Designation: ~~F1466 – 99 (Reapproved 2015)~~ F1466 – 20

Standard Specification for Iron-Nickel-Cobalt Alloys for Metal-to-Ceramic Sealing Applications[1]

This standard is issued under the fixed designation F1466; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers two iron-nickel-cobalt alloys, the former, (UNS No. K94630), containing nominally 29 % nickel, 17 % cobalt, and 53 % iron, the latter, (UNS No. K94620), nominally 27 % nickel, 25 % cobalt and 48 % iron, in the forms of wire, rod, bar, strip, sheet, and tubing, intended primarily for brazed metal-to-ceramic seals with alumina ceramics, for vacuum electronic applications. Unless otherwise indicated, all articles apply to both alloys.

1.2 The values stated in ~~inch-pound~~SI units are to be regarded as standard. The values given in parentheses ~~are mathematical conversions to~~ after SI units ~~that~~ are provided for information only and are not considered standard.

1.3 The following hazard caveat pertains only to the test method portion, Sections 14 and 16 of this specification. *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1971 Practices for Digestion of Water Samples for Determination of Metals by Flame Atomic Absorption, Graphite Furnace Atomic Absorption, Plasma Emission Spectroscopy, or Plasma Mass Spectrometry
E3 Guide for Preparation of Metallographic Specimens
E8 Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M
E18 Test Methods for Rockwell Hardness of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E45 Test Methods for Determining the Inclusion Content of Steel
E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
E112 Test Methods for Determining Average Grain Size
E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness
E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer

[1] This specification is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.03 on Metallic Materials, Wire Bonding, and Flip Chip.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Inert Gas Fusion Techniques

~~E1060~~E1601 Practice for ~~Interlaboratory Testing of Spectrochemical Methods of Analysis~~Conducting an Interlaboratory Study to Evaluate the Performance of an Analytical Method ~~(Withdrawn 1997)~~

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 19), and

3.1.6 Certification, if required. Please note that 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.

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.

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 E29.

Element	UNS No. K94630	UNS No. K94620
Iron, nominal	remainder [A]	remainder [A]
Nickel, nominal	29 [A]	27 [A]
Cobalt, nominal	17 [A]	25 [A]
Manganese, max	0.35	0.35
Silicon, max	0.15	0.15
Carbon, max	0.02	0.02
Aluminum, max	0.01 [B]	0.01 [B]
Magnesium, max	0.01 [B]	0.01 [B]
Zirconium, max	0.01 [B]	0.01 [B]
Titanium, max	0.01 [B]	0.01 [B]
Copper, max	0.20	0.20
Chromium, max	0.03	0.03
Molybdenum, max	0.06	0.06
Phosphorus, max	0.006 [C]	0.006 [C]
Sulfur, max	0.006 [C]	0.006 [C]

[A] The iron, nickel, and cobalt requirements are nominal and 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 0.04 %.

[C] The total of phosphorus and sulfur shall not exceed ~~0.010 %.~~0.010 %.

6.2 *Tube*—Unless otherwise agreed upon between the supplier or the manufacturer and the purchaser, these forms shall be given a final bright anneal by the manufacturer and supplied in the annealed temper.

6.3 *Strip and Sheet*—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).

NOTE 1—For rod forms, air anneal, followed by centerless grinding to remove scale, is an acceptable alternate.

7. Grain Size

7.1 Strip and sheet for deep drawing shall have an average grain size not larger than ASTM No. 5 (Note 2), and no more than 10 % of the grains shall be larger than No. 5 when measured in accordance with Test Methods E112.

NOTE 2—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*—For deep drawing, the hardness shall not exceed 82 HRB for material ~~0.100 in. (2.54 mm)~~2.5 mm (0.098 in.) and less in thickness, and 85 HRB for material over ~~0.100 in.~~ 2.5 mm (0.098 in.) in thickness when determined in accordance with Test Methods E18. See also Test Method E92 for Vickers Hardness Testing and tables in E140.

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:*

TABLE 2 Tensile Strength Requirements for Strip and Sheet

Temper Designation	Temper Name	Tensile Strength, ~~ksi (MPa)~~	
		UNS No. K94630	UNS No. K94620 (Nominal Values)
~~A~~	~~annealed~~	~~82 max (565 max)~~	~~85 max (586 max)~~
~~B~~	~~¼ hard~~	~~75 to 90 (517 to 621)~~	~~85 to 100 (586 to 689)~~
~~C~~	~~half hard~~	~~85 to 100 (586 to 689)~~	~~95 to 110 (655 to 758)~~
~~D~~	~~¾ hard~~	~~95 to 110 (655 to 758)~~	~~105 to 120 (724 to 827)~~
~~E~~	~~hard~~	~~100 min (689 min)~~	~~120 min (827 min)~~

TABLE 2 Tensile Strength Requirements for Strip and Sheet

Temper Designation	Temper Name	Tensile Strength, MPa (ksi)	
		UNS No. K94630	UNS No. K94620 (Nominal Values)
A	annealed	560 max (81 max)	590 max (86 max)
B	¼ hard	520 to 620 (75 to 90)	590 to 690 (86 to 100)
C	half hard	590 to 690 (86 to 100)	660 to 760 (96 to 110)
D	¾ hard	660 to 760 (96 to 110)	720 to 830 (104 to 120)
E	hard	690 min (100 min)	830 min (120 min)

TABLE 3 Tensile Strength Requirements for Wire and Rod

Temper Designation	Tensile Strength, ~~ksi (MPa)~~	
	UNS No. K94630	UNS No. K94620 (Nominal Values)
~~A~~	~~85 (586) max~~	~~85 (586) max~~
~~B~~	~~85 to 105 (586 to 724)~~	~~85 to 100 (586 to 689)~~
~~C~~	~~95 to 115 (655 to 793)~~	~~95 to 110 (655 to 758)~~
~~D~~	~~105 to 125 (724 to 862)~~	~~105 to 120 (724 to 827)~~
~~E~~	~~125 (862) min~~	~~120 (827) min~~

TABLE 3 Tensile Strength Requirements for Wire and Rod

Temper Designation	Tensile Strength, MPa (ksi)	
	UNS No. K94630	UNS No. K94620 (Nominal Values)
A	590 max (86 max)	590 max (86 max)
B	590 to 720 (86 to 104)	590 to 690 (86 to 100)
C	660 to 790 (96 to 115)	660 to 760 (96 to 110)
D	720 to 860 (104 to 125)	720 to 830 (104 to 120)
E	860 min (125 min)	830 min (120 min)

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.

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 E8.

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.

9.2.2 The test shall be performed in accordance with Test Methods E8.

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, and

10.1.6 Wire and rod drawing.

11. Inclusion Content

11.1 *Wire, Rod, Bar, Strip, and Sheet*—These product forms shall be free of inclusions, cracks, blow holes and other defects that are detrimental to the quality of subsequent product. The maximum inclusion rating number shall be 2 for Inclusion Types, A, B, C and D in both the thin and heavy series shown in Plate I using Practice E45, Method A, Worst-Field Technique.

NOTE 3—The test for inclusions may be performed on billet sections. In such cases, the sample section must include regions that correspond to the top of the ingot.

NOTE 4—Product section size information at which the inclusion ratings were taken should be included.

12. Thermal Expansion Characteristics

12.1 The average linear coefficients of thermal expansion shall be within the limits specified in Table 4.

13. Test for Thermal Expansion

13.1 Heat the specimen in a non-oxidizing atmosphere for 1 h at 1000°C. Cool at a rate not to exceed 300°C per hour.

13.2 Determine the thermal expansion characteristics in accordance with Test Method E228.

14. Transformation

14.1 (UNS No. K94630 only) The temperature of the gamma-to-alpha transformation shall be ~~below – 78.5°C~~below –78.5°C when the material is tested in accordance with Section 16. However, for material whose smallest dimension is over ~~⅞ in. (22.2 mm),~~22 mm (0.87 in.), some localized transformation, acceptable to the purchaser, may be tolerated.

14.2 The temperature of the gamma-alpha transformation for UNS No. K94620 is well below – 78.5°C. Tests for transformation in this alloy, if necessary, shall be negotiated between supplier and purchaser.

14.3 For alloy UNS No. K94630, consult the nonmandatory appendix of Specification E92 for applicable thermal expansion information based on producer heat data and recommended thermal expansion values over a wide range of temperatures.

15. Test for Transformation

15.1 Cut the specimen from any part of the material, but preferably including the entire cross section, degrease it, then heat treat it as described in 13.1. When cool, polish the cross section of the specimen and etch (Note 5) it in accordance with Methods E3. Then subject the specimen to the temperature produced by an excess of dry ice in methanol (–78.5°C) for at least 4 h. After the low-temperature treatment, examine the specimen at a magnification of 150× for the presence of the acicular crystals characteristic of the alpha phase. Because these crystals may occur only in small localized areas, examine carefully the entire polished cross section.

NOTE 5—A suggested etchant is a solution of three parts by volume of concentrated hydrochloric acid and one part of concentrated nitric acid saturated with cupric chloride ($CuCl_2 \cdot 2H_2O$). This etchant is more effective when allowed to stand for 20 min after mixing. After several hours it loses its strength and should be discarded at the end of the day. Etching is best accomplished by swabbing the specimen with cotton soaked with the etchant. Etching is usually complete when the surface of the metal appears to have turned dull.

15.2 Specimens that show no transformation and that show partial transformation are illustrated in Fig. 1 and Fig. 2, respectively.

16. Chemical Analysis

16.1 This describes the chemical analysis techniques to be used in case of dispute. Wherever applicable, the analysis procedures described in Practices D1971, Test Methods ~~E3~~E354, E1019 and Practice ~~E1060~~E1601 should be utilized.

16.2 Do chemical analysis as follows:

16.2.1 *Carbon, Sulfur,* Combustion method.

TABLE 4 Coefficients of Thermal Expansion

Temperature Range,° C	Average Linear Coefficient of Thermal Expansion, µm/m·°C	
	UNS No. K94630	UNS No. K94620 (Nominal Values)
30–400	4.60–5.20	...
30–450	5.10–5.50	...
30–500	...	7.30–7.90
30–600	...	8.00–8.60

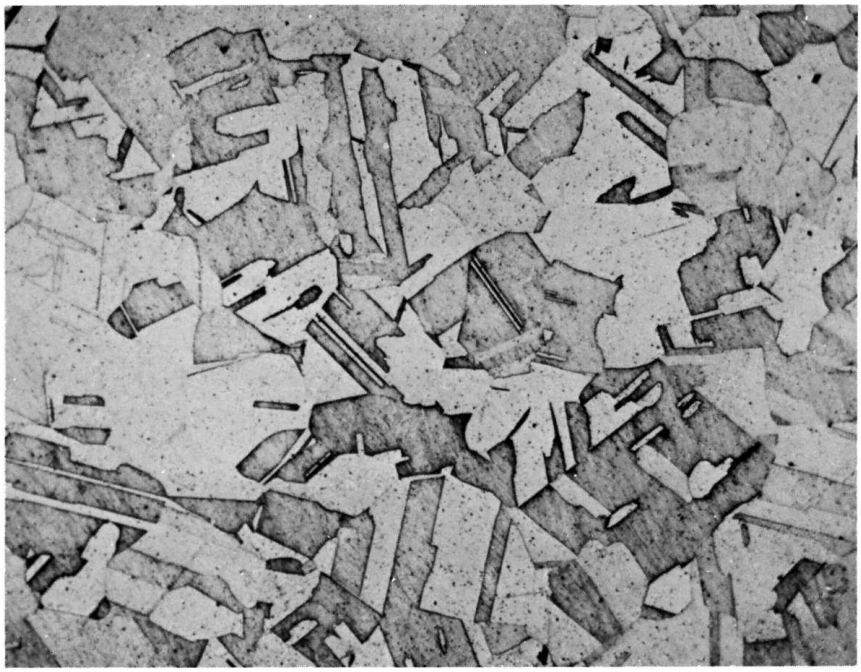

FIG. 1 Normal Annealed Specimen Showing No Transformation

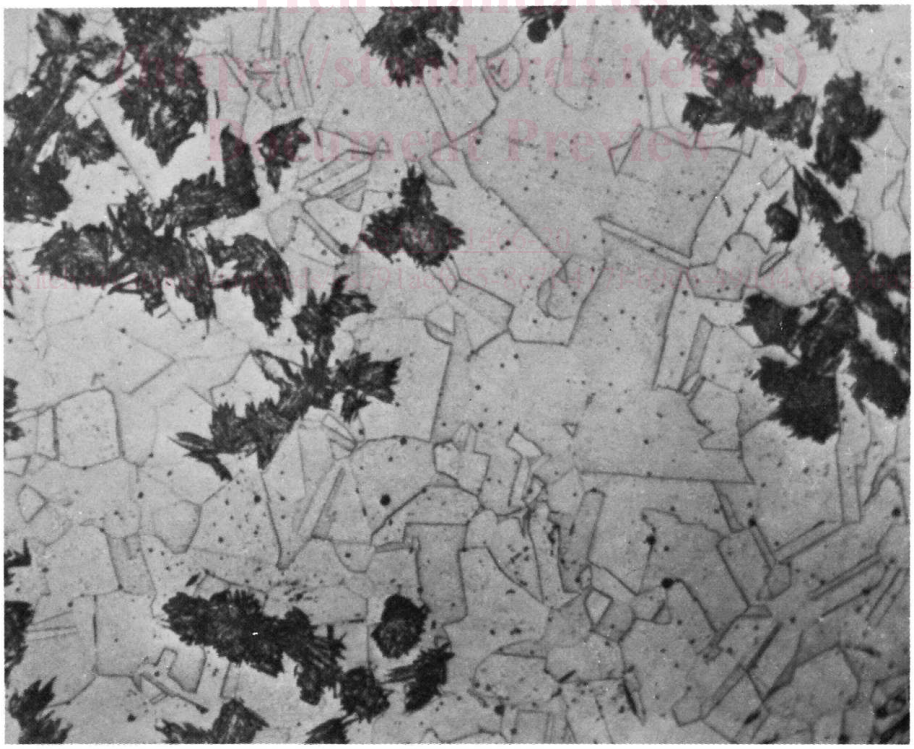

FIG. 2 Partially Transformed Specimen

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

16.2.3 *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).

17. Dimensions, Mass, and Permissible Variations

17.1 *Cold-Rolled Strip*—Cold-rolled strip shall conform to the permissible variations in dimensions prescribed in Table 5~~, Table 6, and~~ and Table ~~7~~6.

NOTE 7—The thickness tolerance applies for the entire width of the strip except for 10 mm from each edge of as-rolled, unslit coils.

NOTE 8—For thicknesses other than those shown in Table 5, the tolerances for the next higher thickness shall apply.

NOTE 9—For thicknesses other than those shown in Table 6, the width tolerances for the next higher thickness shall apply.

17.2 *Round Wire and Rod*—Wire and rod shall conform to the permissible variations in ~~dimensions prescribed~~diameters shown in Table ~~8~~7.

17.3 ~~*Cold-Drawing*~~*Cold-Drawn Tubing*—Cold-drawn tubing, available either as seamless or welded, shall conform to the permissible variations prescribed in Table ~~9~~8.

18. General Requirements

18.1 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.

19. Packaging and Package Marking

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

TABLE 5 Permissible Variations in Thickness of Cold-Rolled Strip

Specified Thickness, ~~in. (mm)~~	~~Permissible Variations in Thickness for Width Given, ± in. (mm)~~			
	~~Under 3 (76)~~	Over ~~3~~ to ~~6~~ ~~(76 to 152)~~	Over ~~6~~ to ~~12~~ ~~(152 to 305)~~	~~Over 12 to 1~~
~~0.160–0.100 (4.06–2.54), incl~~	~~0.002 (0.051)~~	~~0.003 (0.076)~~	~~0.004 (0.102)~~	~~0.004 (0.102~~
~~0.099–0.069 (2.51–1.75), incl~~	~~0.002 (0.051)~~	~~0.003 (0.076)~~	~~0.003 (0.076)~~	~~0.004 (0.102~~
~~0.068–0.050 (1.73–1.27), incl~~	~~0.002 (0.051)~~	~~0.003 (0.076)~~	~~0.003 (0.076)~~	~~0.003 (0.076~~
~~0.049–0.035 (1.24–0.89), incl~~	~~0.002 (0.051)~~	~~0.0025 (0.064)~~	~~0.003 (0.076)~~	~~0.003 (0.076~~
~~0.034–0.029 (0.86–0.74), incl~~	~~0.0015 (0.038)~~	~~0.002 (0.051)~~	~~0.0025 (0.064)~~	~~0.0025 (0.06~~
~~0.028–0.026 (0.71–0.66), incl~~	~~0.0015 (0.038)~~	~~0.0015 (0.038)~~	~~0.002 (0.051)~~	~~0.002 (0.051~~
~~0.025–0.020 (0.64–0.51), incl~~	~~0.001 (0.025)~~	~~0.0015 (0.038)~~	~~0.002 (0.051)~~	~~0.002 (0.051~~
~~0.019–0.017 (0.48–0.43), incl~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.0015 (0.038)~~	~~0.002 (0.051~~
~~0.016–0.012 (0.41–0.31), incl~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.0015 (0.038)~~	~~0.0015 (0.03~~
~~0.011–0.0101 (0.28–0.26), incl~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.0015 (0.03~~
~~0.010–0.0091 (0.25–0.23), incl~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.001 (0.025)~~	~~0.001 (0.025~~
~~0.009–0.006 (0.23–0.15), incl~~	~~0.00075 (0.019)~~	~~0.00075 (0.019)~~	~~...~~	~~...~~
~~Under 0.006 (0.15)~~	~~0.0005 (0.013)~~	~~0.0005 (0.013)~~	~~...~~	~~...~~

TABLE 5 Permissible Variations in Thickness of Cold-Rolled Strip

Specified Thickness, mm (in.)	Thickness Tolerances for Thickness and Widths Given, ± mm (in.)		
	50 to 150 (2.0 to 5.9)	Over 150 to 300 (5.9 to 11.8), incl	Over 300 to 600 (11.8 to 23.6), excl
5.00 (0.20)	0.070 (0.0028)	0.070 (0.0028)	0.090 (0.0035)
4.00 (0.16)	0.070 (0.0028)	0.070 (0.0028)	0.090 (0.0035)
3.00 (0.12)	0.060 (0.0024)	0.070 (0.0028)	0.090 (0.0035)
2.50 (0.098)	0.050 (0.0020)	0.070 (0.0028)	0.080 (0.0031)
2.00 (0.079)	0.050 (0.0020)	0.060 (0.0024)	0.070 (0.0028)
1.75 (0.069)	0.050 (0.0020)	0.060 (0.0024)	0.070 (0.0028)
1.50 (0.059)	0.040 (0.0016)	0.050 (0.0020)	0.060 (0.0024)
1.25 (0.049)	0.035 (0.0014)	0.045 (0.0018)	0.050 (0.0020)
1.00 (0.039)	0.030 (0.0012)	0.040 (0.0016)	0.050 (0.0020)
0.75 (0.030)	0.030 (0.0012)	0.040 (0.0016)	0.050 (0.0020)
0.50 (0.020)	0.025 (0.00098)	0.030 (0.0012)	0.035 (0.0014)
0.25 (0.0098)	0.015 (0.00059)	0.020 (0.00079)	0.025 (0.00098)
0.15 (0.0059)	0.010 (0.00039)	0.015 (0.00059)	0.020 (0.00079)