INTERNATIONAL STANDARD

ISO 6207

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Seamless nickel and nickel alloy tube

Tubes sans soudure en nickel et alliages de nickel

Reference number
ISO 6207:1992(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 6207 was prepared by Technical Committee ISO/TC 155, *Nickel and nickel alloys*, Sub-Committee SC 2, *Wrought and cast nickel and nickel alloys*.

Annex A of this International Standard is for information only.

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INTERNATIONAL STANDARD ISO 6207:1992(E)

Seamless nickel and nickel alloy tube

1 Scope

1.1 This International Standard specifies requirements for round seamless nickel and nickel alloy tube for general purposes as well as for condenser and heat-exchanger applications in the following size ranges.

1.1.1 Tube for general purposes

Cold worked:	outside diameter 4 mm to 240 mm
Hot worked:	outside diameter 38 mm to 240 mm

1.1.2 Tube for condenser and heat-exchanger applications

Cold worked: maximum outside diameter 80 mm with wall thickness up to and including 5 mm.

1.2 Dimensional requirements and limiting bend radii are also specified for U-bent heat-exchanger tubes of outside diameter up to and including 26 mm.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/R 204:1961, *Non-interrupted creep testing of steel at elevated temperatures.*

ISO 6372-1:1989, *Nickel and nickel alloys — Terms and definitions — Part 1: Materials.*

ISO 6372-3:1989, *Nickel and nickel alloys — Terms and definitions — Part 3: Wrought products and castings.*

ISO 6507-1:1982, *Metallic materials — Hardness test — Vickers test — Part 1: HV 5 to HV 100.*

ISO 6508:1986, *Metallic materials — Hardness test — Rockwell test (scales A - B - C - D - E - F - G - H - K).*

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO/TR 7003:1990, *Unified format for the designation of metals.*

ISO 8493:1986, *Metallic materials — Tube — Drift expanding test.*

ISO/TR 9721:—[1], *Nickel and nickel alloys — Code of designation based on chemical symbols (To be published as an ISO/TR type 2).*

ISO 9722:1992, *Nickel and nickel alloys — Composition and forms of wrought products.*

ASTM E 112:1988, *Standard methods for determining the average grain size.*

3 Definitions

For the purposes of this International Standard, the definitions for nickel and nickel alloys in ISO 6372-1 and for tube in ISO 6372-3 apply.

1) To be published.

3.1 mean diameter: The average of the maximum and minimum diameters as determined at any cross-section.

3.2 heat: The product of a furnace melt or a number of melts that are mixed prior to casting.

3.3 thick-wall tube: Tube with a specified wall thickness which is greater than 3 % of the specified outside diameter.

3.4 thin-wall tube: Tube with a specified wall thickness which is 3 % or less of the specified outside diameter.

3.5 lot: Tubes of the same cross-sectional dimensions from the same heat, heat treated together or sequentially heat treated in a continuous furnace, but in no case for longer than 16 h of production. When tubes cannot be identified by heat, a lot shall consist of not more than 250 kg of material in the same heat-treated condition and size.

4 Alloy identification

For the purposes of this International Standard, the principles for alloy identification in ISO/TR 7003 and ISO/TR 9721 apply.

5 Ordering information

Orders for tubes according to this International Standard shall include the following information.

5.1 The number of this International Standard.

5.2 A specification of whether the tube is for general purposes or for condensers or heat exchangers.

5.3 Quantity (mass, number of pieces, or total length).

5.4 Alloy identification (see table 1).

NOTE 1 For alloy identification either the number or the description may be used.

5.5 Alloy temper (see table 2).

5.6 Dimensions: outside diameter and nominal wall thickness or outside diameter and minimum wall thickness.

5.7 Optional requirements:

a) ends other than plain-cut and deburred;

b) straightness (see 6.1.7.5);

c) annealed ends for stress-relieved condenser and heat-exchanger tube (see 6.2.3);

d) samples for product analysis (see 7.1.2);

e) determination of 1 % proof stress ($R_{p1,0}$) (see 9.2);

f) pressure test other than standard (see 9.7.2 or 9.8);

g) non-destructive testing (see 9.9);

h) individual tube marking (see 10.2);

i) purchaser or third party inspection (see clause 11);

j) declaration of conformity (see clause 12).

5.8 Additional information for U-bent tubes.

5.8.1 Specify if tubes are to be U-bent (see limitations in 6.2.2 to 6.2.5).

5.8.2 Specify if U-bent areas are to be subsequently stress relieved.

5.8.3 Specify size of radii and length of U-bent tube legs (see 6.2.5.4 and table 6).

5.8.4 Specify if proof of conformance of wall thickness in U-bent area is required (see 6.2.5.3).

5.8.5 Specify if hydrostatic testing is to be applied after bending (see 9.7.4).

6 Requirements

Tubes shall meet the following requirements.

6.1 Tubes for general purposes

6.1.1 Composition

Heat analysis shall meet the composition limits specified in table 1.

The composition limits do not preclude the possible presence of other elements that are not specified. If the purchaser's requirements necessitate limits for any other element that is not specified, these shall be agreed upon between the purchaser and the supplier. The percentage content of elements shown as "remainder" shall be calculated by difference from 100 %.

6.1.2 Tensile properties

Tubes shall have the tensile properties specified in table 2.

6.1.3 Hydrostatic pressure test

Any tube exhibiting leaks during hydrostatic testing shall be deemed not to comply with this International Standard.

6.1.4 Grain size

Alloys NW8810/FeNi32Cr21AlTi-HC and NW8811/FeNi32Cr21AlTi-HT shall have an average grain diameter of ASTM 5 or coarser (average diameter 0,06 mm or greater).

6.1.5 Creep requirements

Alloy NW7263/NiCo20Cr20Mo5Ti2Al shall meet the creep requirements specified in table 2, footnote 2). (For sampling for creep testing, see 7.3).

6.1.6 Surface quality

All tubes shall be clean and free from detrimental surface imperfections.

NOTE 2 Where appropriate, the acceptance criteria should be agreed upon by the purchaser and the supplier.

6.1.7 Dimensional tolerances

6.1.7.1 Cold-worked tube

The wall thickness and outside diameter shall not differ at any point from that specified by more than the tolerance given in table 3, except that

a) for thick-wall tube (see 3.3) of outside diameter over 115 mm, the mean diameter shall not exceed the tolerance specified in table 3 and individual measurements shall not exceed twice the tolerance specified in table 3.

b) for thin-wall tube (see 3.4), the mean diameter shall not exceed the tolerance specified in table 3 and individual measurements shall not exceed the tolerance specified in table 3 with the values increased by 0,5 % of the nominal outside diameter.

NOTE 3 Tolerances for wall thickness are given in table 3 for both "nominal" and "minimum" wall requirements. The appropriate column should be referred to, depending upon the product specified.

6.1.7.2 Hot-worked tube

For all tubes, the wall thickness and outside diameter shall not differ at any point from that specified by more than the tolerance given in table 4, except that for tubes of outside diameter over 125 mm, the mean diameter shall not exceed the tolerance specified in table 4, and individual measurements shall not exceed twice the tolerance specified in table 4.

When the minimum wall thickness is specified, the thickness tolerance on the specified minimum wall thickness shall be $^{+28,5}_{0}$ %.

For tubes supplied with machined outside or inside surfaces, the tolerances on the machined surface shall be

$^{+0,8}_{0}$ mm for the outside diameter;

$^{0}_{-1,6}$ mm for the inside diameter.

6.1.7.3 Concentricity

For cold-worked tube and hot-worked tube, the permissible variations in individual measurements of wall thickness in 6.1.7.1 and 6.1.7.2 include concentricity.

6.1.7.4 Length

Tube ordered according to a specified length shall not differ from that length by more than the appropriate tolerance given in table 5.

6.1.7.5 Straightness

Tubes shall be free from kinks.

NOTE 4 Where appropriate, the acceptance criteria should be agreed upon by the purchaser and the supplier.

6.2 Tubes for condensers and heat-exchangers

In addition to the requirements of 6.1, tubes for condensers and heat-exchangers shall meet the following requirements.

6.2.1 Materials

The requirements given in 6.2.2 to 6.2.5.5 apply only to the following materials in their appropriate heat-treated conditions (see table 2):

NW2200/Ni99,0
NW2201/Ni,99,0-LC
NW6600/NiCr15Fe8
NW6690/NiCr29Fe9
NW6625/NiCr22Mo9Nb
NW4400/NiCu30
NW8825/NiFe30Cr21Mo3
NW8800/FeNi32Cr21AlTi
NW8810/FeNi32Cr21AlTi-HC
NW8811/FeNi32Cr21AlTi-HT

6.2.2 Tube size and bending radii limitations for U-bent tubes (see table 6)

6.2.3 Hardness of annealed ends of stress-relieved tubes

When stress-relieved condenser or heat-exchanger tubes are furnished with annealed ends, the Rockwell or Vickers hardness of the ends after annealing shall not exceed the values specified in table 7.

6.2.4 Drift expanding

The tube shall be expanded without rupture until the outside diameter has been increased by 30 %.

6.2.5 Tolerances for U-bent tubes

6.2.5.1 Leg spacing

The leg spacing, measured between the points of tangency of the bend to the legs, shall not vary from the value: ($2r$ − specified tube outside diameter) by more than the amounts shown in table 8, where r is the specified centreline bend radius.

6.2.5.2 Diameter of the tube in U-bent section

Neither the major nor minor outside diameter of the tube, at any one cross-section included within the points of tangency of the bend, shall deviate from the nominal diameter prior to bending by more than 10 %.

6.2.5.3 Wall thickness of tube in U-bent section

The wall thickness of the tube at the apex of the U-bent section shall be not less than the value determined by the following equation:

$$\delta_f = \delta(2_r)/(2_r + D)$$

where

δ_f is the thickness after bending, in millimetres;

δ is the minimum permissible thickness of tube wall prior to bending, in millimetres;

r is the centreline bend radius, in millimetres;

D is the nominal outside diameter of the tube, in millimetres.

When specified by the purchaser, proof of conformance to this requirement shall be obtained by bending a tube specimen, representative of the material offered, to the scheduled radius of bend, cutting the tube at the apex of the bend, measuring the wall thickness at the cross-section of this apex and comparing the measured value with the calculated value of δ_f.

6.2.5.4 Length of U-bent tube legs

The length of the tube legs, measured from the point of tangency of the bend to the end of the tube leg, shall be within the tolerance specified in table 9.

The difference in the length of the tube legs shall be not greater than 4 mm.

6.2.5.5 Squareness of ends

The end of any tube shall not depart from square by more than the amounts shown in table 10.

7 Sampling

7.1 Chemical analysis

7.1.1 Representative heat analysis samples shall be taken during pouring or subsequent processing.

7.1.2 Product analysis samples shall be taken from the finished product.

7.2 Tensile testing

7.2.1 Unless otherwise indicated in table 2, tensile test specimens shall be taken from material in the final heat-treated condition, and tested in the longitudinal direction.

7.2.2 In the case of stress-relieved tubes furnished with annealed ends, the tensile test specimen shall be taken from tubes in the stress-relieved condition prior to annealing.

7.3 Creep testing

Creep test specimens may be taken from the finished product of alloy NW7263/ NiCo20Cr20Mo5Ti2Al, or at an intermediate stage of processing, and shall be tested in the longitudinal direction.

8 Number of tests

8.1 Chemical analysis

One test per heat.

8.2 Tensile test

One test per lot.

8.3 Creep test

One test per lot.

8.4 Drift expanding test

A drift expanding test shall be performed on one end of each mill length of condenser and heat exchanger tube.

8.5 Pressure test

Each tube or finished mill length of condenser and heat exchanger tube.

8.6 Hardness test

3 % of each lot of stress-relieved tubes with annealed ends.

8.7 Grain size determination

One test per lot.

9 Test procedures

9.1 Chemical analysis

9.1.1 The method of chemical analysis shall be at the option of the supplier, however in cases of dispute the method specified in the relevant International Standard shall be used.

If no International Standard exists, an analytical method that can be calibrated to a reference standard agreed upon by the purchaser and the supplier shall be used.

9.1.2 For a list of ISO analytical standards, see annex A.

9.2 Tensile testing

Testing shall be carried out in accordance with ISO 6892.

The offset method shall be used for the determination of proof stress. An offset of 0,2 % ($R_{p0,2}$) shall be standard. However, a 1 % proof stress ($R_{p1,0}$) shall be determined and reported for information when requested by the purchaser. Determination of proof stress is not required for tubes with wall thickness less than 0,5 mm.

2) 1 bar = 10^5 Pa.

9.3 Creep testing

Testing shall be carried out in accordance with ISO/R 204, except that only the final total plastic strain need be reported.

9.4 Hardness testing

9.4.1 Vickers hardness

Testing shall be carried out in accordance with ISO 6507.

9.4.2 Rockwell hardness

Testing shall be carried out in accordance with ISO 6508.

9.5 Drift expanding test

Testing shall be carried out in accordance with ISO 8493. It shall consist of flaring a test piece with an expanding tool having an included angle of 60° until the specified outside diameter has been increased by 30 %.

9.6 Grain size determination

A transverse sample representative of the full wall thickness shall be examined in accordance with ASTM E 112.

9.7 Hydrostatic test (also see 9.9.2)

9.7.1 Tubes with outside diameters of 4 mm and over and tubes with wall thicknesses of 0,4 mm and over shall be subjected to an internal hydrostatic pressure of 70 bar[2] (gauge) by the manufacturer, provided that the fibre stress calculated in accordance with the following equation does not exceed the allowable fibre stress. The test pressure shall be held for a minimum of 20 s.

The hydrostatic test pressure p, in bar, is given by the formula

$$p = \frac{20 R_F \cdot \delta_{min}}{D}$$

where

R_F is the allowable fibre stress, in newtons per square millimetre, for material in the temper furnished as shown in table 2;

δ_{min} is the minimum wall thickness, in millimetres, equal to the nominal wall thickness minus the permissible "minus" wall tolerance (see table 3) or the minimum wall thickness, as applicable;

D is the specified outside diameter of the tube, in millimetres.

9.7.2 If agreed upon by the purchaser and the supplier, tubes may be tested to 1,5 times the above allowable fibre stress.

9.7.3 When stress-relieved condenser or heat-exchanger tubes with annealed ends are to be tested, such pressure testing shall be done prior to annealing of the ends of the tubes.

9.7.4 When specified by the purchaser, U-bent condenser and heat-exchanger tubes shall be tested after bending. When this is specified, it will not be required on straight length tube prior to bending.

9.8 Pneumatic test (also see 9.9.2)

When agreed upon by the purchaser and the supplier, a pneumatic test may be performed instead of the hydrostatic test. The conditions of the test shall be specified in the purchase order.

9.9 Non-destructive testing

9.9.1 When non-destructive examination is required by the purchase order, the method of test and standards of acceptance shall be agreed upon by the purchaser and manufacturer.

9.9.2 When permitted by the purchaser, eddy current testing may be used instead of either hydrostatic or pneumatic pressure tests. The method of test and standards of acceptance shall be as agreed upon by the purchaser and supplier.

9.10 Rounding-off

For the purpose of determining compliance with the specified limits of the properties listed below, an observed value or calculated value shall be rounded as follows.

When the figure immediately after the last figure to be retained is lower than 5, the last figure to be retained remains unchanged.

When the figure immediately after the last figure to be retained is 5 or greater, the last figure to be retained is increased by one.

Composition, creep, grain size and hardness	Nearest unit to the last right-hand place of figures of the specified limit
Tensile strength (R_m)	Nearest 10 N/mm^2
0,2 % -Proof stress ($R_{p0,2}$)	Nearest 5 N/mm^2
Elongation (A)	Nearest 1 %

9.11 Retests

If any one of the test pieces first selected fail to pass the specified tests, two further samples from the same lot shall be selected for testing, one of which shall be from the original product tested, unless that product has been withdrawn by the supplier. If the test pieces from both these additional samples pass the tests, the lot represented by the samples shall be deemed to comply with the requirements of this Internatonal Standard. If the test pieces from either of these additional samples fail, the lot represented by these samples shall be deemed to comply with the requirements of this International Standard.

10 Marking

10.1 Each bundle or shipping container shall be marked with the number of this International Standard, the alloy identification (either the number or the description), heat-treated condition, the size, the gross, tare and net weight, the consignor and consignee address, contract or order number, or any other information defined in the contract or order.

10.2 If agreed upon by the purchaser and supplier, the supplier shall mark each tube with the number of this International Standard and the alloy identification (either the number or the description). The method of marking will be at the option of the supplier, unless otherwise agreed. Marking shall not result in harmful contamination.

11 Purchaser and third party inspection

One-site inspection of the tubes shall be in accordance with the agreement made between the purchaser and the supplier as part of the purchase contract.

12 Declaration of conformity

When requested by the purchaser in the contract or order, the supplier shall certify that the material was manufactured and tested in accordance with this International Standard. The declaration of conformity shall detail the results of all tests required by this International Standard and the order.

Table 1 — Composition and density of wrought nickel and nickel alloys (taken from ISO 9722)

Alloy identification[1]		Composition, % (*m*/*m*)[2]																Density[3]
Number	Description	Al	B	C	Co[4]	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	W	Others[5]	g/cm³
NW2200	Ni99,0			0,15			0,2	0,4	0,3		99,0		0,010	0,3				8,9
NW2201	Ni99,0-LC			0,02			0,2	0,4	0,3		99,0		0,010	0,3				8,9
NW7263	NiCo20Cr20Mo5Ti2Al	0,3 0,6	0,005	0,04 0,08	19,0 21,0	19,0 21,0	0,2	0,7	0,6	5,6 6,1	Remainder		0,007	0,4	1,9 2,4		Ag: 0,0005(5) Bi: 0,0001(1) Pb: 0,0020(20) Ti + Al: 2,4 to 2,8	8,4
NW6617	NiCr22Co12Mo9	0,8 1,5	0,006	0,05 0,15	10,0 15,0	20,0 24,0	0,5	3,0	1,0	8,0 10,0	Remainder		0,015	1,0	0,6			8,4
NW6600	NiCr15Fe8			0,15		14,0 17,0	0,5	6,0 10,0	1,0		72,0		0,015	0,5				8,4
NW6602	NiCr15Fe8-LC			0,02		14,0 17,0	0,5	6,0 10,0	1,0		72,0		0,015	0,5				8,4
NW6002	NiCr21Fe18Mo9		0,010	0,05 0,15	0,5 2,5	20,5 23,0		17,0 20,0	1,0	8,0 10,0	Remainder	0,040	0,030	1,0		0,2 1,0		8,2
NW6007	NiCr22Fe20Mo6Cu2Nb			0,05	2,5	21,0 23,5	1,5 2,5	18,0 21,0	1,0 2,0	5,5 7,5	Remainder	0,040	0,030	1,0			Nb + Ta: 1,7 to 2,5	8,3
NW6985	NiCr22Fe20Mo7Cu2			0,015	5,0	21,0 23,5	1,5 2,5	18,0 21,0	1,0	6,0 8,0	Remainder	0,040	0,030	1,0		1,5	Nb + Ta: 0,5	8,3
NW6601	NiCr23Fe15Al	1,0 1,7		0,10		21,0 25,0	1,0	Remainder	1,0		58,0 63,0		0,015	0,5				8,0
NW6633	NiCr26Fe20Co3Mo3W3			0,10	2,5 4,0	24,0 27,0		Remainder	2,0	2,5 4,0	44,0 48,0	0,030	0,030	1,5		2,5 4,0		
NW6690	NiCr29Fe9			0,05		27,0 31,0	0,5	7,0 11,0	0,5		Remainder		0,015	0,5				8,2
NW6455	NiCr16Mo16Ti			0,015	2,0	14,0 18,0		3,0	1,0	14,0 17,0	Remainder	0,040	0,030	0,08	0,7			8,6
NW6022	NiCr21Mo13Fe4W3			0,015	2,5	20,0 22,5		2,0 6,0	0,5	12,5 14,5	Remainder	0,025	0,020	0,08		2,5 3,5	V: 0,35	8,7
NW6625	NiCr22Mo9Nb	0,40		0,10	1,0	20,0 23,0		5,0	0,50	8,0 10,0	58,0	0,015	0,015	0,50	0,40		Nb + Ta: 3,15 to 4,15	8,5
NW6621	NiCr20Ti			0,08 0,15	5,0	18,0 21,0	0,5	5,0	1,0		Remainder		0,020	1,0	0,20 0,60		Pb: 0,0050 (50)	8,4
NW4400	NiCu30			0,30			28,0 34,0	2,5	2,0		63,0		0,025	0,5				8,8
NW4402	NiCu30-LC			0,04			28,0 34,0	2,5	2,0		63,0		0,025	0,5				8,8
NW8825	NiFe30Cr21Mo3	0,2		0,05		19,5 23,5	1,5 3,0	Remainder	1,0	2,5 3,5	38,0 46,0		0,015	0,5	0,6 1,2			8,1

Alloy identification[1]		Composition, % (*m*/*m*)[2]																Density[3]
Number	Description	Al	B	C	Co[4]	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	W	Others[5]	g/cm³
NW0276	NiMo16Cr15Fe6W4			0,010	2,5	14,5 16,5		4,0 7,0	1,0	15,0 17,0	Remainder	0,040	0,030	0,08		3,0 4,5		8,9
NW0665	NiMo28			0,02	1,0	1,0		2,0	1,0	26,0 30,0	Remainder	0,040	0,030	0,1				9,2
NW0001	NiMo30Fe5			0,05	2,5	1,0		4,0 6,0	1,0	26,0 30,0	Remainder	0,040	0,030	1,0			V: 0,2 to 0,4	9,2
NW8028	FeNi31Cr27Mo4Cu1			0,030		26,0 28,0	0,6 1,4	Remainder	2,5	3,0 4,0	30,0 34,0	0,030	0,030	1,0				8,0
NW8800	FeNi32Cr21AlTi	0,15 0,60		0,10		19,0 23,0	0,7	Remainder	1,5		30,0 35,0		0,015	1,0	0,15 0,60			8,0
NW8810	FeNi32Cr21AlTi-HC	0,15 0,60		0,05 0,10		19,0 23,0	0,7	Remainder	1,5		30,0 35,0		0,015	1,0	0,15 0,60			8,0
NW8811	FeNi32Cr21AlTi-HT	0,25 0,60		0,06 0,10		19,0 23,0	0,7	Remainder	1,5		30,0 35,0		0,015	1,0	0,25 0,60		Al + Ti: 0,85 to 1,2	8,0
NW8801	FeNi32Cr20Ti			0,10		19,0 22,0	0,5	Remainder	1,5		30,0 34,0		0,015	1,0	0,7 1,5			8,0
NW8020	FeNi35Cr20Cu4Mo2			0,07		19,0 21,0	3,0 4,0	Remainder	2,0	2,0 3,0	32,0 38,0	0,040	0,030	1,0			Nb + Ta: 8 × C to 1,0	8,1

1) For alloy identification either the number or the description may be used.

2) Single values are maximum limits, except for nickel where single values are minimum.

3) Density values are average values and are given for information only.

4) Where no limits are specified, cobalt up to a maximum of 1,5 % is allowed and counted as nickel. In this case, an indication of cobalt content is not required.

5) Values for Ag, Bi and Pb may be expressed in mass percentage [% (*m*/*m*)] or in parts per million (ppm).

Table 2 — Tensile properties and fibre stress

Alloy identification[1]		Temper	Size	Tensile strength	0,2 % -Proof stress	Elongation	Allowable fibre stress for hydrostatic testing
Number	Description		[outside diameter (D) or wall thickness (δ)]	$R_{m,\ min}$	$R_{p0,2,\ min}$	$A_{5,\ min}/A_{50,\ min}$	R_F
			mm	N/mm²	N/mm²	%	N/mm²
NW2200	Ni99,0	Cold worked, annealed	$D \leqslant 125$ $D > 125$	380 380	105 85	35 40	70 57
		Cold worked, stress relieved	—	450	275	15	113
NW2201	Ni99,0-LC	Cold worked, annealed	$D \leqslant 125$ $D > 125$	350 350	85 70	35 40	57 47
		Cold worked, stress relieved	—	410	205	15	103
NW7263	NiCo20Cr20Mo5Ti2Al	Cold worked[2]	$\delta \leqslant 0,5$ $\delta > 0,5$	540[2] 540[2]	— 400[2]	9[2]	135 135
NW6617	NiCr22Co12Mo9	Hot or cold worked, annealed	—	655	240	35	160
NW6600	NiCr15Fe8	Cold worked, annealed	$D \leqslant 125$ $D > 125$	550 550	240 205	30 35	138 137
		Hot worked, annealed	$D \leqslant 125$ $D > 125$	550 520	205 170	35 35	137 113
		Hot worked	$D \leqslant 125$ $D > 125$	550 520	205 170	35 35	137 113
		Hot worked, solution treated	—	500	170	35	113
NW6602	NiCr15Fe8-LC	Cold worked, annealed	—	500	170	30	113
NW6002	NiCr21Fe18Mo	Cold worked, solution treated	—	690	275	35	173
NW6007	NiCr22Fe20Mo6Cu2Nb	Cold worked, solution treated	—	620	240	35	155
NW6985	NiCr22Fe20Mo7Cu2	Cold worked, annealed	—	620	240	45	155
NW6601	NiCr23Fe5Al	Cold worked, annealed	—	550	205	30	137
		Hot worked, annealed	—	515	170	30	113
NW6333	NiCr26Fe20Co3Mo3W3	Hot worked, annealed	—	550	240	30	138
NW6690	NiCr29Fe	Hot worked, annealed	—	585	205	30	137
NW6455	NiMo16Cr16Ti	Cold worked, solution treated	—	690	275	40	173
NW6022	NiCr21Mo14W3	Hot worked, annealed	—	690	310	45	173
NW6625	NiCr22Mo9Nb	Cold worked, annealed Cold worked, solution treated	— —	830 690	415 275	30 30	207 172
NW6621	NiCr20Ti	Cold worked, annealed	$\delta \leqslant 0,5$ $\delta > 0,5$	690 to 830 690 to 830	— 300	— 30	173 173

Alloy identification[1]		Temper	Size [outside diameter (D) or wall thickness (δ)]	Tensile strength	0,2 % -Proof stress	Elongation	Allowable fibre stress for hydrostatic testing
Number	Description		mm	$R_{m,\ min}$ N/mm²	$R_{p0,2,\ min}$ N/mm²	$A_{5,\ min}/A_{50,\ min}$ %	R_F N/mm²
NW4400	NiCu30	Cold worked, annealed	$D \leqslant 125$ $D > 125$	480 480	190 170	35 35	120 113
		Cold worked, stress relieved	—	590	380	15	148
		Hot worked, annealed	—	450	155	30	103
NW4402	NiCu30-LC	Cold worked, annealed	—	430	160	35	107
NW8825	NiCr21Mo3	Cold worked, annealed	—	590	240	30	148
		Hot worked, annealed	—	520	170	30	113
NW0276	NiMo16Cr15W4	Cold worked, solution treated	—	690	280	40	173
NW0665	NiMo28	Cold worked, solution treated	—	755	350	40	189
NW0001	NiMo30Fe5	Cold worked, solution treated	—	690	315	40	173
NW8028	FeNi31Cr27Mo3,5Cu1	Cold worked, annealed	—	500	215	40	117
NW8800	FeNi32Cr21AlTi	Cold worked, annealed	—	520	205	30	130
		Hot worked, annealed	—	450	170	30	113
		Hot worked	—	450	170	30	113
NW8810	FeNi32Cr21AlTi-HC	Cold worked, solution treated	—	450	170	30	113
		Hot worked, solution treated	—	450	170	30	113
NW8811	FeNi32Cr21AlTi-HT	Cold worked, solution treated	—	450	170	30	113
		Hot worked, solution treated	—	450	170	30	113
NW8801	FeNi32Cr20Ti	Cold worked, annealed	—	450	175	30	113
		Hot worked, annealed	—	450	175	30	113
NW8020	FeNi35Cr20Cu4Mo2	Cold worked, annealed	—	585	275	30	146

1) For alloy identification either the number or the description may be used.

2) Tube shall be supplied solution treated. The minimum tensile properties specified are to be determined on a solution-treated plus aged sample tested at 780 °C. Elongation shall be measured on a gauge length of 25 mm. A solution-treated plus aged sample shall also be creep tested, at a temperature of 780 °C and at a stress of 116 N/mm² for 50 h. Total plastic strain shall not exceed 0,1 %. Aging treatment for test samples shall consist of heating to 800 °C, holding at this temperature for 8 h, then cooling in air.

Table 3 — Tolerance on diameter and wall thickness for cold-worked tube

Nominal outside diameter mm		Tolerance[1] on outside diameter mm	Tolerance[2] on nominal wall thickness %	Tolerance[2] on minimum wall thickness %	
over	up to and including	plus and minus	plus and minus	plus	minus
4	16	0,15	12,0	25	0
16	38	0,20	10	22	0
38	90	0,25	10	22	0
90	115	0,40	10	22	0
115	150	0,50	12,5	25	0
150	170	0,60	12,5	25	0
170	210	0,70	12,5	25	0
210	240	0,90	12,5	25	0

1) For ovality tolerance, see 6.1.7.1.

2) For concentricity tolerance, see 6.1.7.3.

Table 4 — Tolerance on diameter and wall thickness for hot-worked tube

Nominal outside diameter mm		Tolerance[1] on outside diameter mm	Tolerance[2], [3] on nominal wall thickness %
over	up to and including	plus and minus	plus and minus
38	50	0,6	12,5
50	60	0,7	12,5
60	140	0,8	12,5
140	240	1,2	12,5

1) For ovality tolerance, see 6.1.7.2.

2) For minimum wall tolerance, see 6.1.7.2.

3) For concentricity tolerance, see 6.1.7.3.

Table 5 — Tolerance on exact length

Values in millimetres

Length		Tolerance
over	up to and including	
—	9 000	$^{+4}_{0}$
9 000	12 000	$^{+7}_{0}$
12 000	15 000	$^{+10}_{0}$
15 000	—	$^{+13}_{0}$

Table 6 — Tube size and bending radii limitation

Values in millimetres

Outside diameter		Mean wall thickness		Minimum bend radius[1]	
over	up to and including		up to and including	annealed	stress relieved
—	13	from 1,1 over 1,5	1,5 3,1	30 25	31 28
13	16	from 0,9 over 1,5	1,5 3,1	30 25	31 30
16	20	from 1,2 over 1,5	1,5 2,8	31 30	38 31
20	26	from 1,2 over 1,5	1,5 2,8	50 44	65 57

1) For tubes with a specified minimum wall thickness, compute first the corresponding mean wall thickness from the tolerance in table 3 and then determine the minimum bend radius from this table.

Table 7 — Hardness requirements for annealed ends of stress-relieved condenser and heat exchanger tubes

Alloy identification		Vickers hardness[1]	Rockwell hardness[1]
Number	Description	maximum	maximum
NW2200	Ni99,0	116	65
NW2201	LC-Ni99,0	112	62
NW4400	NiCu30	137	75

1) The supplier has the option of determining compliance by either the Vickers or the Rockwell test.

Table 8 — Tolerance on leg spacing for U-bent tubes

Values in millimetres

Centreline bend radius (r)		Tolerance
over	up to and including	
—	500	± 1,5
500	750	± 2,5
750	1 000	± 3,5

Table 9 — Tolerance on specified length for U-bent tube legs

Specified length		Tolerance
m		mm
over	up to and including	
—	7	$^{+4}_{0}$
7	10	$^{+5}_{0}$
10	19	$^{+7}_{0}$
19	—	$^{+10}_{0}$

Table 10 — Tolerance on squareness of ends

Values in millimetres

Outside diameter		Tolerance
over	up to and including	
—	16	0,3
16	—	0,5

Annex A
(informative)

List of ISO methods of analysis

[1] ISO 6351:1985, *Nickel — Determination of silver, bismuth, cadmium, cobalt, copper, iron, manganese, lead and zinc contents — Flame atomic absorption spectrometric method.*

[2] ISO 7523:1985, *Nickel — Determination of silver, arsenic, bismuth, cadmium, lead, antimony, selenium, tin, tellurium and thallium contents — Electrothermal atomic absorption spectrometric method.*

[3] ISO 7524:1985, *Nickel, ferronickel and nickel alloys — Determination of carbon content — Infra-red absorption method after induction furnace combustion.*

[4] ISO 7525:1985, *Nickel — Determination of sulfur content — Methylene blue molecular absorption spectrometric method after generation of hydrogen sulfide.*

[5] ISO 7526:1985, *Nickel, ferronickel and nickel alloys — Determination of sulfur content — Infra-red absorption method after induction furnace combustion.*

[6] ISO 7527:1985, *Nickel, ferronickel and nickel alloys — Determination of sulfur content — Iodimetric titration method after induction furnace combustion.*

[7] ISO 7528:1989, *Nickel alloys — Determination of iron content — Titrimetric method with potassium dichromate.*

[8] ISO 7529:1989, *Nickel alloys — Determination of chromium content — Potentiometric titration method with ammonium iron(II) sulfate.*

[9] ISO 7530-1:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 1: General requirements and sample dissolution.*

[10] ISO 7530-2:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 2: Determination of cobalt content.*

[11] ISO 7530-3:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 3: Determination of chromium content.*

[12] ISO 7530-4:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 4: Determination of copper content.*

[13] ISO 7530-5:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 5: Determination of iron content.*

[14] ISO 7530-6:1990, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 6: Determination of manganese content.*

[15] ISO 7530-7:—[3], *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 7: Determination of aluminium content.*

[16] ISO 7530-8:—[3], *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 8: Determination of silicon content.*

[17] ISO 7530-9:—[3], *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 9: Determination of vanadium content.*

[18] ISO 9388:—[3], *Nickel alloys — Determination of phosphorus content — Molybdenum blue molecular absorption spectrometric method.*

[19] ISO 9389:1989, *Nickel alloys — Determination of cobalt content — Potentiometric titration method with potassium hexacyanoferrate(III).*

3) To be published.

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