JIS G4904 Seamless nickel-chromium-iron alloy heat exchanger tubes

1. Scope

This Japanese Industrial Standard specifies the seamless nickel-chromium-iron alloy tubes (hereafter referred to as the "tubes"), intended for heat exchanger tubes and condenser tubes for chemical and petroleum industries, steam generator tubes for nuclear industry, and the like, all of them designed for exchanging heat between the inside and outside of tubes.

Tubes for fired heater are not covered by this Standard and specified in other Standard.

Remarks

1. The purchaser may specify, in addition to the items given in this text, part or all of the supplementary quality requirements of Z 1 to 4 in Annex 1 and U0bend tube specified in Annex 2 by prior agreement with the manufacturer.

Annex 1 Z 1 Hardness

Annex 1 Z 2 High temperature yield point or proof stress

Annex 1 Z 3 Ultrasonic examination

Annex 1 Z 4 Eddy current examination

Annex 1 U U-bend tube

2. Applicable standards to this Standard are shown as follows

JIS G 0303 General Rules for Inspection of Steel

JIS G 0551 Methods of Austenite Grain Size Test for Steel

JIS G 0567 Method of High Temperature Tensile Test for Steels and Heat-Resisting Alloys

JIS G 0582 Ultrasonic Examination for Steel Pipes and Tubes

JIS G 0583 Eddy Current Examination of Steel Pipes and Tubes

JIS G 1256 Method for X-Ray Fluorescence Spectrometric Analysis of Iron and Steel

JIS G 1257 Methods for Atomic Absorption Petrochemical Analysis of Iron and Steel

JIS G 1281 Methods for Chemical Analysis of Nickel-Chromium-Iron Alloys

JIS Z 2201 Test Pieces for Tensile Test for Metallic Materials

JIS Z 2241 Method of Tensile Test for Metallic Materials

JIS Z 2245 Method of Rockwell and Rockwell Superficial Hardness Test

JIS Z 8401 Rules for Rounding off of Numerical Values

2. Grade and symbol

Tubes shall be classified into 6 grades and their symbols shall be as given in Table 1.

Table 1 Symbol of grade

Symbol of grade
NCF600TB
NCF625TB
NCF690TB
NCF800TB
NCF800HTB
NCF825TB

World Standard Comferens Table

	KS	JIS	ASTM			
Grade number	D 3757	G 4904	B163	B167	B407	B423
Designation of Grade	NCF 600TB	NCF 600 TB	N02200	-	-	-
	NCF 625TB	NCF 625 TB	N02201	-	-	-
	NCF 690TB	NCF 690 TB	N04400	-	-	-
	NCF 800TB	NCF 800 TB	N06600 N06690 N06025	-	-	-
	NCF 800HTB	NCF 800 HTB	N08800 N08801 N06045	-	-	-
	NCF 825TB	NCF 825 TB	N08810 N08811 N08825	-	-	-

	-	-	-	UNS N06600 N06690 N06601 N08800 N08810 N08811 N06025 N06045 N08825 N08221	UNS N06600 N06690 N06601 N08800 N08810 N08811 N06025 N06045 N08825 N08221	UNS N06600 N06690 N06601 N08800 N08810 N08811 N06025 N06045 N08825 N08221

3. Chemical composition

Tubes shall be subjected to the test of 10.1 and their cast analyses shall conform to Table 2.

Table 2 Chemical composition

Unit: %

Symbol of grade	C	Si	Mn	P	S	Ni	Cr	Fe	Mo	Cu	Al	Ti	Nb+Ta
NCF600TB	0.15 max.	0.50 max.	1.00 max.	0.030 max.	0.015 max.	72.00 min.	14.00~ 17.00	6.00~ 10.00	-	0.50 max.	-	-	-
NCF625TB	0.10 max.	0.50 max.	0.50 max.	0.015 max.	0.015 max.	58.00 min.	20.00~ 23.00	5.00 max.	8.00~ 10.00	-	0.40 max.	0.40 max.	3.15~ 4.15
NCF690TB	0.05 max.	0.50 max.	0.50 max.	0.030 max.	0.015 max.	58.00 min.	27.00~ 31.00	7.00 11.00	-	0.50 max.	-	-	-
NCF800TB	0.10 max.	1.00 max.	1.50 max.	0.030 max.	0.015 max.	30.00~ 35.00	19.00~ 23.00	Remainder	-	0.75 max.	0.15~ 0.60	0.15~ 0.60	-
NCF800HTB	0.05 ~0.10	1.00 max.	1.50 max.	0.030 max.	0.015 max.	30.00~ 35.00	19.00~ 23.00	Remainder	-	0.75 max.	0.15~ 0.60	0.15~ 0.60	-
NCF825TB	0.05 max.	0.50 max.	1.00 max.	0.030 max.	0.015 max.	33.00~ 45.00	19.50~ 23.50	Remainder	2.50~ 3.00	1.50~ 3.00	0.20 max.	0.60~ 1.20	-

Remarks

1. An analytical value of Ni may contain Co..

2. When requested by the purchaser, product analysis may be conducted. In this case, the permissible variation of chemical composition shall be agreed upon between the parties concerned with delivery.

4. Mechanical properties

4.1 Tensile strength, proof stress, and elongation Tubes shall be tested in accordance with 10.2 and the resultant tensile strength, proof stress, and elongation shall conform to Table 3.

Table 3 Mechanical properties

Symbol of grade	Heat treatment	Tensile strength N/㎟	Proof stress N/㎟	Elongation %
NCF600TB	Annealing	550 min.	245 min.	30 min.
NCF625TB	Annealing	820 min.	410 min.	30 min.
	Soultion treatment	690 min.	275 min.	30 min.
NCF690TB	Annealing	590 min.	245 min.	30 min.
NCF800TB	Annealing	520 min.	205 min.	30 min.
NCF800HTB	Soultion treatment	450 min.	175 min.	30 min.
NCF825TB	Annealing	580 min.	235 min.	30 min.

Remarks

1. The elongation indicates the value obtained from the tensile test on no. 11 or no. 12 test piece.

2. When a tensile test is conducted on no. 12 test piece for tubes of under 8mm in wall thickness, the minimum value of elongation shall be reduced at the rate of 1.5 % from the elongation value given in Table 3 for each 1mm decrease in wall thickness from 8mm, and be rounded off to an integer in accordance with JIS Z 8401.

3. The tubes of under 20mm in outside diameter, the value in the above table shall bit be applied, though the values shall be noted.

4.2 Flattening resistance

Tubes shall be tested in accordance with 10.3 and shall be free from flaws, cracks on their wall surfaces.

In that case, the distance between the flattening plates shall conform to the following formula

$$H = (1 + e)\, t / (e + t/D)$$

Where, H: distance between flattening plates (mm)

T: wall thickness of tube(mm)

D: outside diameter of tube(mm)

e: 0.09(constant)

4.3 Flaring resistance

When tubes are tested in accordance with 10.4 and are flared into a trumpet shape to 1.3 times the outside diameter for NCF600TB, NCF690TB, NCF800TB, and NCF800TB and 1.2 times for NCF825TB, and NCF625TB, the tube walls shall be free from flaws.

5. Austenitic grain size

NCF 800 HTB tubes shall be tested in accordance with 10.4 and the resulting austenitic grain size number shall be equal to or coarser than no.5

6. Hydrostatic characteristic or nondestructive characteristic

Tubes shall be tested in accordance with 10.5 for either hydrostatic characteristic or nondestructive characteristic, and the result shall conform to the following alternative. The preference shall be committed either to the purchaser's designation or to the discretion of the manufacturer.

(1) Hydrostatic characteristic

When hydrostatic pressure P (this is 7 MPa if the value P exceeds 7 MPa) calculated from the following formula is applied, the tubes shall withstand it without leakage.

In the case where the hydrostatic test is conducted by the specification of the purchaser and the test pressure exceeds the value P calculated from the following formula, the test pressure shall be agreed upon between the parties concerned with delivery. The designated hydrostatic pressure shall be graduated in 0.5 MPa for under 10 MPa and in 1 MPa for 10 MPa or over. In calculation, the value P in the following formula shall be obtained and likewise rounded off to 0.5 MPa or 1 Mpa

$P = 2st/D$

Where P: test pressure (MPa)

t: wall thickness of tube(mm)

D: outside diameter of tube (mm)

s: 1/4 of minimum value of tensile strength specified in Table 3 (N/mm)

Table 3 Mechanical properties

Symbol of grade	Heat treatment	Tensile strength N/㎟	Proof stress N/㎟	Elongation %
NCF600TB	Annealing	550 min.	245 min.	30 min.
NCF625TB	Annealing	820 min.	410 min.	30 min.
	Solution treatment	690 min.	275 min.	30 min.
NCF690TB	Annealing	590 min.	245 min.	30 min.
NCF800TB	Annealing	520 min.	205 min.	30 min.
NCF800HTB	Solution treatment	450 min.	175 min.	30 min.

NCF825TB	Annealing	580 min.	235 min.	30 min.

Remarks

1. The elongation indicates the value obtained from the tensile test on no. 11 or no. 12 test piece.

2. When a tensile test is conducted on no. 12 test piece for tubes of under 8mm in wall thickness, the minimum value of elongation shall be reduced given in Table 3 for each 1mm decrease in wall thickness from 8mm, and be rounded off to an integer in accordance with JIS Z 8401.

3. The tubes of under 20mm in outside diameter, the values in the above table shall not be applied, though the values shall be noted

(2) Nondestructive characteristic

Unless otherwise particularly specified by the purchaser, the ultrasonic examination or the eddy current examination may substitute for the hydrostatic test. In this case, the acceptance criteria shall conform to the test sensitivity division UD in JIS G 0582 or the flaw detection sensitivity division EY in JIS G 0583.

7. Dimensional tolerances

Dimensional tolerances shall be as follows

(1) The tolerances on outside diameter and wall thickness for tubes shall be as specified in Table 4.

Table Tolerances on outside diameter and wall thickness

Outside diameter mm	Tolerance on outside diameter mm	Tolerances on wall thickness %	
		Under 2mm in wall thickness	2mm and over in wall thickness
Under 40	【 0.25	+0.4(mm) 0	+20 0
40 or over to and excl. 50	【 0.25	+22 0	+22 0
50 or over to and excl. 60	【 0.25		
60 or over to and excl. 80	【 0.30		
80 or over to and excl. 100	【 0.40		
100 or over to and excl. 120	+ 0.40 - 0.60		
120 or over	+0.40 -0.80		

Remarks

1. The purchaser may specify that the tolerances on the outside diameter shall be 【 0.15mm for the tubes of under 25mm in outside diameter and 【 0.20mm for the tubes of 25mm or over to and excluding 40mm

2. The purchaser, if necessary, may specify that the tolerances on wall thickness shall be from 0 to plus 20% (however, the minimum tolerance range from 0 to plus 0.2mm) for tubes of under 25mm in outside diameter and under 2mm in wall thickness.

(2) The tolerances on length for tubes shall be as specified in Table 5.

Table 5 Tolerances on length

Classification		Tolerances on length mm
50m max. in outside diameter	7m max. in length	+7 0
	Over 7m in length	Add 3mm to the above plus side tolerance for each increment of 3m or its fraction in length, However, the maximum value shall be 15mm.
Over 50mm in outside diameter	7m max. in length	+10 0
	Over 7m in length	Add 3mm to the above plus side tolerance for each increment of 3m or its fraction in length, However, the maximum value shall be 15mm.

Remarks

In the case where closer tolerances on length are especially required, the tolerances shall be agreed upon between the parties concerned with delivery.

8. Appearance

The appearance shall be as follows

(1) Tubes shall be straight for practical purposes, and their both ends shall be at right angles to the axes.

(2) The inside and outside surfaces of tubes shall be finished excellently and be free from defects detrimental to practical use.

9. Manufacturing method

The manufacturing method shall be as follows

(1) Tubes shall be manufactured by seamless process.

(2) Tubes shall be annealed or solution treated in accordance with Table 6, and thereafter pickled or similarly treated.

Table 6 Heat treatment

Symbol of grade	Heat treatment℃	
	Solution treatment	Annealing
NCF 600 TB	-	900 or higher rapid cooling

NCF 625 TB	1090 or higher rapid cooling	870 or higher rapid cooling
NCF 690 TB	-	900 or higher rapid cooling
NCF 800 TB	-	950 or higher rapid cooling
NCF 800 HTB	1100 or higher rapid cooling	-
NCF 825 TB	-	930 or higher rapid cooling

(3) A symbol expressing manufacturing method shall be as specified in Table 7.

Table 7 Symbol expressing manufacturing method

Classification	Symbol
Cole finished seamless tube	- S - C

Remarks

The symbol - may be replaced by a blank.

10. Tests

10.1 Analytical test

10.1.1 Analytical test

General matters for analytical test and the sampling for analytical sample shall be in accordance with 3. (Chemical composition) of JIS G 0303.

10.1.2 Analytical method

The analytical method shall be in accordance with any one of the following standards. However, when these standards can not be applied, the analytical method shall be agreed upon between the parties concerned with delivery.

JIS G 1256, JIS G 1257, JIS G 1281

10.2 Tensile test

10.2.1 Test piece

The test piece shall be no. 11, no. 12 A, no. 12 B, or no.12 C test piece specified in JIS Z 2201 and shall be cut off from a tube.

10.2.2 Test method

The test method shall be as specified in JIS Z 2241.

10.3 Flattening test

10.3.1 Test piece

A test piece of 50mm or over in length shall be cut off from one end of a tube.

10.3.2 Test method

A test piece shall be placed between two flat plates at ordinary temperature and flattened by compression until the distance between the plates becomes a specified height H, and

shall be checked for flaws and cracks on the wall surface of the tubular test piece

10.4 Flaring test

10.4.1 Test piece

A test piece of a proper length shall be cut off from one end of a tube.

10.4.2 Test method

When one end of a test piece is flared to the specified size in a trumpet shape at ordinary temperature as it is with a conical tool having an included angle of 60°, the test piece shall be checked for flaws or other defects.

10.5 Austenitic grain size test

10.5.1 Test piece

A test piece of 20mm in length shall be cut off from one end of a tube.

10.5.2 Test method

The test method shall be as specified in JIS G 0551

10.6 Hydraulic test or nondestructive test

Either the hydraulic test or the nondestructive test shall be carried out in accordance with the following, respectively.

(1) When tubes are subjected to hydrostatic pressure to be kept at a specific pressure, whether they withstand said pressure and whether leakage is generated are examined.

(2) The test method for nondestructive inspection shall be as specified in either JIS G 0582 or JIS G 0583

11. Inspection

The inspection shall be as follows

(1) General matters for inspection shall be in accordance with JIS G 0303.

(2) The chemical composition shall conform to the requirements specified in 3.

(3) The mechanical properties shall conform to the requirements specified in 4.

(4) NCF 800 HTB tubes shall be subjected to an austenitic grain size test and the result shall conform to the requirements specified in 5.

(5) Either the hydrostatic characteristic or nondestructive characteristic shall conform to the requirements specified in 6. However, the hydrostatic test may be replaced by a suitable nondestructive test other than those specified in 10.6 (2) as agreed upon between the parties concerned with delivery.

(6) The dimensions shall conform to the requirements specified in 7.

(7) The appearance shall conform to the requirements specified in 8.

(8) When supplementary quality requirements in Annex 1 or the U-bend tubes in Annex 2 are specified as agreed upon between the parties concerned with deolvety, the results of inspection shall conform to Z 2 to Z 4 in Annex 1 and the relevant requirements specified in Annex 2.

(9) Either the hydrostatic test or the nondestructive test shall be conducted on each tube.

(10) A number of samples for product analysis shall be agreed upon between the parties concerned with delivery.

(11) The sampling of test specimens and the number of test pieces for tensile test, flattening test, and austenitic grain size test shall be as specified below. Take two specimens from each lot of 100 tubes or its fraction of the same cast and heat treatment rolled to the same dimensions. Take one test piece for tensile test from each test specimen. and then take one test piece for flattening test from both ends of either of the two test specimens.
Further, take one test piece for austenitic grain size test from either of the two test specimens.

12. Marking

Each tube having passed the inspection shall be marked with the following peculiarities at the manufacturer's workshop. Smaller tubes, however, may be bundled together, and marked on each bundle by a suitable means. The order of arranging the peculiarities is not specified.
Further, a part of the peculiarities may be omitted as agreed upon between the parties concerned with delivery.
(1) Symbol of grade
(2) Dimensions (outer diameter × wall thickness)
(3) Symbol expressing manufacturing method
(4) Manufacturer's name or its abbreviation
(5) Symbol Z expressing the specification of supplementary quality requirements

13. Report

The manufacturer, as required, shall submit to the purchaser a report on the test results, manufacturing method, ordered dimensions, quantity, and work lot number indication the history of manufacture.

Annex 1 Supplementary quality requirements

The supplementary quality requirements shall be applied only when required by the purchaser, and shall be executed by the manufacturer for the designated items on the straight tube.

Z 1. Hardness

The hardness shall be as follows

(1) The hardness of tubes shall be as given in Annex 1 Table 1.

Annex 1 Table 1. Hardness

Symbol of grade	Heat treatment	Rockwell hardness (average value of three points) HRB
NCF 600 TB NCF 625 TB	Annealing Solution treatment	92 max. 100 max.

	Annealing	36(HRB) max.
NCF 690 TB	Annealing	92 max.
NCF 800 TB	Annealing	95 max.
NCF 800 HTB	Solution treatment	92 max.
NCF 825 TB	Annealing	90 max.

(2) A suitable length shall be cut off from one end of a tube to save as a test piece.

(3) The test method shall be as specified in JIS Z 2245. The hardness in the cross section or on the inside surface of the test piece shall be measured at three points for each test piece.

Further, for tubes of 2mm or under in wall thickness, the hardness test shall not be applied.

(4) The hardness shall conform to the requirements specified in Annex 1 Table 1.

(5) The sampling of a test specimen and the number of test pieces shall be in accordance with the tensile test specified in 11. (11) of this text.

Z 2. High temperature yield point or proof stress

The high temperature yield point or proof stress shall be as follows

(1) The values of the high temperature yield point or proof stress and test-temperature shall be agreed upon between the parties concerned with delivery.

(2) The test piece and test method shall be as specified in JIS G 0567.

Further, for tubes from which the test piece with a shape specified in JIS G 0567 is difficult to be sampled, the shape of the test piece shall be agreed upon between the parties concerned with delivery.

(3) The sampling of a test specimen and the number of test pieces shall be as follows. Take one test specimen from each lot of the same cast, and take one test piece for each test temperature from each specimen.

Z 3. Ultrasonic examination

(1) The criteria of the ultrasonic examination shall be the division UA of the test sensitivity in JIS G 0582, and there shall be no signal equal to or greater than the signals produced by the artificial flaws of the reference test piece.

(2) The test method of the ultrasonic examination shall be as specified in JIS G 0582.

(3) The ultrasonic examination shall be performed for each tube and the results shall conform to the requirements of (1).

Z 4. Eddy current examination

The eddy current examination shall be as follows

(1) The criteria of the eddy current examination shall be division EV of the test sensitivity in JIS G 0583, and there shall be no signal equal to or greater than the signals produced by the artificial flaws of the reference test piece.

(2) The test method of eddy current examination shall be as specified in JIS G 0583.

(3) The eddy current examination shall be performed be performed for each tube and the results shall conform to the requirement of (1).

Annex 2 U-bend tube

The U-bend tube shall be applied only when specified by the purchaser, and shall be prepared by the manufacturer.

1. Manufacturing process

The manufacturing process shall be as specified below (see Annex 2 Fig 1).

(1) The U-bend tube shall be made by the cold-bending process, and the bending radius shall be at least 1.5 times the outside diameter of the tube.

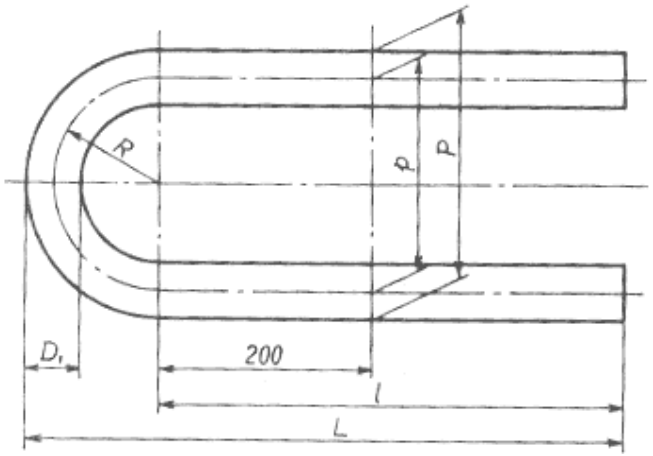
(2) The bent portion of the tube shall, as a rule, not be subjected to heat treatment. However, when required by the purchaser, heat treatment may be agreed upon between the parties concerned with delivery.

2. The bent portion shall be free from defects detrimental to practical use.

3. The dimensional tolerances on the bent portion shall be as specified in Annex 2 Table 1, and the tolerances on length after bending shall be as specified in Annex 2 Table 2.

Annex 2 Fig 1.

Unit: mm



R: bending radius

D1: outside diameter in bent portion

t1: minimum wall thickness in bent portion

P: *p*+*Dn*

L: *l*+*R*+(*Dn*/2)

Dn: nominal outside diameter

tn: nominal wall thickness

p: pitch

l: leg length in straight portion

Annex 2 Table 1. Dimensional tolerances on bent portion

Deviation in outside diameter (*D1* - *Dn* / *Dn*) 】 100 %		Reduction in wall thickness (*tn* - *t1* / *tn*) 】 100 %	Tolerances on pitch (p) or *P* mm
Short radius	Long radius		
(*Dn* / 4R) 】 100max. (Minimum value 0.5mm)	*Dn* / 8R) 】 100max. (Minimum value 0.5mm)	*Dn* / 2.5R) 】 100max.	【 1.5

Annex 2 Table 2. Tolerances on length

Division of length	Tolerances on length (l or L) mm
Up to and incl. 7m in straight portion after bending	+7 0
Over 7m in straight portion after bending	+10 0

4. For measurement of the bent portion, take one test specimen from the tube of the smallest bending radius of all the tubes of the same dimensions concurrently undergoing the U-bend processing, measure the outside diameters at two points in the bent portion forming 90 X in two directions on the circumference, measure the wall thickness at 4 points on the circumference, and obtain the outside diameter deviation rate and the wall thickness reduction rate.

JIS Number and Corresponding Foreign Standards

JIS			ASTM			BS			DIN			Index Number
Standard Number	Grade	Type	Standard Number	Grade	Type	Standard Number	Grade	Type	Standard Number	Grade	Type	
G4904	NCF600TB	A	B167	NO6600	A							C014
	NCF800TB	A	B407	NO8800	A							
	NCF825TB	A	B423	NO8825	A							