fraction), %
C	<0.30	0.06
	≥0.30	0.07
Mn	--	0.30
Si	--	0.30
Cr*	<1.50	0.30
	≥1.50	0.50
Ni*	--	0.40
Mo*	--	0.15

Notes: ① The requirements in the table above must be complied with where the element marked by "*" are alloy elements of the steel;

② The maximum content of any intentionally added element is to be reported;

③ Total content of V+Ni+Ti+B+Zr is not to exceed 0.15%.

5.5 The cylinder body is generally to be manufactured with nationally or internationally recognized steel used for pressure vessels. Typical recognized steels include CrMo steel and CMn steel.

5.6 Rough rolled billets or steel billets are to be subject to macrostructure examination and defects such as flakers, residual shrinkage cavity, delamination, air bubble, foreign matters and impurity inclusion are not allowed. The center porosity is to be no greater than grade 1.5 and segregation no greater than grade 2.5. For seamless steel pipes, the wall thickness deviation is not to exceed -10%~+15% of the nominal wall thickness and the steel pipes are to be 100% satisfied by NDT.

6 Design and technical requirements

6.1 General design requirements

6.1.1The design formula used to determine the wall thickness of cylinder body is to comply with

the requirements of recognized standards (e.g. ISO 9809-1).

6.1.2 The guarantee value of the yield strength of heat treated material, R_{eg}, is to be taken for design of wall thickness of parts under pressure, and the limit of the ratio of yield strength guarantee value R_{eg} to tensile strength guarantee value R_{mg} is to comply with the requirements of the standards;

6.1.3 In general, more than two openings on a gas cylinder are not allowed, and the openings can only be designed to be arranged along the neutral axis of the gas cylinder.

6.1.4 For CrMo steel, the actual maximum tensile strength of cylinder body material Rma is generally not to exceed 1100MPa; for CMn steel, the actual maximum tensile strength Rma is not to exceed1030MPa. For cylinders filled with the medium posing a risk of hydrogen embrittlement, the actual maximum tensile strength of cylinder body material Rma is generally not to exceed 880MPa, or may not exceed 950Mpa when the actual yield-strength ratio is not more than 0.9.

6.1.5 The bottom structure of seamless steel cylinders is to comply with the following requirements:

6.1.5.1The structural form and dimensions are to comply with the requirements of relevant standards;

6.1.5.2 The part in connection to convex base is to be smooth and its thickness is to be no less than the design thickness of the cylinder body;

6.1.5.3 There is to be a transitional section between the annulated shell of concave base and the cylinder body. The connection of transitional section to cylinder body is to be smooth.

6.1.5.4 The design of convex base and concave base is to be subject to fatigue test by means of cyclic pressurization. The design of cylinder bases is considered qualified provided that the cylinder bases can withstand 80000 cycles of pressurization with the upper limit of cyclic pressure being at the nominal working pressure, or 12000 cycles of pressurization with the upper limit of cyclic pressure being at the test pressure, without being damaged; the design is not to be adopted if the cylinder bases have not passed the said test successfully.

6.1.6 The thickness of steel cylinder opening is to be measured from the thread groove and to be no less than the design thickness of the cylinder body in order to ensure that the opening will not be deformed when subject to the moment of valve-tightening force couple and the additional external force of neck ring riveting.

6.1.7 The internal threads of cylinder openings are to comply with the following requirements:

6.1.7.1The thread form, dimensions and tolerances are to comply with the requirements of recognized standards. Existence of reverse pitch, flat pitch, pitch double-line, pitch base flatness, pitch sharpness, pitch broadness and apparent jumping ripples on the thread surface are not allowed.

6.1.7.2 The number of useful threads is to be such that the shear safety factor calculated at the

hydraulic test pressure of steel cylinder, Ph, is at least 10, and is to be no less than 6.

6.2 General requirements for manufacturing

6.2.1 The manufacture of marine seamless steel gas cylinders, the main inspections during manufacture and inspections/tests upon completion are to comply with the requirements of CCS Rules for Classification of Sea-going Steel Ships, approved drawings and relevant standards.

6.2.2 The manufacturers of seamless steel gas cylinders are to introduce the manufacturing process, describe the manufacturing tools having significant impact on product quality such as the press head for air cylinder pressing and drawing, mold plate or mold tool for shell nosing during rotary pressing or mold pressing, and specify other requirements for process verification before the product is put into service, regular inspection, repair and replacement when the product is in service, etc.

6.2.3 For steel cylinders manufactured through closing the bottom of seamless steel pipes, means are to be provided by the manufacturer to ensure the sealing tightness of the cylinder bottom; the internal surface of cylinder bottom is to be free from any visible pit, fold, overlap and oxide scale; removal of bottom and the defects thereof is allowable, however, the design thickness of cylinder bottom must be guaranteed; weld repair on the bottom is not allowed.

6.2.4 Gas cylinders are to be type tested in accordance with 7.2 of This guideline prior to going into service.

6.2.5 Welding on seamless steel gas cylinders is not allowed.

6.3 The filling ratio is to be consistent with the strength of cylinder body and also comply with the requirements of the administration.

7 Type test

7.1 Sampling principle of type test

7.1.1 Seamless steel cylinders are to be type tested according to different types. Cylinders are considered to be of different types in any one of the following cases:

(1) Production process flow is different;

(2) Material designation is different;

(3) Heat treatment process is different;

(4) Structural form of cylinder bottom and ratio of bottom thickness to cylinder diameter are different;

(5) The overall length of the cylinder has increased by more than 50 % (cylinders with a length/diameter ratio less than 3 shall not be used as reference cylinders for any new design with this ratio greater than 3);

(6) The outside diameter or minimum guarantee thickness of the cylinder is different;

(7)The hydraulic test pressure is different (the design on the same basis with only hydraulic test pressure being reduced is not to be considered as new design);

(8) The minimum guaranteed yield strength and/or minimum guaranteed tensile strength are different.

7.1.2 For each type of gas cylinders for which approval is to be applied, at least 50 gas cylinders are to be manufactured by the applicant and tested in accordance with the corresponding requirements of the table in 7.2.

7.1.3 For marine seamless steel gas cylinders for type test, the acceptance of raw materials, main manufacturing process, inspection and test, and transfer of relevant marks must be carried out under the supervision of the surveyor and the results thereof are to comply with the requirements of CCS Rules for Classification of Sea-going Steel Ships and approved drawings.

7.2 Type test items and requirements

Type test items and requirements **Table 7.2**

Test item	Test quantity	Test requirements
Raw material inspection	Each heat or each batch	1. Raw materials are to be furnished with product quality certificates; 2. Elements to be analyzed are to include C, Si, Mn, P, S, Nb, V, Ti, Cr, Ni, Mo, Cu, Al, B, As, Sn, Zr, [N], [O] and purposefully added elements; 3. Rough rolled billets or steel billets are also to be subject to macrostructure examination; 4. For seamless steel pipes, visual inspection, wall thickness inspection and mechanical properties tests are also to be carried out;

Continued Table 7.2

Test item	Test quantity	Test requirements
Internal and external visual inspection of gas cylinders	Each cylinder	1. The internal and external surfaces of cylinder body are to be smooth, even and free from detects affecting the strength of cylinder body, such as visible crack, fold, ripple, double skin, inclusion, etc.; existence of smooth local pits formed after fall-off of oxide scale and minor traces generated due to grinding repair are allowable, however, the design thickness of cylinder body must be guaranteed. 2. For a cylinder body manufactured by pressing and drawing process, the depth of its concave base is to be consistent with the specified design value, and the thickness of base spherical shell and annulated shell is to comply with the design requirements. 3. Connection between cylinder shoulder and cylinder body must be smooth and the cylinder shoulder is to be free from groove marks.
Internal and external visual inspection of gas cylinders	Each cylinder	1. The internal and external surfaces of cylinder body are to be smooth, even and free from detects affecting the strength of cylinder body, such as visible crack, fold, ripple, double skin, inclusion, etc.; existence of smooth local pits formed after fall-off of oxide scale and minor traces generated due to grinding repair are allowable, however, the design thickness of cylinder body must be guaranteed. 2. For a cylinder body manufactured by pressing and drawing process, the depth of its concave base is to be consistent with the specified design value, and the thickness of base spherical shell and annulated shell is to comply with the design requirements. 3. Connection between cylinder shoulder and cylinder body must be smooth and the cylinder shoulder is to be free from groove marks.

Continued Table 7.2

Test item	Test quantity	Test requirements
Inspection of dimension, shape and position tolerances	Each cylinder	1. Dimensional inspection: wall thickness, outer diameter and height of cylinder body, thickness and central depth (applicable to concave base) of cylinder base are to be measured. The results are to be consistent with the requirements of 7.3~7.5 of ISO 9809-1:2010 and approved drawings. For each steel cylinder, three cross sections, namely the upper, middle and lower cross sections, are to be taken along the length of cylinder body. The wall thickness and outer diameter are to be measured respectively. Wall thickness of each cross section is to be measured at four measuring points evenly distributed along the circumference. The outer diameter is to be measured for two times vertically and crosswise. The thickness of cylinder base is to be measured at one measuring point located in the center of the base. For concave base, the thickness of the earthing point is also to be measured at the four measuring points evenly distributed along the circumference. The wall thickness measured at various points is to be no les-
Inspection of dimension, shape and position tolerances	Each cylinder	-s than the minimum thickness guarantee value. 2. Form and position tolerances are to comply with the requirements of 8.5~8.9 of ISO 9809-1:2010.
Hardness test	Each cylinder	Hardness is to be tested at three points respectively located in the upper, middle and lower portions of the cylinder body and the results are to be consistent with the requirements of 11.3 of ISO 9809-1:2010 and approved drawings.
Ultrasonic test	Each cylinder	To be in accordance with 8.4 of ISO9809-1:2010.
Magneticparticle inspection (when applicable)	Each cylinder	To be carried out in accordance with JB/T 4730.4-2005.

Continued Table 7.2

Test item	Test quantity		Test requirements
Tensile test	2 cylinders to be taken randomly	2 test pieces/cylinder	To be in accordance with 10.2 of ISO 9809-1:2010 and approved drawings.
Bending or flattening or ring flattening test		Bending: 2 test pieces/ cylinder, flattening/ring flattening: 1 test piece / cylinder	To be in accordance with 10.3 of ISO 9809-1:2010.
Impact test		1 group 3 test pieces/ cylinder	To be in accordance with 10.4 of ISO9809-1:2010 and approved drawings.
Strain ageing impact test (when applicable)		1 group 3 test pieces/cylinder	5% plastic deformation, 2500 ^{0}C temperature maintained for 1h. Test temperature is to be the same as that for conventional impact test and the average values of impact test not less than 80% of the values required by relevant standards.
Base check		1 test piece/cylinder	To be in accordance with 9.2.3 of ISO 9809-1:2010.
Metallographic inspection		1 test piece/ cylinder	Microstructures, crystal grain size and thickness of decarburized layer are to be determined.
Hydraulic burst test	2 cylinders to be taken randomly		To be in accordance with 10.5 of ISO 9809-1:2010.
Pressure cycling test	3 cylinders to be taken randomly		To be in accordance with 9.2.2 of ISO 9809-1:2010.
Hydraulic test	Each cylinder		To be in accordance with 11.2 of ISO 9809-1:2010.
Thread inspection	Each cylinder		To be in accordance with 8.9 of ISO 9809-1:2010.
Neck ring torque test (when applicable)	1 cylinder to be taken randomly		To be in accordance with 7.8 of ISO 9809-1:2010.

8 Unit/batch inspection

8.1 Unit/batch inspection for issuing product certificates of marine seamless steel gas cylinders is to be carried out after works approval has been obtained by the manufacturer, unless otherwise specially considered. Marine seamless steel gas cylinders are to be subject to unit/batch inspection. The unit/batch inspection of unapproved seamless steel gas cylinders is to be carried out according to the requirements for type test.

8.2 The unit/batch inspection (see 3.1 (6) for the definition of batch quantity) of seamless steel gas cylinders after CCS approval is to be carried out in accordance with the product inspection plan already approved during the approval. The test items listed in the table 8.2 are to be included:

Type test items and requirements **Table 8.2**

<table>
<tr><th>Test item</th><th colspan="2">Test quantity</th><th>Inspection method</th></tr>
<tr><td>Raw material inspection</td><td colspan="2">Each heat or each batch</td><td>Report review</td></tr>
<tr><td>Visual inspection of cylinder body</td><td colspan="2">Random inspection</td><td>Random inspection + report review</td></tr>
<tr><td>Inspection of dimension, shape and position tolerances</td><td colspan="2">Random inspection</td><td>Random inspection+report review</td></tr>
<tr><td>Hardness test (at 1 measuring point on the cylinder body)</td><td colspan="2">Each cylinder</td><td>Report review</td></tr>
<tr><td>Ultrasonic test</td><td colspan="2">Each cylinder</td><td>Report review</td></tr>
<tr><td>Tensile test</td><td rowspan="3">1 cylinder/batch</td><td>1 time</td><td>Test witness</td></tr>
<tr><td>Bending or flattening or ring flattening test</td><td>Bending:2 times
Flattening/ring flattening:1 time</td><td>Test witness</td></tr>
<tr><td>Impact test (when applicable)</td><td>1 group 3 times</td><td>Test witness</td></tr>
<tr><td>Burst test</td><td colspan="2">1 cylinder/batch</td><td>Test witness</td></tr>
<tr><td>Hydraulic test</td><td colspan="2">Random inspection</td><td>Random inspection+report review</td></tr>
<tr><td>Metallographic inspection (when applicable)</td><td colspan="2">1 cylinder/batch</td><td>Report review</td></tr>
<tr><td>Dissection test of cylinder base (when applicable)</td><td colspan="2">1 cylinder/batch</td><td>Test witness</td></tr>
<tr><td>Other inspections</td><td colspan="2"></td><td></td></tr>
</table>

Notes: ① The tests are to be carried out in accordance with the type test requirements specified in 7.2;

② Where the test results are not satisfactory, disposal is to be made according to the following provisions:

a. Where the non-conformity results from abnormal testing operation, noncompliance of test specimen preparationor measurement error, specimens of the same quantity may be re-tested; where the results of such re-test are satismanufacturer, the initial test will be invalidated;

b.Where a non-conformity due to heat treatment is confirmed, re-conducting the heat treatment to this batch of cylinders is allowable; however, the heat treatment is not be repeated for more than

twice; for cylinder bodies which have been heat treated again, the design wall thickness is to be guaranteed; the batch of cylinder bodies which have been heat treated again are to be treated as a new batch for single batch inspection;

c. Where the non-conformity results from other causes, the non-conforming steel cylinders are to be discarded or repaired by approved means; the repaired steel cylinders are to be re-tested for the original non-conforming items.

8.3 Cylinders qualified through inspection are to be clearly identified with permanent marks including but not limited to the following information:

Vessel weight;

Nominal water capacity;

Hydraulic test pressure;

Date of test;

Manufacturer serial number;

CCS steel stamp;

CCS certificate code.

8.4 The product certificates will be issued for qualified products by CCS surveyor upon completion of product inspection.