Designation: A 753 – 02

Standard Specification for Wrought Nickel-Iron Soft Magnetic Alloys (UNS K94490, K94840, N14076, N14080)[1]

This standard is issued under the fixed designation A 753; 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 commonly used wrought nickel-iron soft magnetic alloys produced or supplied expressly for use in magnetic cores and other parts requiring high magnetic permeability, high electrical resistivity, low coercive field strength, and low core loss.

1.2 This specification covers materials supplied by a producer or converter to the form and physical condition desired for fabrication into parts that will later be given a final heat treatment to achieve the desired magnetic characteristics. It covers materials supplied in the form of forging billet; hot-rolled plate, strip, and bar; cold-finished bar; cold-rolled and annealed sheet and strip; shaped bar and wire; and wire.

1.2.1 This specification does not cover either powder metallurgically produced or cast parts.

1.2.2 This specification lists requirements for strip products having isotropic or semi-isotropic magnetic properties but does not include requirements for anisotropic or square hysteresis loop alloys or alloys processed to yield flattened hysteresis loops by use of heat treatments in an applied magnetic field.

1.2.3 This specification does not cover alloys modified by the addition of elements such as sulfur and selenium to enhance machinability.

1.3 The values stated in customary (cgs-emu and inch-pound) units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units which are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials[2]

A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing[2]

A 341/A 341M Test Method for Direct Current Magnetic Properties of Materials Using dc Permeameters and the Ballistic Test Methods[2]

A 343 Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame[2]

A 480/M 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip[3]

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Steel Bars and Shapes, Carbon, Rolled from "T" Rails[3]

A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods[3]

A 596/A 596M Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens[2]

A 772 Test Method for ac Magnetic Permeability of Materials Using Sinusoidal Current[2]

A 773/A 773M Test Method for dc Magnetic Properties of Materials Using Ring and Permeameter Procedures with dc Electronic Hysteresigraphs[2]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys[5]

3. Terminology

3.1 The terms and symbols used in this specification are defined in Terminology A 340.

[1] This specification is under the jurisdiction of ASTM Committee A06 on Magnetic Properties , and is the direct responsibility of Subcommittee A06.02 on Material Specifications.

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[2] *Annual Book of ASTM Standards*, Vol 03.04.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

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

4. Classification

4.1 Four specific alloy types are covered:

Alloy Type	UNS Number[A]	Nominal Range of Nickel, %[B]
1	K94490	43.5 to 46.5
2	K94840	47.0 to 49.0
3	N14076	75.0 to 78.0
4	N14080	79.0 to 82.0

[A] UNS refers to the Unified Numbering System, an alloy identification system supported by ASTM. Refer to Practice E 527 for details.

[B] Alloy Types 3 and 4 have additions of molybdenum, copper, and chromium to improve magnetic performance.

4.2 Alloy Type 2 in thin-strip form (thickness less than or equal to 0.0200 in. (0.508 mm)) is available in two different grades. Grade 1 is semi-isotropic and is recommended for use in transformer laminations. Grade 2 is isotropic and is recommended for use in rotating machinery laminations. These grades are the result of different mill processing (that is, cold-rolling and annealing) practices and cannot be created by changes in the final heat treatment given to the laminations.

5. Ordering Information

5.1 Orders for material conforming to this specification shall include the following information:

5.1.1 Reference to this specification and year of issue or revision.

5.1.2 Alloy type (Section 6) and grade where appropriate.

5.1.3 Dimensions and tolerances (Section 11).

5.1.4 Quantity (weight or number of pieces as appropriate).

5.1.5 Form and condition (Section 7).

5.1.6 Magnetic property requirements if they are other than those listed in this specification.

5.1.7 Certification of chemical analysis and magnetic quality evaluation.

5.1.8 Marking and packaging requirements.

5.1.9 *End Use*—Whenever possible, the user should specify whether the material will be machined, blanked into flat pieces, blanked and formed, deep drawn to shape, wound into a core, punched into laminations, or photo-etched. This will help the producer to provide the most suitable material for the user's fabricating practices.

5.1.10 Exceptions to this specification or special requirements such as mechanical property requirements.

6. Chemical Composition

6.1 The alloys shall conform to the requirements prescribed in Table 1. Since magnetic performance is paramount, analysis variations are permitted by mutual agreement between the user and producer.

6.2 Determination of metallic constituents and phosphorus shall be by a method(s) acceptable to both producer and user. Analysis of carbon and sulfur shall be done in accordance with Test Methods E 1019.

7. Form and Condition

7.1 These materials are capable of being produced in a wide variety of forms and conditions suitable for further manufacture into specific magnetic articles. The desired form and condition shall be specified and should be discussed with the producer before ordering to assure receiving the appropriate product. Available forms and conditions are:

TABLE 1 Chemical Requirements (Weight Percent)

	Alloy 1 UNS K94490	Alloy 2 UNS K94840	Alloy 3 UNS N14076	Alloy 4 UNS N14080
Carbon, max.	0.05	0.05	0.05	0.05
Manganese, max.	0.80	0.80	1.5	0.80
Silicon, max.	0.50	0.50	0.50	0.50
Phosphorus, max.	0.03	0.03	0.02	0.02
Sulfur, max.	0.01	0.01	0.01	0.01
Chromium	0.30 max.	0.30 max.	2.0-3.0	0.30 max.
Nickel	43.5-46.5	47.0-49.0	75.0-78.0	79.0-82.0
Molybdenum	0.30 max.	0.30 max.	0.50 max.	3.5-6.0
Cobalt, max.	0.50	0.50	0.50	0.50
Copper	0.30 max.	0.30 max.	4.0-6.0	0.30 max.
Iron[A]	balance	balance	balance	balance

[A] Iron is the balance by difference. Quantitative analysis of this element is not required.

7.1.1 *Forging Billet*—Hot worked; hot worked with surfaces prepared by grinding.

7.1.2 *Hot-Rolled Plate, Strip, and Bar*—Hot-rolled; hot-rolled and acid cleaned; hot-rolled and annealed; hot-rolled, annealed, and acid cleaned; hot-rolled and mechanically cleaned; mechanical properties as specified.

7.1.3 *Cold-Finished Bars*—Cold-drawn; cold-drawn and centerless ground; cold-drawn and annealed to specified mechanical properties.

7.1.4 *Cold-Rolled Sheet and Strip*—Cold-rolled; deep draw quality; cold-rolled and annealed to specified mechanical properties.

7.1.5 *Wire*—Cold-drawn; cold-drawn and annealed to specified mechanical properties.

7.1.6 *Shaped Bar and Wire*—Cold-worked; cold-worked and annealed to specified mechanical properties.

8. Magnetic Property Requirements—General Requirements

8.1 *Test Methods*—Because of the extremely high magnetic permeabilities developed in these alloys after heat treatment, the use of permeameters (Test Method A 341/A 341M) is expressly forbidden. Allowable test methods are those using ring-type specimens.

8.2 *Test Specimen*—Whenever possible, test specimen size and shape shall conform to those listed in Practice A 34/A 34M. Specimen shapes such as stacked laminations, solid rings, and spirally wound tape and wire cores are necessary for the most accurate results. If, however, the product form or dimensions precludes the use of a preferred test specimen, the specimen shape and size shall be mutually agreed upon between the producer and user.

8.3 *Density*—The assumed densities of these materials for purposes of magnetic testing shall be as follows:

Alloy Type	UNS No.	Assumed Density g/cm^3	Assumed Density (kg/m^3)
1	K94490	8.17	8170
2	K94840	8.25	8250
3	N14076	8.58	8580
4 (4 % Mo)	N14080	8.74	8740
4 (5 % Mo)	N14080	8.77	8770

8.4 *Heat Treatment*—The heat treatment applied to the test specimen shall be mutually agreed upon between the producer and user. If no such agreement exists, the heat treatment

applied to the test specimen shall be chosen by the producer to exceed the magnetic property requirements listed in Tables 2 and 3 of this specification. Refer to Appendix X2 for information on heat treatment of these alloys.

9. dc Magnetic Property Requirements

9.1 dc magnetic testing shall be the only magnetic test methods used for all product forms and sizes other than thin strip and sheet. Thin sheet and strip is defined as flat-rolled product having a thickness of 0.0200 in. (0.508 mm) or less.

9.2 Testing shall be conducted using either Test Method A 596/A 596M or Test Method A 773/A 773M.

9.3 The dc magnetic property requirements after appropriate heat treatment are shown in Table 2. The symbol *d* refers to the minimum dimension such as thickness or diameter.

10. ac Magnetic Property Requirements (Thin Sheet and Strip Only)

10.1 ac magnetic testing shall be used for all strip and sheet with a thickness of 0.0200 in. (0.508 mm) or less.

10.2 Testing shall consist of impedance permeability measurement and shall be conducted using Test Method A 772.

10.3 The ac magnetic property requirements after appropriate heat treatment are shown in Table 3.

TABLE 2 dc Magnetic Property Requirements

NOTE 1—The coercive field strength for Alloy Types 1 and 2 is determined from a maximum induction of 10 kG (1.0 T), while for Alloy Types 3 and 4 the coercive field strength is determined from a maximum induction of 5 kG (0.5 T).

Product Form and Size	Magnetic Property	Alloy Type 1 UNS K94490	Alloy Type 2 UNS K94840	Alloy Type 3 UNS N14076	Alloy Type 4 UNS N14080
Billet (all sizes) *Bar, Wire, Plate, Plate Coil* $d > 0.500$ in. (12.7 mm)	(Relative) Permeability at 40 G (14 mT), min	. . .	. . .	. . .	35 000
	(Relative) Permeability at 100 G (10 mT), min	4 500	6 000	. . .	42 000
	(Relative) Maximum Permeability, min	35 000	50 000	. . .	175 000
	Coercive Field Strength, Oe (A/m), max.	0.080 (6.4)	0.075 (6.0)	. . .	0.025 (2.0)
Bar, Wire, Plate, Plate Coil $d \leq 0.500$ in. (12.7 mm)	(Relative) Permeability at 40 G (4 mT), min	. . .	. . .	. . .	35 000
	(Relative) Permeability at 100 G (10 mT), min	5 000	7 500	. . .	42 000
	(Relative) Maximum Permeability, min	40 000	60 000	. . .	175 000
	Coercive Field Strength, Oe (A/m), max.	0.080 (6.4)	0.070 (5.6)	. . .	0.025 (2.0)
Sheet and Strip $0.0600 \leq d \leq 0.187$ in. ($1.52 \leq d \leq 4.75$ mm)	(Relative) Permeability at 40 G (4 mT), min	. . .	. . .	. . .	35 000
	(Relative) Permeability at 100 G (10 mT), min	6 000	8 000	. . .	42 000
	(Relative) Maximum Permeability, min	50 000	90 000	. . .	200 000
	Coercive Field Strength, Oe (A/m), max.	0.080 (6.4)	0.070 (5.6)	. . .	0.025 (2.01)
Sheet and Strip $0.0200 < d < 0.0700$ in. ($0.508 < d < 1.52$ mm)	(Relative) Permeability at 40 g (4 mT), min	. . .	. . .	50 000	50 000
	(Relative) Permeability at 100 G (10 mT), min	7 500	9 000	65 000	65 000
	(Relative) Maximum Permeability, min	55 000	100 000	230 000	230 000
	Coercive Field Strength, Oe (A/m), max.	0.070 (5.6)	0.060 (4.8)	0.015 (1.2)	0.015 (1.2)