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Welded stainless steel pipes for liquefied natural gas

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(*English Translation*)

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Foreword

SAC/TC 183 is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This standard is drafted in accordance with the rules given in the GB/T 1.1—2009 *Directives for standardization—Part 1: Structure and drafting of standards*.

This standard was proposed by China Iron and Steel Association.

This standard was prepared by SAC/TC 183 Technical Committee on Steel of Standardization Administration of China.

Welded stainless steel pipes for liquefied natural gas

1 Scope

This standard specifies the classification, ordering information, dimensions and masses, shapes, technical requirements, test methods, inspection rules, packaging, marking and quality certification of the welded stainless steel pipes for liquefied natural gas.

This standard is applicable to the welded stainless steel pipes (hereinafter referred to as steel pipe) with nominal outside diameter from 219.1 mm to 1 219 mm for liquefied natural gas.

2 Normative references

The following referenced documents are indispensable for 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 222, *Permissible tolerances for chemical composition of steel products*

GB/T 223.11, *Iron, steel and alloy—Determination of chromium content—Visual titration or potentiometric titration method*

GB/T 223.16, *Methods for chemical analysis of iron, steel and alloy—The chromotropic acid photometric method for the determination of titanium content*

GB/T 223.25, *Methods for the chemical analysis of iron, steel and alloy—The dimethylglyoxime gravimetric method for the determination of nickel content*

GB/T 223.28, *Methods for the chemical analysis of iron, steel and alloy—The α-benzoinoxime gravimetric method for the determination of molybdenum content*

GB/T 223.40, *Iron, steel and alloy—Determination of niobium content by the sulphochlorophenol S spectrophotometric method*

GB/T 223.58, *Methods for chemical analysis of iron, steel and alloy—The extraction-absorption catalytic polarographic method for the determination of manganese content*

GB/T 223.59，*Iron，steel and alloy—Determination of phosphorus content—Bismuth phosphomolybdate blue spectrophotometric method and antimony phosphomolybdate blue spectrophotometric method*

GB/T 223.60，*Methods for chemical analysis of iron，steel and alloy—The perchloric acid dehydration gravimetric method for the determination of silicon content*

GB/T 223.67，*Iron，steel and alloy—Determination of sulfur content—Methylene blue spectrophotometric method*

GB/T 223.86，*Steel and iron—Determination of total carbon content—Infrared absorption method after combustion in an induction furnace*

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 230.1，*Metallic materials—Rockwell hardness test—Part 1：Test method*

GB/T 231.1，*Metallic materials—Brinell hardness test—Part 1：Test method*

GB/T 232，*Metallic materials—Bend test*

GB/T 241，*Metallic materials—Tube—Hydro static pressure test*

GB/T 1954，*Methods of measurement for ferrite content in austenitic Cr-Ni stainless steel weld metals*

GB/T 2102，*Acceptance，packing，marking and quality certification of steel pipe*

GB/T 2650，*Impact test methods on welded joints*

GB/T 2975，*Steel and steel products—Location and preparation of samples and test pieces for mechanical testing*

GB/T 3323—2005，*Radiographic examination of fusion welded joints in metallic materials*

GB/T 4334—2008，*Corrosion of metals and alloys—Test methods for intergranular corrosion of stainless steels*

GB/T 11170，*Seamless steel—Determination of multi-element contents-Spark discharge atomic emission spectrometric method（Routine method）*

GB/T 20066, *Steel and iron-Sampling and preparation of samples for the determination of chemical composition*

GB/T 20123, *Steel and iron—Determination of total carbon and sulfur content—Infrared absorption method after combustion in an induction furnace (routine method)*

GB/T 21835, *Dimensions and masses per unit length of welded steel pipes*

NB/T 47013.2, *Nondestructive testing of pressure equipments—Part 2: Radiographic testing*

NB/T 47013.5, *Nondestructive testing of pressure equipments—Part 5: Penetrant testing*

3 Classification

The steel pipe is classified into the following three classes according to production process:

Class Ⅰ—the double-welded steel pipe with the addition of filler metal in the welding passes except for root-pass and the inner cover pass.

Class Ⅱ—the double-welded steel pipe with the addition of filler metal in all passes.

Class Ⅲ—the single-welded steel pipe with the addition of filler metal in all passes.

4 Ordering information

The purchase contract or order according to this standard shall include, but be not limited to the following information:

a) reference to this standard;

b) name of product;

c) steel grade;

d) class of steel pipe;

e) dimensions(nominal outside diameter and nominal wall thickness, in mm);

f) quantity (total mass or total length);

g) delivery condition;

h) special requirements.

5 Dimensions, shapes and masses

5.1 Outside diameter and wall thickness

5.1.1 The range of nominal outside diameter (D) is from 219.1 mm to 1 219 mm. The nominal outside diameter and nominal wall thickness (S) of the steel pipes shall comply with the requirements in GB/T 21835. If required by the purchaser and agreed between supplier and purchaser, steel pipe with dimensions not specified in GB/T 21835 may be supplied.

5.1.2 Permissible variations in outside diameter shall be $\pm 0.5\%\ D$.

5.1.3 Permissible variations in wall thickness shall be -0.30 mm.

5.2 Out-of-Roundness

The out-of-roundness of steel pipe (the difference between the maximum value and minimum value of measured outside diameter) shall not exceed $1.0\%\ D$. For the thin-wall steel pipes with the S/D ratio no more than 3%, the out-of-roundness shall not exceed $1.5\%\ D$.

5.3 Length

5.3.1 The random length of steel pipe is 6 000 mm to 12 000 mm.

5.3.2 If required by the purchaser, agreed between supplier and purchaser, and specified in the contract, steel pipe may be supplied by cut-length. The permissible variations in cut-length is $^{+20}_{0}$ mm.

5.4 Straightness

The deviation from straightness of steel pipes shall not exceed 3 mm/3 m.

5.5 End shape

5.5.1 The both ends of steel pipe shall be perpendicular to the axis of the steel pipe, and deburred.

5.5.2 If required by the purchaser, agreed between supplier and purchaser, and specified in the contract, steel pipe with nominal wall thickness over 3 mm and up to 22 mm may be supplied with beveled ends. The groove angle is $37.5^\circ \pm 2.5^\circ$, and root face is 1.6 mm $\pm$ 0.8 mm.

5.6 Masses

5.6.1 Steel pipes are delivered by actual mass.

5.6.2 If required by purchaser, agreed between supplier and purchaser, and specified in the contract, the steel pipes may be delivered by theoretical mass.

5.6.3 The theoretical mass per meter of the steel pipes shall be calculated according to Formula (1).

$$W = \frac{\pi}{1\,000}\rho S(D - S) \quad (1)$$

where

W is the theoretical mass of steel pipes, in kg/m;

π is 3.141 6;

ρ is the density of steel, in kg/dm^3, density of the steel grades defined as Table 2;

S is the nominal wall thickness, in mm;

D is the nominal outside diameter, in mm.

6 Technical requirements

6.1 Steel grades and chemical composition

6.1.1 The steel grades and chemical composition (heat analysis) shall comply with the requirements of Table1. If required by purchaser, agreed between supplier and purchaser, and specified in the contract, the steel pipes with grades or/ and chemical composition other than those stipulated in Table 1 may be supplied.

Table 1—Steel grades and chemical composition

No.	ISC	Grade	Chemical composition(mass fraction)/%									
			C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Nb
1	S30408	06Cr19Ni10	≤0.08	≤1.00	≤2.00	≤0.040	≤0.030	8.00 to 11.00	18.00 to 19.50	—	—	—
2	S30403	022Cr19Ni10	≤0.030	≤1.00	≤2.00	≤0.040	≤0.030	8.00 to 11.00	18.00 to 19.50	—	—	—

Table 1—Steel grades and chemical composition(*continued*)

No.	ISC	Grade	Chemical composition(mass fraction)/%									
			C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Nb
3	S31608	06Cr17Ni12Mo2	≤0.08	≤1.00	≤2.00	≤0.040	≤0.030	10.00 to 14.00	16.00 to 18.00	2.00 to 3.00	—	—
4	S31603	022Cr17Ni12Mo2	≤0.030	≤1.00	≤2.00	≤0.040	≤0.030	10.00 to 14.00	16.00 to 18.00	2.00 to 3.00	—	—
5	S32168	06Cr18Ni11Ti	≤0.08	≤1.00	≤2.00	≤0.040	≤0.030	9.00 to 12.00	17.00 to 19.00	—	5C to 0.70	—
6	S34778	06Cr18Ni11Nb	≤0.08	≤1.00	≤2.00	≤0.040	≤0.030	9.00 to 12.00	17.00 to 19.00	—	—	10C to 1.10

6.1.2 If required by the purchaser, product analysis shall be specified in the contract. The permissible deviation of the product analysis of the steel pipes shall comply with the requirements in GB/T 222.

6.2 Manufacturing method

6.2.1 Steel-making process

The steel shall be smelted by the method of crude molten steel and external refining. When agreed by supplier and purchaser, and specified in the contract, other equivalent steel-making processes may be used.

6.2.2 Production process of steel pipe

6.2.2.1 Steel Pipes may be manufactured by class Ⅰ, Ⅱ or Ⅲ according to clause 3. When a specific steel pipe production press is required by purchaser, it shall be indicated in the contract.

6.2.2.2 Only a single longitudinal weld seam is permissible on the steel pipe. When agreed by supplier and purchaser,and specified in the contract, two longitudinal weld seams or one longitudinal weld seam plus circumferential welding is permissible for steel pipe with *D* not less than 610 mm.

6.2.2.3 Repair welding at the same position for more than two times is not permissible. The position to be repaired shall be properly cleaned and machined prior to welding, and the defects shall be thoroughly removed by grinding. After repair welding, re-inspection shall be carried out with the same method. Repair weld length shall not exceed 20% of the total weld length.Repair welding shall be performed prior to heat treatment. If repair welding is carried out after heat treatment, the heat treatment shall be performed again after repair welding.

6.2.2.4 For steel pipe welded with filler metal, the chemical composition of the filler metal shall not be less alloyed than that of the base material.

6.3 Delivery conditions

6.3.1 The steel pipes shall be delivered in the condition of heat treatment, pickling and passivation. The recommended heat treatment process of steel pipes is listed in Table 2.

6.3.2 When agreed between supplier and purchaser, and specified in the contract, the other heat treatment processes for steel pipes not listed in Table 2 may be used.

6.4 Mechanical properties

6.4.1 Tensile test

6.4.1.1 The tensile properties of the base material of the heat-treated steel pipe shall comply with the requirements in Table 2.

6.4.1.2 The transverse tensile strength of weld of the heat-treated steel pipe shall comply with the requirements in Table 2.

Table 2—Recommended heat treatment, mechanical properties and density

No.	ISC	Grade	Recommended heat treatment processes	Tensile properties				Hardness		Density ρ kg/dm^3
				Tensile strength R_m MPa	Proof strength $R_{p0.2}$ MPa	Percentage elongation after fracture A/%		HRB	HRW	
						Longitudinal	Transverse	Not exceeding		
1	S30408	06Cr19Ni10	1 040 ℃ to 1 150 ℃ water cooling or other rapid cooling	≥520	≥210	≥40	≥35	90	192	7.93
2	S30403	022Cr19Ni10	1 040 ℃ to 1 150 ℃ water cooling or other rapid cooling	≥490	≥175	≥40	≥35	90	192	7.93
3	S31608	06Cr17Ni12Mo2	1 040 ℃ to 1 150 ℃ water cooling or other rapid cooling	≥520	≥210	≥40	≥35	90	192	8.00
4	S31603	022Cr17Ni12Mo2	1 040 ℃ to 1 150 ℃ water cooling or other rapid cooling	≥490	≥175	≥40	≥35	90	192	7.93

Table 2—Recommended heat treatment, mechanical properties and density (*continued*)

No.	ISC	Grade	Recommended heat treatment processes	Tensile properties				Hardness		Density ρ kg/dm^3
				Tensile strength R_m MPa	Proof strength $R_{p0.2}$ MPa	Percentage elongation after fracture A/%		HRB	HRW	
						Longitudinal	Transverse	Not exceeding		
5	S32168	06Cr18Ni11Ti	⩾1 040 ℃ water cooling or other rapid cooling	⩾520	⩾210	⩾40	⩾35	90	192	8.03
6	S34778	06Cr18Ni11Nb	⩾1 040 ℃ water cooling or other rapid cooling	⩾520	⩾210	⩾40	⩾35	90	192	8.03

6.4.2 Impact test

Transverse Charpy V-notch impact test shall be carried out on weld and base material of steel pipes. The impact test temperature is −196 ℃. The impact absorption energy shall comply with the requirements in Table 3. When the steel pipe size is not enough to take the impact test piece of 10 mm by 3.3 mm, the impact test is not required.

Table 3—Requirement of impact test

Specimen size (height × width) mm	Average impact absorbed energy of three test pieces J	Minimum impact absorbed energy of a test pieces J	Lateral expansion value mm
10 × 10	⩾ 60	⩾ 42	⩾ 0.38
10 × 7.5	⩾ 45	⩾ 31	⩾ 0.38
10 × 5	⩾ 30	⩾ 21	⩾ 0.38
10 × 3.3	⩾ 20	⩾ 14	⩾ 0.38

6.4.3 Hardness test

If required by purchaser, agreed between supplier and purchaser, and specified in the contract, for the steel pipe with wall thickness not less than 1.7 mm, Brinell or Rockwell hardness test of base metal may be carried out. The average hardness value shall comply with the requirements in Table 2.

6.5 Hydrostatic test

6.5.1 Each pipe shall be subjected to a hydrostatic test. The hydrostatic test pressure is calculated

by the Formula (2), and the maximum hydrostatic test pressure shall not exceed 19 MPa.

$$P = \frac{2SR}{D} \quad (2)$$

where

P is the test pressure, in MPa, rounded to the nearest 0.5 MPa for pressure below 7 MPa, and to the nearest 1 MPa for pressures of 7 MPa and above;

S is the wall thickness of the steel pipes, in mm;

D is the nominal outside diameter of the steel pipes, in mm;

R is allowable stress, 50% of the lower yield strength shown in Table 3, in MPa.

The test pressure shall be held for not less than 10 s, and steel pipes shall be free of leakage during the test.

6.5.2 If required by purchaser, agreed between supplier and purchaser, and specified in the contract, the steel pipes may be hydrostatic tested by other pressure.

6.5.3 If required by purchaser, agreed between supplier and purchaser, and specified in the contract, the non-destructive test may be performed in lieu of hydrostatic test.

6.6 Transverse bending test of welds

6.6.1 Transverse bending test shall be carried out on the welds of steel pipes. The test piece shall be taken from the steel pipe or welding test plate, and the welding test plate shall have the same grade, heat number, welding processing and heat treatment as the steel pipe. For wall thickness not larger than 20 mm, one set of samples shall be subject to a face guided-bend test and the second to a root guided-bend test, that is the outside weld and inside weld of steel pipe shall be at the maximum surface of bending respectively. For wall thicknesses over 20 mm, two side-bend test pieces shall be taken with full wall thickness.

6.6.2 When testing, the test piece shall bend around a grooved former with a thickness of three times the wall thickness, having a 180° bending angle. After the test, the test piece shall be free of cracks or breaks.

6.7 Non-destructive test

100% radiographic examination for all welds shall be performed in accordance with GB/T 3323 or NB/T 47013.2 and comply with the requirement of the acceptance level Ⅱ.

6.8 Surface quality

6.8.1 The internal andexternal surfaces of the steel pipes shall befree of cracks, lamination, lack of penetrations. These defects shall be completely removed, and the actual wall thickness shall be not less than the permitted minimum wall thickness.

6.8.2 For double welded steel pipes, the internal and external weld surface on either side of the weld shall be flush with the base plate or to have a reasonably uniform crown, not to exceed 2.0 mm. For single welded steel pipes, the external weld surface shall be smooth with the base plate, and the reinforcement of the internal weld surface shall be less than 15%S, but 2.0 mm at maximum.

6.8.3 Weld repair is not permitted. Only grinding may be used for removing defects.

6.9 Special requirements

The following special requirements may be required by the purchaser, subject to agreement between the purchaser and the manufacturer, and specified in the contract:

a) ferrite content test;

b) penetrant test;

c) intergranular corrosion test.

7 Test methods

7.1 The sampling of the chemical composition of the steel pipes shall comply with GB/T 20066. Chemical analysis is usually conducted according to GB/T 223.11, GB/T 223.16, GB/T 223.25, GB/T 223.28, GB/T 223.40, GB/T 223.58, GB/T 223.59, GB/T 223.60, GB/T 223.67, GB/T 223.86, GB/T 11170, GB/T 20123. In case of arbitration, the analysis shall be conducted according to the requirement in GB/T 223.11, GB/T 223.16, GB/T 223.25, GB/T 223.28, GB/T 223.40, GB/T 223.58, GB/T 223.59, GB/T 223.60, GB/T 223.67 and GB/T 223.86.

7.2 The dimensions and shapes of steel pipes shall be measured using tools that meet the requirements for accuracy. The outside diameter may be calculated in accordance with the circumference measurement.

7.3 The internal and external surfaces of steel pipes shall be visually inspected under sufficient illumination or by endoscope.

7.4 The sampling method and test methods for other inspection items of the steel pipes shall comply with the requirement in Table 4.

Table 4—Test items, sampling quantities, sampling methods and test methods for steel pipes

No.	Test item	Sampling quantity	Sampling method	Test method
1	Chemical composition	One per heat	GB/T 20066	See 7.1
2	Tensile test	One taken from each lot on two steel pipes or plate	GB/T 2975	GB/T 228.1
3	Hardness test	One taken from each lot on two steel tubes or plate	GB/T 2975	GB/T 230.1 GB/T 231.1
4	Transverse bending test of welds	One taken from each lot on two steel tubes or plate	GB/T 232	GB/T 232
5	Hydrostatic Test	Each pipe	—	GB/T 241
6	Radiographic examination	Each pipe	—	GB/T 3323 NB/T 47013.2
7	Impact test	One set of test pieces (3 samples) taken from each lot or plate including the weld and base metal	GB/T 2975	GB/T 229 GB/T 2650
8	Ferrite content	Agreement	Agreement	GB/T 1954
9	Penetration test	Agreement	Agreement	NB/T 47013.5
10	Inter-granular corrosion test	One taken from each lot on two steel tubes or plate	GB/T 4334—2008	GB/T 4334—2008 method E

8 Inspection rules

8.1 Inspection and acceptance

The inspection and acceptance of the steel pipes shall be carried out by the supplier's quality and technical supervision department.

8.2 Test unit

Steel pipes shall be checked and accepted according to the lot. Each lot of the steel pipes shall consist of the same grade, heat number, dimensions, welding process and heat treatment system. The quantity of each lot shall not exceed the following requirements:

a) 100 pcs for steel pipes not greater than 610 mm in outside diameter;

b) 50 pcs for steel pipes greater than 610 mm in outside diameter.