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Standard Specification for Iron-Nickel and Iron-Nickel-Cobalt Alloys for Low Thermal Expansion Applications[1]

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1. Scope

1.1 This specification covers two iron-nickel alloys and one iron-nickel-cobalt alloy, for low thermal expansion applications. The two iron-nickel alloys, both containing nominally 36 % nickel and 64 % iron, with the conventional alloy designated by UNS No. K93603, and the free-machining alloy designated as UNS No. K93050. The iron-nickel-cobalt alloy, containing nominally 32 % nickel, 5 % cobalt and 63 % iron, is designated by UNS No. K93500. This specification defines the following product forms for UNS No. K93603 and UNS No. K93500: wire, rod, bar, strip, sheet, and tubing. The free-machining alloy, UNS No. K93050, is defined for bar products only. Unless otherwise indicated, all articles apply to all three alloys.

1.2 The values stated in inch-pound units are to be regarded as the standard. SI values, shown in parentheses, are for information only.

1.3 This pertains only to the test method section, Section 13. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1971 Practices for Digestion of Samples for Determination of Metals by Flame Atomic Absorption or Plasma Emission Spectroscopy[2]

E 3 Methods of Preparation of Metallographic Specimens[3]

E 8 Test Methods of Tension Testing of Metallic Materials[3]

E 10 Test Method for Brinell Hardness of Metallic Materials[3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 45 Test Methods for Determining the Inclusion Content of Steel[3]

E 92 Test Method for Vickers Hardness of Metallic Materials[3]

E 112 Test Methods for Determining Average Grain Size[3]

E 140 Hardness Conversion Tables for Metals[3]

E 228 Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer[4]

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys[5]

E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel and Cobalt Alloys[6]

E 1601 Practice for Conducting an Interlaboratory Study to Evaluate the Performance of an Analytical Method[6]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Alloy, as indicated with UNS number,

3.1.2 Size,

3.1.3 Temper designation (Section 6),

3.1.4 Surface finish (Section 10),

3.1.5 Marking and packaging (Section 18), and

3.1.6 Certification, if required.

NOTE 1—Certification should include traceability of the heat to the original manufacturer.

4. Chemical Requirements

4.1 Each alloy shall conform to the requirements as to chemical composition prescribed in Table 1.

NOTE 2—Lower levels of phosphorus and sulfur may be required for certain welding applications. These lower levels shall be negotiated, as

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.06.

TABLE 1 Chemical Requirements

NOTE 1—Round observed or calculated values to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off method of Practice E 29.

Element	UNS No. K93603	UNS No. K93050	UNS No. K93500
Iron, nominal	remainder[A]	remainder[A]	remainder[A]
Nickel, nominal	36[A]	36[A]	32[A]
Cobalt, max	0.50	0.50	5[A]
Manganese, max	0.60	1.00	0.60
Silicon, max	0.40	0.35	0.25
Carbon, max	0.05	0.15	0.05
Aluminum, max	0.10[B]	...[C]	0.10[B]
Magnesium, max	0.10[B]	...[C]	0.10[B]
Zirconium, max	0.10[B]	...[C]	0.10[B]
Titanium, max	0.10[B]	...[C]	0.10[B]
Chromium, max	0.25	0.25	0.25
Selenium	...	0.15 to 0.30	...
Phosphorus, max	0.015[D]	0.020	0.015[D]
Sulfur, max	0.015[D]	0.020	0.015[D]

[A] For UNS No. K93603 and K93050, the iron, and nickel requirements are nominal, while for UNS No. K93500, the iron, nickel, and cobalt requirements are nominal. These levels may be adjusted by the manufacturer to meet the requirements for the coefficient of thermal expansion as specified in 12.1.

[B] The total of aluminum, magnesium, titanium, and zirconium shall not exceed 0.20 %.

[C] These elements are not measured for this alloy.

[D] The total of phosphorus and sulfur shall not exceed 0.025 %.

needed, between the vendor and user. Welding of the free-machining alloy (UNS No. K93050) is generally not recommended.

5. Surface Lubricants

5.1 All lubricants used during cold-working operations, such as drawing, rolling, or spinning, shall be capable of being removed readily by any of the common organic degreasing solvents.

6. Temper

6.1 The desired temper of the material shall be specified in the purchase order.

6.2 *Tube*—(UNS No. K93603 and No. K93500 only) Unless otherwise agreed upon between the supplier or manufacturer and the purchaser, these forms shall be given either a final bright anneal or anneal and descale by the manufacturer, and supplied in the annealed temper.

6.3 *Strip and Sheet*— (UNS No. K93603 and No. K93500 only) These forms shall be supplied in one of the tempers given in Table 2 or in deep-drawing temper, as specified.

6.4 *Wire and Rod*— These forms shall be supplied in one of the tempers given in Table 3 as specified. Unless otherwise specified, the material shall be bright annealed and supplied in Temper A (annealed).

6.5 *Rod*—(UNS K93050 only) For Temper D (unannealed) material, in rod sizes greater than ½ in. diameter, the mid-radius Brinell Hardness shall be 235 maximum. Consult Test Method E 10 for Brinell Hardness test procedures.

6.6 For rod forms, air anneal, followed by centerless grinding to remove scale, is an acceptable alternate.

TABLE 2 Tensile Strength Requirements for Strip and Sheet

Temper Designation	Temper Name	Tensile Strength ksi (MPa)	
		UNS No. K93603	UNS No. K93500 (Nominal Values)
A	anealed	85 max (586 max)	85 max (586 max)
B	1/2 hard	86 min (593)	86 min (593)
C	hard	105 min (724)	105 min (724)

TABLE 3 Tensile Strength Requirements for Wire and Rod

NOTE 1—The tensile strength limits for Temper D apply only to material ½ in. diameter and under. Consult 6.5 for hardness limits which apply to larger rod sizes.

Temper Designation	Temper Name	Tensile Strength ksi (MPa)		
		UNS No. K93603	UNS No. K93050	UNS No. K93500
A	Annealed	85 max (586 max)	85 max (586 max)	85 max (586 max)
B	Cold worked	86 min (593 min)	86 min (593 min)	86 min (593 min)
D	Unannealed	. . .	111 max (765 max)	. . .

7. Grain Size

7.1 (UNS No. K93603 and No. K93500 only) Strip and sheet for deep drawing shall have an average grain size not larger than ASTM No. 5 (Note 3), and no more than 10 % of the grains shall be larger than No. 5 when measured in accordance with Test Methods E 112.

NOTE 3—This corresponds to a grain size of 0.065 mm, or 16 grains/in.^{2} of image at 100×.

7.2 Finer grain sizes for deep drawing quality shall be negotiated between user and supplier.

8. Hardness

8.1 *Deep-Drawing Temper*—(UNS No. K93603 and No. K93500 only) For deep drawing, the hardness shall not exceed 157 Vickers Hardness for material 0.100 in. (2.54 mm) and less in thickness and 85 HRB for material over 0.100 in. in thickness. The Vickers Hardness test shall be determined in accordance with Test Method E 92, while the Rockwell Hardness test shall be determined in accordance with Test Methods E 18.

NOTE 4—For hardness conversions, use Table 3 of Standard E 140.

8.2 *Rolled and Annealed Tempers*—Hardness tests when properly applied can be indicative of tensile strength. Hardness scales and ranges for these tempers, if desirable, shall be negotiated between supplier and purchaser.

9. Tensile Strength

9.1 *Strip and Sheet*:

(UNS No. K93603 and No. K93500 only)

9.1.1 Tensile strength shall be the basis for acceptance or rejection for the tempers given in Table 2 and shall conform with the requirements prescribed, unless alternative mechanical properties (for example, ductility) and limits are negotiated between user and supplier.

9.1.2 Tension test specimens shall be taken so the longitudinal axis is parallel to the direction of rolling, and the test shall be performed in accordance with Test Methods E 8.

9.2 *Wire and Rod*:

9.2.1 Tensile strength shall be the basis for acceptance or rejection for the tempers given in Table 3 and shall conform to the requirements prescribed, unless alternative mechanical properties (for example, ductility) and limits are negotiated between user and supplier.

9.2.2 The test shall be performed in accordance with Test Methods E 8.

10. Surface Finish

10.1 The standard surface finishes available shall be those resulting from the following operations:

10.1.1 Hot rolling,
10.1.2 Forging,
10.1.3 Centerless grinding (rod),
10.1.4 Belt polishing,
10.1.5 Cold rolling,
10.1.6 Wire and rod drawing,
10.1.7 Annealed and descaled, and
10.1.8 Bright annealed.

11. Inclusion Content

11.1 *Wire, Rod, Bar, Strip and Sheet*—(UNS No. K93603 and No. K93500 only) These product forms shall be free of inclusions, cracks, blow holes, and other defects that are detrimental to the quality of subsequent product.

11.2 Inclusion ratings for certain applications (for example, deep drawing) shall be negotiated between user and supplier. Rating criteria shall be based on Test Methods E 45.

12. Thermal Expansion Characteristics

12.1 The average linear coefficients of thermal expansion shall be within the limits specified in Table 4. For UNS No. K93050, the supplier is requested to supply data over the temperature range 30 to 150°C. Nonmandatory thermal expansion data are found in the Appendix X1-Appendix X3.

12.2 Typical thermal expansion data, thermal expansion data for annealed material to higher temperatures, and for the three-step anneal used for UNS K93600, are contained in Appendix X1-Appendix X3.

13. Test for Thermal Expansion

13.1 *UNS No. K93603*— Heat the specimen in a non-oxidizing atmosphere for a minimum of 1 h at 875± 25°C. Cool at a rate not to exceed 300°C/h.

13.2 *UNS No. K93050*— Heat the specimen in a non-oxidizing atmosphere for a minimum of 15 min at 815 ± 25°C. Air cool.

13.3 *UNS No. K93500*— (*1*) Heat the specimen in a non-oxidizing atmosphere for a minimum of 1 h at 845 ± 25°C. Water quench. (*2*) Heat the specimen for a minimum of 1 h at 315 ± 15°C. Air cool. (*3*) Heat the specimen for a minimum of 24 h at 95 ± 10°C. Air cool.

NOTE 5—(Applies to 13.1-13.3): Alternative thermal treatments and resulting values of thermal coefficient of expansion may be negotiated between the supplier and purchaser.

13.4 Determine the thermal expansion characteristics in accordance with Test Method E 228.

TABLE 4 Coefficients of Thermal Expansion

Temperature Range,° C	Average Linear Coefficient of Thermal Expansion, µm/m·°C		
	UNS No. K93603	UNS No. K93050	UNS No. K93500
30 to 150	1.2 to 2.7	...	...
−18 to 93	...	...	0.9 max

14. Transformation in UNS No. K93500 Alloy

14.1 Because its nominal 5 wt % addition of cobalt, UNS No. K93500 Alloy is metastable at temperatures less than room temperature. If needed, specific minimum transformation temperatures may be negotiated between purchaser and supplier.

15. Chemical Analysis

15.1 This section describes the chemical analysis techniques to be used in case of dispute. Wherever applicable, the analysis procedures described in Practices D 1971, Test Methods E 354, E 1019, and Practice E 1601 should be utilized.

15.2 *Carbon, Sulfur*— Combustion method.

15.3 *Aluminum, Chromium, Magnesium*—Atomic absorption method.

15.4 *All Other Elements Shown in Table 1 (Excluding Iron, Nickel, and Cobalt)*—Atomic absorption, optical emission or inductively coupled plasma (ICP or ICAP) methods.

NOTE 6—The iron, nickel, and cobalt requirements are nominal (see Table 1).

16. Dimensions and Permissible Variations

16.1 *Cold-Rolled Strip*—(UNS No. K93603 and No. K93500 only) Cold-rolled strip shall conform to the permissible variations in dimensions prescribed in Table 5, Table 6, and Table 7.

16.2 *Round Wire and Rod*—Wire and rod shall conform to the permissible variations in dimensions prescribed in Table 8.

16.3 *Cold-Drawn Tubing*—(UNS No. K93603 and No. K93500 only) Cold-drawn tubing, available either as seamless or welded, shall conform to the permissible variations prescribed in Table 9.

17. General Requirements

17.1 The material supplied under this specification shall be commercially smooth, uniform in cross section, in composition, and in temper, it shall be free of scale, corrosion, cracks, seams, scratches, slivers, and other defects as best commercial practice will permit.

18. Packaging and Package Marking

18.1 Packaging shall be subject to agreement between the purchaser and the seller.

18.2 The material as furnished under this specification shall be identified by the name or symbol of the manufacturer and by heat number. The lot size for determining compliance with the requirements of this specification shall be one heat.

19. Investigation of Claims

19.1 Where any material fails to meet the requirements of this specification, the material so designated shall be handled in accordance with a mutual agreement between the purchaser and the seller.