INTERNATIONAL STANDARD

ISO 9724

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Nickel and nickel alloy wire and drawing stock

Fil et fil-machine en nickel et alliages de nickel

Reference number
ISO 9724:1992(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 9724 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 forms an integral part of this International Standard.

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Nickel and nickel alloy wire and drawing stock

1 Scope

This International Standard specifies requirements for nickel and nickel alloy wire up to and including 10 mm and for drawing stock, both for general purposes.

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

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

ISO 7800:1984, *Metallic materials — Wire — Simple torsion test.*

ISO 7801:1984, *Metallic materials — Wire — Reverse bend test.*

ISO 7802:1983, *Metallic materials — Wire — Wrapping test.*

ISO 9649:1990, *Metallic materials — Wire — Reverse torsion test.*

ISO/TR 9721:1992, *Nickel and nickel alloys — Rules for material description based on chemical symbols.*

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

3 Definitions

For the purposes of this International Standard, the following definitions and those for nickel and nickel alloys in ISO 6372-1 and for wire and drawing stock in ISO 6372-3 apply.

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

3.2 lot: Wire or drawing stock of the same diameter 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.

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 wire or drawing stock according to this International Standard shall include the following information.

5.1 The number of this International Standard.

5.2 Quantity (mass or number of pieces).

5.3 Alloy identification (see table 1).

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

5.4 Alloy temper (see table 2).

5.5 Dimensions: diameter or other cross-sectional dimensions and coil dimensions.

5.6 Tolerances: for cross-sections other than round.

5.7 Optional requirements:

a) samples for product analysis (see 7.1.2);

b) surface finish (see 6.1.3 and 6.2.2);

c) technological tests:

— torsion test (see 9.3.1),

— reverse bend test (see 9.3.2),

— wrapping test (see 9.3.3);

d) purchaser or third-party inspection (see clause 11);

e) declaration of conformity (see clause 12).

6 Requirements

6.1 Requirements for wire

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 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

Wire shall have the tensile properties specified in table 2.

Where tensile properties are not specified in table 2, these shall be agreed between the purchaser and the supplier.

6.1.3 Surface quality

Unless otherwise specified, surfaces shall have a tightly adherent oxide or shall be mechanically or chemically cleaned at the option of the supplier. Wire shall be clean and free from surface imperfections.

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

6.1.4 Dimensional tolerances

The diameter of round wire shall not differ from that specified by more than the tolerances specified in table 3. Out-of-roundness shall not exceed one-half of the total permissible variations specified in table 3. Tolerances for cross-sections other than round shall be agreed between the purchaser and the supplier.

6.2 Requirements for drawing stock

6.2.1 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 between the purchaser and the supplier. The percentage content of elements shown as "remainder" shall be calculated by difference from 100 %.

6.2.2 Surface quality

Unless otherwise specified, surfaces shall have a tightly adherent oxide or shall be mechanically or chemically cleaned at the option of the supplier. Drawing stock shall be clean and free from detrimental surface imperfections.

NOTE 3 Where appropriate, the acceptance criteria should be agreed between the purchaser and the supplier.

6.2.3 Dimensional tolerances

The diameter of round drawing stock shall not differ from that specified by more than $\pm$ 0,4 mm, including ovality.

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 test for wire

7.2.1 Tensile test samples shall be taken from material in the condition supplied, except as noted in 7.2.2.

7.2.2 If precipitation-hardenable alloys are supplied not fully heat treated, test samples other than those required for technological tests (see 9.3) shall be fully heat treated in accordance with table 4 prior to tensile testing.

8 Number of tests

8.1 Chemical analysis, one test per heat, for all products.

8.2 Tensile test, one test per lot, for wire only.

8.3 Technological tests, one test per lot, for wire only.

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

Tensile testing shall be carried out in accordance with ISO 6892.

The offset method shall be used for the determination of the 0,2 % proof stress ($R_{p0,2}$).

9.3 Technological tests

9.3.1 Torsion testing

Simple torsion testing shall be carried out in accordance with ISO 7800, reverse torsion testing in accordance with ISO 9649.

9.3.2 Reverse bend testing

Testing shall be carried out in accordance with ISO 7801.

9.3.3 Wrapping test

Testing shall be carried out in accordance with ISO 7802.

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

9.5 Retests

If any one of the test pieces first selected fails 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 test samples shall be deemed to comply with the requirements of this International Standard. If the test pieces from either of these additional samples fail, the lot represented by these samples shall be deemed not to comply with the requirements of this International Standard.

10 Marking

Each coil of wire or drawing stock shall be marked on a securely attached durable label, with the number of this International Standard, the alloy identification (either the number or the description), the heat number and the manufacturer's name.

11 Purchaser and third party inspection

On-site inspection of wire or drawing stock shall be in accordance with agreements 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 wire or drawing stock were 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 (selected from table 1 of ISO 9722:1992)

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
NW7001	NiCr20Co13Mo4Ti3Al	1,2 1,6	0,003 0,010	0,02 0,10	12,0 15,0	18,0 21,0	0,10	2,0	1,0	3,5 5,0	Remainder	0,015	0,015	0,1	2,8 3,3		Ag: 0,0005(5) Bi: 0,0005(0,5) Pb: 0,0010(10) Zr: 0,02 to 0,08	8,4
NW7090	NiCr20Co18Ti3	1,0 2,0	0,020	0,13	15,0 21,0	18,0 21,0	0,2	1,5	1,0		Remainder		0,015	1,0	2,0 3,0		Zr: 0,15	8,2
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
NW7750	NiCr15Fe7Ti2Al	0,4 1,0		0,08		14,0 17,0	0,5	5,0 9,0	1,0		70,0		0,015	0,5	2,2 2,8		Nb+Ta: 0,7 to 1,2	8,3
NW6600	NiCr15Fe8			0,15		14,0 17,0	0,5	6,0 10,0	1,0		72,0		0,015	0,5				8,4
NW7718	NiCr19Fe19Nb5Mo3	0,2 0,8	0,006	0,08		17,0 21,0	0,3	Remainder	0,4	2,8 3,3	50,0 55,0	0,015	0,015	0,4	0,6 1,2		Nb+Ta: 4,7 to 5,5	8,0
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
NW6333	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

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
NW7080	NiCr20Ti2Al	1,0 1,8	0,008	0,04 0,10	2,0	18,0 21,0	0,2	1,5	1,0		Remainder		0,015	1,0	1,8 2,7		Ag: 0,0005(5) Bi: 0,0001(1) Pb: 0,0020(20)	8,2
NW4400	NiCu30			0,30			28,0 34,0	2,5	2,0		63,0		0,025	0,5				8,8
NW5500	NiCu30Al3Ti	2,2 3,2		0,25			27,0 34,0	2,0	1,5		Remainder	0,020	0,015	0,5	0,35 0,85			8,5
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
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
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 x 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

Alloy identification[1]		Temper	Diameter or thickness mm		Tensile strength R_m, min	0,2 % proof stress $R_{p0,2}$, min	Minimum elongation A_5/A_{50}
Number	Description		over	up to and including	N/mm²	N/mm²	%
NW2200	Ni99,0	Cold drawn	3,20	3,20 10	540 460		
		Cold drawn and annealed	0,45	0,45 10	380 380		20 25
NW2201	Ni99,0-LC	Cold drawn and annealed	0,45	0,45 10	340 340		20 25
NW7090	NiCr20Co18Ti3	Cold drawn		10	max. 1 540		
		Cold drawn and solution treated		10	max. 1 080		30
		Cold drawn and precipitation treated	0,45 1,0 5,0	1,0 5,0 10	1 540 1 390 1 310	1 160 1 005	10
		Cold drawn, solution treated and precipitation treated	0,45 1,0	1,0 10	1 080 1 080	620	15 15
NW7750	NiCr15Fe7Ti2Al	Cold drawn, annealed and precipitation treated		0,65	1 065		
		Cold drawn, annealed, cold reduced (approx. 15 %) and precipitation treated	0,65		1 135		
NW6600	NiCr15Fe8	Cold drawn		3,20	850		
			3,20	10	770		
		Cold drawn and annealed		0,45	550		20
			0,45	10	550		25
NW7718	NiCr19Fe19Nb5Mo3	Cold drawn, annealed and precipitation treated			1 275		
NW6601	NiCr23Fe15Al	Cold drawn and annealed			550		
NW6625	NiCr22Mo9Nb	Cold drawn and annealed			830	415	30
		Cold drawn and solution treated			690	275	30
NW6621	NiCr20Ti	Cold drawn and annealed			650		

Alloy identification[1]		Temper	Diameter or thickness mm		Tensile strength	0,2 % proof stress	Minimum elongation
Number	Description		over	up to and including	R_m, min N/mm²	$R_{p0,2}$, min N/mm²	A_5/A_{50} %
NW4400	NiCu30	Cold drawn and annealed		0,45	480		20
			0,45	10	480		25
		Cold drawn		3,20	770		
			3,20	10	690		
NW5500	NiCu30Al3Ti	Cold drawn		10	760		
		Cold drawn and solution treated		10	max. 760		
		Cold drawn (spring temper)		1,5	1 140		
			1,5	3,0	1 070		
			3,0	6,0	1 030		
			6,0	8,0	1 000		
		Cold drawn and precipitation treated		10	1 070		
		Cold drawn, solution treated and precipitation treated		10	900		
		Cold drawn, spring temper and precipitation treated		3,0	1 240		
			3,0	8,0	1 170		
NW8825	NiFe30Cr21Mo3	Cold drawn and annealed			585		
NW8800	FeNi32Cr21AlTi	Cold drawn and annealed		0,45	520		20
			0,45	10	520		25

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

Table 3 — Tolerances on diameter of cold-drawn wire

Dimensions in millimetres

Specified diameter		Tolerance on diameter
over	up to and including	
0,1	0,4	± 0,006
0,4	0,8	± 0,013
0,8	1,2	± 0,02
1,2	2,0	± 0,03
2,0	3,2	± 0,04
3,2	4,8	± 0,05
4,8	8,0	± 0,06
8,0	10,0	± 0,08

Table 4 — Heat-treatment of precipitation-hardenable alloys

Alloy identification[1]		Recommended solution or annealing treatment[2]	Stabilizing and precipitation heat treatment or precipitation heat treatment, applied to test samples[2]
Number	Description		
NW7090	NiCr20Co18Ti13	1 050 °C to 1 100 °C, air cool or faster.	Cold-drawn wire: 650 °C, 4 h, air cool. Solution treated wire: 750 °C, 4 h, air cool or 700 °C, 16 h, air cool.
NW7750	NiCr15Fe7Ti2Al	1 150 °C, air cool or faster.	730 °C, 16 h, air cool.
NW7718	NiCr19Fe19Nb5Mo3	940 °C to 16 h, 1 060 °C, air cool or faster.	720 °C, 8 h, cool at 55 °C/h to 620 °C, hold at 620 °C for 8 h, air cool. Alternatively, cool to 620 °C at any rate and hold at 620 °C to give a total precipitation treatment time of 18 h.
NW7080	NiCr20Ti2Al	1 050 °C to 1 100 °C, air cool or faster.	750 °C, 4 h, air cool.
NW5500	NiCu30Al3Ti	980 °C minimum, water quench.	590 °C to 610 °C, 8 h to 16 h, furnace cool to 480 °C at between 8 °C/h and 15 °C/h, air cool. Alternatively, furnace cool to 535 °C, hold at 535 °C for 6 h, furnace cool to 480 °C, hold for 8 h, air cool.

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

2) The temperature used for the treatment of the test piece shall be stated on the declaration of conformity.

Annex A
(normative)

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 7530-7:1992, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 7: Determination of aluminium content.*

[16] ISO 7530-8:1992, *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 8: Determination of silicon content.*

[17] ISO 7530-9:—[1], *Nickel alloys — Flame atomic absorption spectrometric analysis — Part 9: Determination of vanadium content.*

[18] ISO 9388:1992, *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).*

1) To be published.