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Carbon steel tubes for boiler and heat exchanger

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry based on the provision of Article 14, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act in response to a proposal for revision of Japanese Industrial Standard with a draft being attached, submitted by The Japan Iron and Steel Federation (JISF), an accredited standards development organization. This edition replaces the previous edition (**JIS G 3461** : 2019), which has been technically revised.

However, **JIS G 3461** : 2019 may be applied in the **JIS** mark certification based on the relevant provisions of Article 30, paragraph (1), etc. of the Industrial Standardization Act until 19 December 2024.

Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, published patent application or utility model rights. The relevant Minister is not responsible for identifying any of such patent rights, published patent application or utility model rights.

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Carbon steel tubes for boiler and heat exchanger

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 9329-2** : 1997, Edition 1, and **ISO 9330-2** : 1997, Edition 1, with some modifications of the technical contents.

Annex JA and Annex JB are unique to **JIS** and not given in the corresponding International Standards. The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standards. A list of modifications with the explanations is given in Annex JC.

1 Scope

This Standard specifies requirements for the carbon steel tubes used for exchanging heat between the inside and outside of the tube (hereafter referred to as tubes), such as water tubes, smoke tubes, superheater tubes, tubes used for air preheater, etc. of boilers, and heat exchanger tubes, condenser tubes and catalyser tubes, etc. used in chemical and petroleum industries. It is not applicable to the steel tubes for fired heater and steel heat exchanger tubes for low temperature service.

NOTE 1 This Standard is generally applicable to tubes of outside diameters 15.9 mm to 139.8 mm.

NOTE 2 The International Standards corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 9329-2 : 1997 *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2 : Unalloyed and alloyed steels with specified elevated temperature properties*

ISO 9330-2 : 1997 *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 2 : Electric resistance and induction welded unalloyed and alloyed steel tubes with specified elevated temperature properties* (overall evaluation : MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standards and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

Part or all of the provisions of the following standards, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS G 0201 *Glossary of terms used in iron and steel (Heat treatment)*

JIS G 0202 *Glossary of terms used in iron and steel (Testing)*

JIS G 0203 *Glossary of terms used in iron and steel (Products and quality)*

JIS G 0320 *Standard test method for heat analysis of steel products*

JIS G 0321 *Product analysis and its tolerance for wrought steel*

JIS G 0404 *Steel and steel products — General technical delivery requirements*

JIS G 0415 *Steel and steel products — Inspection documents*

JIS G 0567 *Method of elevated temperature tensile test for steels and heat-resisting alloys*

JIS G 0582 *Automated ultrasonic examination of steel pipes and tubes*

JIS G 0583 *Automated eddy current examination of steel pipes and tubes*

JIS Z 2241 *Metallic materials — Tensile testing — Method of test at room temperature*

JIS Z 2245 *Rockwell hardness test — Test method*

JIS Z 8401 *Rounding of numbers*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS G 0201**, **JIS G 0202** and **JIS G 0203** apply.

4 Symbols of grade

Tubes are classified into 3 grades. The symbols of grade and symbols for manufacturing method are as given in Table 1.

Table 1 Symbols of grade and symbols for manufacturing method

Symbol of grade	Symbol for manufacturing method		
	Tube manufacturing method	Finishing method	Marking
STB340 STB410 STB510	Seamless : S Electric resistance welded : E	Hot-finished : H Cold-finished : C As electric resistance welded : G	As given in **15 b**).

5 Manufacturing method

The manufacturing method shall be as follows.

a) Tubes shall be manufactured from the killed steel and by a combination of the tube manufacturing method and the finishing method which is given in Table 1. Symbols for manufacturing method are as given in Table 1.

b) Tubes shall be subjected to the heat treatment given in Table 2. Other heat treat-

ments may be applied upon agreement between the purchaser and the manufacturer.

c) Tubes shall be finished with plain ends unless otherwise specified.

d) When tubes are manufactured by electric resistance welding, the weld beads on external and internal surfaces shall be removed to smooth the surfaces along the contour of the tube. The weld beads on internal surface may be left unremoved if so agreed between the purchaser and the manufacturer.

Table 2 Heat treatment

Symbol of grade	Heat treatment				
	Hot-finished seamless steel tube	Cold-finished seamless steel tube	As electric resistance welded steel tube	Hot-finished electric resistance welded steel tube	Cold-finished electric resistance welded steel tube [a)]
STB340	As manufactured. Low temperature annealing or normalizing may be performed as necessary.	Low temperature annealing, normalizing or full annealing	Normalizing	As manufactured. Low temperature annealing or normalizing may be performed as necessary.	Normalizing
STB410	As manufactured. Low temperature annealing or normalizing may be performed as necessary.	Low temperature annealing, normalizing or full annealing	Normalizing	Low temperature annealing	Normalizing
STB510	Normalizing				
Note [a)]	The cold-finished electric resistance welded steel tube which has been normalized prior to cold finishing may be finished by low temperature annealing or full annealing.				

6 Chemical composition

Tubes shall be tested in accordance with **13.1** and the obtained heat analysis values shall satisfy the requirements given in Table 3. When the product analysis is requested by the purchaser, the test shall be carried out in accordance with **13.1**. The obtained product analysis values shall satisfy the requirements in Table 3 within tolerances given below.

a) For seamless steel tubes, tolerances given in Table 3 of **JIS G 0321** shall apply.

b) For electric resistance welded steel tubes, tolerances in Table 2 of **JIS G 0321** shall

apply.

Table 3 Chemical composition

Unit: %

Symbol of grade	C	Si [a)]	Mn	P	S
STB340	0.18 max.	0.35 max.	0.30 to 0.60	0.035 max.	0.035 max.
STB410	0.32 max.	0.35 max.	0.30 to 0.80	0.035 max.	0.035 max.
STB510	0.25 max.	0.35 max.	1.00 to 1.50	0.035 max.	0.035 max.
Alloy elements not listed in this table may be added as necessary. Note [a)] Si content may be in a range of 0.10 % to 0.35 %, as specified by the purchaser.					

7 Mechanical properties

7.1 Tensile strength, yield point or proof stress, and elongation

Tubes shall be tested in accordance with **13.2.1**, **13.2.2** and **13.2.3**, and the tensile strength, yield point or proof stress, and elongation shall be as given in Table 4. When the tensile test is carried out on Test piece No. 12 for the tube under 8 mm in wall thickness, the elongation shall be in accordance with Table 5.

Table 4 Tensile strength, yield point or proof stress, and elongation

Symbol of grade	Tensile strength [a)]	Yield point or proof stress [b)]	Elongation %		
			Outside diameter		
			Under 10 mm	10 mm or over to and excl. 20 mm	20 mm or over
			Test piece		
			Test piece No. 11	Test piece No. 11	Test piece No. 11 or Test piece No. 12
			Tensile test direction		
	N/mm²	N/mm²	Parallel to tube axis	Parallel to tube axis	Parallel to tube axis
STB340	340 min.	175 min.	27 min.	30 min.	35 min.
STB410	410 min.	255 min.	17 min.	20 min.	25 min.
STB510	510 min.	295 min.	17 min.	20 min.	25 min.
NOTE 1 N/mm² = 1 MPa Note [a)] Exclusively for the heat exchanger tubes, the purchaser may, where necessary, specify the maximum value of tensile strength. In this case, the maximum tensile strength value shall be the value obtained by adding 120 N/mm² to the value in this table. Note [b)] Unless otherwise specified, the yield point to be determined shall be the upper yield point, R_{eH}, or, wherever this is not pronounced, the 0.2 % proof stress, $R_{p0.2}$.					

Table 5 Elongation for Test piece No. 12 of tube under 8 mm in wall thickness (direction parallel to tube axis)

Unit: %

Symbol of grade	Wall thickness						
	Over 1 mm up to and incl. 2 mm	Over 2 mm up to and incl. 3 mm	Over 3 mm up to and incl. 4 mm	Over 4 mm up to and incl. 5 mm	Over 5 mm up to and incl. 6 mm	Over 6 mm up to and incl. 7 mm	Over 7 mm to and excl. 8 mm
STB340	26 min.	28 min.	29 min.	30 min.	32 min.	34 min.	35 min.
STB410	16 min.	18 min.	19 min.	20 min.	22 min.	24 min.	25 min.
STB510	16 min.	18 min.	19 min.	20 min.	22 min.	24 min.	25 min.
NOTE	The elongation values in this table are calculated by subtracting 1.5 % from the elongation value given in Table 4 for each 1 mm decrease of tube wall thickness from 8 mm, and by rounding the result to an integer according to Rule A of **JIS Z 8401**.						

7.2 Flattening resistance

Tubes shall be tested in accordance with **13.2.1**, **13.2.2** and **13.2.4**. When flattened until the distance between two platens H reaches the value obtained by Formula (1), the test piece shall be free from cracks.

$$H = \frac{(1+e)\ t}{e+\frac{t}{D}} \quad \cdots\cdots(1)$$

where, H: distance between platens (mm)

t : wall thickness of tube (mm)

D: outside diameter of tube (mm)

e : constant for each grade of tube

STB340 : 0.09
STB410 : 0.08
STB510 : 0.07

NOTE For the details of flattening test, see **13.2.4**.

7.3 Flaring property

Tubes shall be tested in accordance with **13.2.1**, **13.2.2** and **13.2.5**. When flared into a trumpet shape until the outside diameter is enlarged 1.2 times the original size, the test piece shall be free from cracks. For tubes of outside diameter exceeding 101.6 mm, this requirement shall apply when the flaring test is requested by the purchaser.

NOTE For the details of flaring test, see **13.2.5**.

7.4 Reverse flattening resistance

Electric resistance welded steel tubes shall be tested in accordance with **13.2.1**, **13.2.2** and **13.2.6** and the test piece shall be free from cracks in the weld.

NOTE For the test of reverse flattening resistance, see **13.2.6**.

8 Selection of hydraulic test characteristics or non-destructive test characteristics

Tubes shall be subjected to the hydraulic test in accordance with **13.3** or the

non-destructive test in accordance with **13.4**, and their characteristics shall conform to either of the following. The decision on which characteristics to be tested shall be left to the discretion of the purchaser. If not specified by the purchaser, it shall be left to the discretion of the manufacturer.

a) **Hydraulic test characteristics**, as follows.

1) When a hydraulic test pressure is not specified by the purchaser, the tube shall be subjected to the minimum hydraulic test pressure P calculated by Formula (2) (10 MPa if P exceeds 10 MPa), and shall withstand the pressure without leakage.

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

where, P : test pressure (MPa)
t : wall thickness of tube (mm)
D : outside diameter of tube (mm)
s : 60 % of the specified minimum value of yield point or proof stress given in Table 4 (N/mm^2)

2) When a hydraulic test pressure is specified by the purchaser, the tube shall be subjected to the pressure, which is regarded as the minimum hydraulic test pressure, and shall withstand the pressure without leakage. If the pressure specified by the purchaser is greater than either the test pressure P calculated by Formula (2) or 10 MPa, the test pressure to be applied shall be as agreed between the purchaser and the manufacturer. The test pressure shall be specified in 0.5 MPa increments if lower than 10 MPa, and in 1 MPa increments if 10 MPa or higher.

b) **Non-destructive test characteristics** Tubes shall be tested by either the ultrasonic examination or the eddy current examination, and their non-destructive test characteristics shall be as follows. Other non-destructive tests specified in relevant Japanese Industrial Standards (**JIS**s) may replace these tests upon agreement between the purchaser and the manufacturer, in which case the judgement criteria shall be at least equal to those applied in the ultrasonic examination or the eddy current examination.

NOTE Other non-destructive tests in accordance with **JIS**s include the test specified in **JIS G 0586** [1].

1) For the ultrasonic examination characteristics, the signals from the reference sample containing Category UD reference standard specified in **JIS G 0582** shall be regarded as alarm level, and there shall be no signals equivalent to or greater than the alarm level. When the tube to be tested is finished by other methods than cold finishing, the minimum depth of square notch shall be 0.3 mm.

2) For the eddy current examination characteristics, the signals from the reference sample containing Category EY reference standard specified in **JIS G 0583** shall be regarded as alarm level, and there shall be no signals equivalent to or greater than the alarm level.

9 Dimensions, unit masses and dimensional tolerances

9.1 Dimensions and unit masses

The outside diameters, wall thicknesses and unit masses of tubes shall be as given in Table 6. Dimensions not specified in Table 6 may be used upon agreement between the purchaser and the manufacturer. In this case, the unit mass shall be calculated by Formula (3), assuming 1 cm^3 steel to be 7.85 g, and the result shall be rounded to 3 significant figures according to Rule A of **JIS Z 8401**. The result value exceeding 1 000 kg/m shall be rounded to a four-digit integer.

$$W = 0.024\,66\,t\,(D - t) \quad \cdots\cdots (3)$$

where, W: unit mass of tube (kg/m)

t : wall thickness of tube (mm)

D: outside diameter of tube (mm)

0.024 66 : unit conversion factor for obtaining W

NOTE The unit mass values in Table 6 are the results of the calculation given above.

Table 6 Outside diameters, wall thicknesses and unit masses of carbon steel tubes for boiler and heat exchanger

Unit: kg/m

Outside diameter (mm)	Wall thickness (mm)																		
	1.2	1.6	2.0	2.3	2.6	2.9	3.2	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0	9.5	11.0	12.5
15.9	0.435	0.564	0.686	0.771	0.853	0.930													
19.0	0.527	0.687	0.838	0.947	1.05	1.15													
21.7	0.607	0.793	0.972	1.10	1.22	1.34	1.46												
25.4	0.716	0.939	1.15	1.31	1.46	1.61	1.75	1.89											
27.2	0.769	1.01	1.24	1.41	1.58	1.74	1.89	2.05	2.29										
31.8	0.906	1.19	1.47	1.67	1.87	2.07	2.26	2.44	2.74	3.03									
34.0		1.28	1.58	1.80	2.01	2.22	2.43	2.63	2.96	3.27	3.58								
38.1		1.44	1.78	2.03	2.28	2.52	2.75	2.99	3.36	3.73	4.08	4.42							
42.7			2.01	2.29	2.57	2.85	3.12	3.38	3.82	4.24	4.65	5.05	5.43						
45.0			2.12	2.42	2.72	3.01	3.30	3.58	4.04	4.49	4.93	5.36	5.77	6.17					
48.6			2.30	2.63	2.95	3.27	3.58	3.89	4.40	4.89	5.38	5.85	6.30	6.75	7.18				
50.8			2.41	2.75	3.09	3.43	3.76	4.08	4.62	5.14	5.65	6.14	6.63	7.10	7.56	8.44	9.68	10.8	11.8
54.0			2.56	2.93	3.30	3.65	4.01	4.36	4.93	5.49	6.04	6.58	7.10	7.61	8.11	9.07	10.4	11.7	12.8
57.1			2.72	3.11	3.49	3.88	4.25	4.63	5.24	5.84	6.42	7.00	7.56	8.11	8.65	9.69	11.2	12.5	13.7
60.3			2.88	3.29	3.70	4.10	4.51	4.90	5.55	6.19	6.82	7.43	8.03	8.62	9.20	10.3	11.9	13.4	14.7
63.5				3.47	3.90	4.33	4.76	5.18	5.87	6.55	7.21	7.87	8.51	9.14	9.75	10.9	12.7	14.2	15.7
65.0				3.56	4.00	4.44	4.88	5.31	6.02	6.71	7.40	8.07	8.73	9.38	10.0	11.2	13.0	14.6	16.2
70.0				3.84	4.32	4.80	5.27	5.74	6.51	7.27	8.01	8.75	9.47	10.2	10.9	12.2	14.2	16.0	17.7
76.2				4.19	4.72	5.24	5.76	6.27	7.12	7.96	8.78	9.59	10.4	11.2	11.9	13.5	15.6	17.7	19.6
82.6							6.27	6.83	7.75	8.67	9.57	10.5	11.3	12.2	13.1	14.7	17.1	19.4	21.6
88.9							6.76	7.37	8.37	9.37	10.3	11.3	12.3	13.2	14.1	16.0	18.6	21.1	23.6
101.6								8.47	9.63	10.8	11.9	13.0	14.1	15.2	16.3	18.5	21.6	24.6	27.5
114.3									10.9	12.2	13.5	14.8	16.0	17.3	18.5	21.0	24.6	28.0	31.4
127.0									12.1	13.6	15.0	16.5	17.9	19.3	20.7	23.5	27.5	31.5	35.3
139.8												18.2	19.8	21.4	22.9	26.0	30.5	34.9	39.2

NOTE The standard unit mass is used in transactions. The standard unit mass is to be the value given in this table increased by 15 % for the hot-finished seamless steel tube, by 10 % for the cold-finished seamless steel tube, and by 9 % for the electric resistance welded steel tube.

9.2 Dimensional tolerances

The dimensional tolerances for tubes shall be as follows.

a) Tolerances on outside diameter of tubes shall be as given in Table 7.

b) Tolerances on wall thickness and eccentricity of tubes shall be as given in Table 8.

c) Tolerances on length of tubes shall be as given in Table 9.

Table 7 Tolerances on outside diameter

Unit: mm

Outside diameter range	Hot-finished seamless steel tube	Cold-finished seamless steel tube	Hot-finished electric resistance welded steel tube and as electric resistance welded steel tube [a]	Cold-finished electric resistance welded steel tube
Under 25	+0.4 –0.8	±0.10	±0.15	±0.10
25 or over to and excl. 40		±0.15	±0.20	±0.15
40 or over to and excl. 50		±0.20	±0.25	±0.20
50 or over to and excl. 60		±0.25	±0.30	±0.25
60 or over to and excl. 80		±0.30	±0.40	±0.30
80 or over to and excl. 100		±0.40	+0.40 –0.60	±0.40
100 or over to and excl. 120	+0.4 –1.2	+0.40 –0.60	+0.40 –0.80	+0.40 –0.60
120 or over to and excl. 160		+0.40 –0.80	+0.40 –1.00	+0.40 –0.80
160 or over to and excl. 200	+0.4 –1.8	+0.40 –1.20	+0.40 –1.20	+0.40 –1.20
200 or over	+0.4 –2.4	+0.40 –1.60	+0.40 –1.60	+0.40 –1.60

The tolerances on outside diameter in this table do not apply to local repaired parts.

Note [a] For the electric resistance welded steel tubes which are finished by methods other than cold finishing, the tolerances on the outside diameter of cold-finished electric resistance welded steel tubes may apply when requested by the purchaser.

Table 8 Tolerances on wall thickness and eccentricity

Tolerance	Wall thickness mm	Outside diameter mm					
		Hot-finished seamless steel tube		Cold-finished seamless steel tube		Electric resistance welded steel tube	
		Under 100	100 or over	Under 40	40 or over	Under 40	40 or over
Tolerance on wall thickness	Under 2	[a] 0	[a] 0	+0.4 mm 0	+22 % 0	+0.3 mm 0	+18 % 0
	2 or over to and excl. 2.4	+40 % 0	[a] 0	+20 % 0		+18 % 0	
	2.4 or over to and excl. 3.8	+35 % 0	+35 % 0				
	3.8 or over to and excl. 4.6	+33 % 0	+33 % 0				
	4.6 or over	+28 % 0	+28 % 0				
Tolerance on eccentricity [b]	5.6 or over	22.8 % max. of wall thickness		—		—	

Note [a] The plus tolerance is not specified.

Note [b] Eccentricity is expressed by the ratio, in percentage, of the difference between the maximum value and the minimum value of the wall thickness measured on the same cross-section of the tube to the wall thickness value specified in the order. This requirement does not apply to tubes under 5.6 mm in wall thickness.

Table 9 Tolerances on length

Outside diameter	Length	Tolerance on length
50 mm or under	7 m or under	+7 mm 0
	Over 7 m up to and incl. 10 m	+10 mm 0
	Over 10 m up to and incl. 13 m	+13 mm 0
	Over 13 m	+15 mm 0
Over 50 mm	7 m or under	+10 mm 0
	Over 7 m up to and incl. 10 m	+13 mm 0
	Over 10 m	+15 mm 0
The tolerances on length may be $^{+30}_{0}$ mm upon agreement between the purchaser and the manufacturer.		

10 Appearance

The appearance shall be as follows.

a) Tubes shall be straight for practical purposes with both ends at right angles to the tube axis.

b) The internal and external surfaces of tubes shall be finished smoothly and free from defects detrimental to use. For the electric resistance welded steel tubes, the convex on internal surface of the weld shall be 0.25 mm or under. The purchaser may specify the internal convex to be 0.15 mm or under for tubes of outside diameter 50.8 mm or under and of wall thickness 3.5 mm or under.

c) The surfaces of tubes may be repaired by grinding, machining or other methods, provided that the wall thickness after repair is within the specified tolerance on wall thickness.

d) The surface of the repaired part shall be smooth along the contour of the tube.

11 Supplementary quality requirements

The supplementary quality requirements to be applied upon agreement between the purchaser and the manufacturer shall be as given in Annex JA.

12 U-bent tubes

U-bent tubes shall be produced upon agreement between the purchaser and the manufacturer. The manufacturing method, appearance, dimensional tolerances on bent portion, measuring method of dimensions and hydraulic test characteristics of U-bent tubes shall be in accordance with Annex JB.