Designation: ~~A801 – 14~~ A801 – 21

Standard Specification for Wrought Iron-Cobalt High Magnetic Saturation Alloys (UNS R30005 and K92650)[1]

This standard is issued under the fixed designation A801; 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 wrought iron-cobalt alloy types for use in magnetic components requiring high permeability at and above ~~15 kG (1.5 T)~~1.5 T (15 kG) or high ~~magnetic saturation.~~ saturation flux density. The specific alloy types covered are:

Alloy Type	UNS	Nominal Composition
1	R30005	49 % Co, 49 % Fe, 2 % V
2	K92650	27 % Co, 0.50 % Cr, balance Fe

1.1.1 This specification also covers material supplied by a producer in the form and physical condition suitable for fabrication into parts that will later be given final heat treatment to achieve the desired magnetic characteristics and, where required, mechanical properties. It covers material supplied in form of forging billets, hot-rolled products (that is, bar, plate, and strip), cold-finished bars, and cold-rolled strip.

1.2 This specification does not cover parts produced by casting or by powder metallurgical techniques.

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

1.3.1 There are selected values presented in two units, both of which are in acceptable SI units. These are differentiated by the word ", or," as in "g/cm^3, or, (kg/m^3)."

1.4 *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.*

1.5 *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.*

[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. Referenced Documents

2.1 *ASTM Standards:*[2]

A34/A34M Practice for Sampling and Procurement Testing of Magnetic Materials
A340 Terminology of Symbols and Definitions Relating to Magnetic Testing
A341/A341M Test Method for Direct Current Magnetic Properties of Soft Magnetic Materials Using D-C Permeameters and the Point by Point (Ballistic) Test Methods
A596/A596M Test Method for Direct-Current Magnetic Properties of Materials Using the Point by Point (Ballistic) Method and Ring Specimens
A773/A773M Test Method for Direct Current Magnetic Properties of Low Coercivity Magnetic Materials Using Hysteresigraphs
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

3. Terminology

3.1 The terms and symbols used in this specification are defined in Terminology A340.

4. Ordering Information

4.1 Purchase orders for material under this specification shall include the following information:

4.1.1 Reference to this specification and year of ~~issue/revision,~~issue/revision.

4.1.2 Alloy ~~type,~~type.

4.1.3 Form and conditions (see Section 6~~),~~).

4.1.4 Dimensions and tolerances, (tolerances other than those in Section 9 must be stated as mutually agreed upon between the producer and the ~~user),~~user).

4.1.5 Quantity (weight or number of ~~pieces),~~pieces).

4.1.6 Magnetic property requirements if other than shown in this specification (see Section 7~~),~~).

4.1.7 Certification of analysis or magnetic quality evaluation, or both, if ~~needed,~~needed.

4.1.8 Marking and ~~packaging, and~~packaging.

4.1.9 Exceptions to this specification or special requirements.

4.2 *End Use*—When possible, the user should specify whether the material will be machined, blanked into flat pieces, wound into a core, punched into laminations, ~~or photo-etched.~~photo-etched, or processed using other techniques. This will help the producer to provide the most suitable material for the user's fabricating practices.

5. Chemical Composition

5.1 The material shall conform to the requirements prescribed in Table 1. Since magnetic and possibly mechanical properties are of primary importance to the user, analysis variations are permitted subject to mutual agreement between the producer and user.

5.2 Determination of metallic constituents shall be by a method acceptable to both producer and user. Analysis of carbon, nitrogen, sulfur, and oxygen shall be done in accordance with Test Method E1019.

[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.

TABLE 1 Chemical Requirements (Weight Percent)

	Alloy 1 UNS R30005	Alloy 2 UNS K92650
Carbon, max	0.025	0.025
Manganese, max	0.15	0.35
Silicon, max	0.15	0.35
Phosphorus, max	0.015	0.015
Sulfur, max	0.010	0.015
Chromium, max	0.15	0.75
Nickel, max	0.25	0.75
Cobalt	47.50 to 49.50	26.50 to 28.50
Vanadium	1.75 to 2.10	0.35 max
Iron	remainder	remainder

6. Form and Condition

6.1 These materials are capable of being produced in forms and conditions described suitable for further manufacture into specific magnetic components. The desired form and condition should be discussed with the producer to ensure receiving the correct product. Available forms and conditions are:

6.1.1 *Forging Billet*—Hot-worked and surface prepared by grinding.

6.1.2 *Hot-Rolled Bar, Plate, and Strip*—Hot-rolled, hot-rolled and acid cleaned, and hot-rolled and mechanically cleaned.

6.1.3 *Cold-Finished Bars*—Centerless ground.

6.1.4 *Cold-Rolled Strip.*

7. Magnetic Property Requirements

7.1 *General*—Material supplied under terms of this specification shall be tested only by use of dc test methods. AC magnetic property measurements and requirements for thin strip (thickness less than ~~0.020 in. (0.5 mm))~~0.5 mm (0.020 in.)) are subject to mutual agreement between the producer and user.

7.2 *Test Specimen*—Whenever possible, test specimen size and shape shall conform to Practice A34/A34M. Shapes such as stacked ring laminations, solid rings, and tape wound cores are the preferred test specimens. If, however, it is impossible to prepare a preferred test specimen shape from the item, the specimen shape used shall be mutually agreed upon between the producer and the user.

7.3 *Density*—The assumed densities of these materials for magnetic test purposes are:

~~Alloy Type~~ Alloy Type	~~UNS~~ UNS	~~Density g/cm^3 (kg/m^3)~~ Density g/cm^3, or, (kg/m^3)
~~1~~	~~R30005~~	~~8.12 (8120)~~
1	R30005	8.12, or, (8120)
~~2~~	~~K92650~~	~~7.95 (7950)~~
2	K92650	7.95, or, (7950)

7.4 *Test Specimen Heat Treatment*—The heat treatment applied to the test specimen shall be in accordance with a procedure mutually agreed upon between the producer and the user or a procedure recommended by the producer to achieve the magnetic properties described in this specification (see Appendix X1).

7.5 *Test Methods*—Magnetic testing shall be conducted in accordance with Test Method A341/A341M, Test Method A596/A596M, or Test Method A773/A773M. Testing shall be conducted at the magnetic field strengths as shown in Table 2 for the alloy type.

7.6 *Requirements*—The material shall meet the requirements listed in Table 2.

TABLE 2 DC Magnetic Property Requirements

~~Alloy Type 1 (UNS R30005)~~

~~Product Form~~	~~Size~~	~~Minimum Magnetic Flux Density kG, (T) for Magnetic Field Strengths of 10 Oe (800 A/m)~~	~~20 Oe (1.6 kA/m)~~	~~50 Oe (4 kA/m)~~	~~100 Oe (8 kA/m)~~
~~Cold-rolled Strip~~	~~all~~	~~20.0 (2.00)~~	~~21.0 (2.10)~~	~~22.0 (2.20)~~	~~22.5 (2.25)~~
~~Bar~~	~~0.500 to 1 in. (12.7 to 25.4 mm)~~	~~16.0 (1.60)~~	~~18.0 (1.80)~~	~~20.0 (2.00)~~	~~21.5 (2.15)~~
~~Bar~~	~~over 1 in. (25.4 mm)~~	~~15.0 (1.50)~~	~~17.5 (1.75)~~	~~19.5 (1.95)~~	~~21.5 (2.15)~~
~~Forging Billet, Hot Rolled Plate, Hot Rolled Strip~~	~~all~~	~~15.0 (1.50)~~	~~17.5 (1.75)~~	~~19.5 (1.95)~~	~~21.5 (2.15)~~

~~Alloy Type 2 (UNS K92650)~~

~~Product Form~~	~~Size~~	~~Minimum Magnetic Flux Density kG, (T) for Magnetic Field Strengths of: 50 Oe (4 kA/m)~~	~~100 Oe (8 kA/m)~~	~~150 Oe (12 kA/m)~~	~~200 Oe (16 kA/m)~~
~~Cold-Rolled Strip~~	~~all~~	~~18.7 (1.87)~~	~~20.3 (2.03)~~	~~21.2 (2.12)~~	~~21.7 (2.17)~~
~~Bar~~	~~up to 0.250 in. (6.35 mm)~~	~~18.7 (1.87)~~	~~20.3 (2.03)~~	~~21.2 (2.12)~~	~~21.7 (2.17)~~
~~Bar~~	~~over 0.250 in. (6.35 mm)~~	~~11.0 (1.10)~~	~~17.5 (1.75)~~	~~19.5 (1.95)~~	~~21.0 (2.10)~~
~~Forging Billet, Hot Rolled Plate, Hot Rolled Strip~~	~~all~~	~~11.0 (1.10)~~	~~17.5 (1.75)~~	~~19.5 (1.95)~~	~~21.0 (2.10)~~

TABLE 2 DC Magnetic Property Requirements

Alloy Type 1 (UNS R30005)

Product form	Size	Minimum Magnetic Flux Density T (kG), for Magnetic Field Strengths of: 800 A/m (10 Oe)	1.6 kA/m (20 Oe)	4 kA/m (50 Oe)	8 kA/m (100 Oe)
Cold-rolled strip	all	2.00 (20.0)	2.10 (21.0)	2.20 (22.0)	2.25 (22.5)
Bar	12.7 to 25.4 mm (0.500 to 1 in.)	1.60 (16.0)	1.80 (18.0)	2.00 (20.0)	2.15 (21.5)
Bar	over 25.4 mm (1 in.)	1.50 (15.0)	1.75 (17.5)	1.95 (19.5)	2.15 (21.5)
Forging billet, hot rolled plate, hot rolled strip	all	1.50 (15.0)	1.75 (17.5)	1.95 (19.5)	2.15 (21.5)

Alloy Type 2 (UNS K92650)

Product form	Size	Minimum Magnetic Flux Density T (kG), for Magnetic Field Strengths of: 4 kA/m (50 Oe)	8 kA/m (100 Oe)	12 kA/m (150 Oe)	16 kA/m (200)
Cold-rolled strip	all	1.87 (18.7)	2.03 (20.3)	2.12 (21.2)	21.7 (21.7)
Bar	up to 6.35 mm (0.250 in.)	1.87 (18.7)	2.03 (20.3)	2.12 (21.2)	21.7 (21.7)
Bar	over 6.35 mm (0.250 in.)	1.10 (11.0)	1.75 (17.5)	1.95 (19.5)	2.10 (21.0)
Forging billet, hot rolled plate, hot rolled strip	all	1.10 (11.0)	1.75 (17.5)	1.95 (19.5)	2.10 (21.0)

8. Typical Physical and Mechanical Properties

8.1 For typical physical and mechanical properties, see Appendix X2.

9. Dimensions and Tolerances

9.1 *Forging Billet and Hot-Rolled Bar, Plate, and Strip*—As agreed upon between the producer and user.

9.2 *Cold-Finished Bars*—See Table 3.

9.3 *Cold-Rolled Strip*—See Tables 4 and 5.

10. Rejection and Rehearing

10.1 Material that fails to conform to the requirements of this specification may be rejected by the user. The rejection shall be reported to the producer promptly and in writing. The rejected material shall be ~~correctly identified, adequately protected, and set aside for eventual return to the producer or for another disposition.~~ set aside, adequately protected and correctly identified.

TABLE 3 Dimensional Tolerances for Ground Bars

~~Specified Diameter, in. (mm)~~	~~Variation in Diameter, ±in. (±mm)~~
~~Under 0.500 to 0.3125 (12.7 to 7.94)~~	~~0.0025 (0.064)~~
~~Under 1.000 to 0.500 (25.4 to 12.7)~~	~~0.0025 (0.064)~~
~~Under 1.500 to 1.000 (38.1 to 25.4)~~	~~0.0030 (0.076)~~
~~4.000 to 1.500 (101.6 to 38.1)~~	~~0.0050 (0.13)~~

TABLE 3 Dimensional Tolerances for Ground Bars

Specified Diameter, mm (in.)	Variation in Diameter, ± mm (± in.)
Under 12.7 to 7.94 (0.500 to 0.3125)	0.064 (0.0025)
Under 25.4 to 12.7 (1.000 to 0.500)	0.064 (0.0025)
Under 38.1 to 25.4 (1.500 to 1.000)	0.076 (0.0030)
101.6 to 38.1 (4.000 to 1.500)	0.13 (0.0050)

TABLE 4 Thickness Tolerances for Cold-Rolled Strip[A]

~~Specified Thickness, in. (mm)~~	~~Permissible Variations in Thickness, ±in. (±mm)~~	
	~~Width ≤6 in. (152 mm)~~	~~Width >6 in. (152 mm)~~
~~0.000 20 to 0.0040 (0.051 to 0.10)~~	~~0.0002 (0.0051)~~	~~0.0003 (0.0076)~~
~~0.0041 to 0.0060 (0.10 to 0.15)~~	~~0.0003 (0.0076)~~	~~0.0004 (0.010)~~
~~0.0061 to 0.0100 (0.16 to 0.254)~~	~~0.0005 (0.013)~~	~~0.000 75 (0.019)~~
~~0.0101 to 0.0140 (0.257 to 0.356)~~	~~0.0010 (0.025)~~	~~0.0015 (0.038)~~
~~0.0141 to 0.0250 (0.358 to 0.635)~~	~~0.0015 (0.038)~~	~~0.0020 (0.051)~~
~~0.0251 to 0.0600 (0.638 to 1.52)~~	~~0.0020 (0.051)~~	~~0.0030 (0.076)~~

TABLE 4 Thickness Tolerances for Cold-Rolled Strip[A]

Specified Thickness, mm (in.)	Permissible Variations in Thickness, ± mm (± in.)	
	Width ≤152 mm (6 in.)	Width >152 mm (6 in.)
0.051 to 0.10 (0.000 20 to 0.0040)	0.0051 (0.0002)	0.0076 (0.0003)
0.11 to 0.15 (0.0043 to 0.0060)	0.0076 (0.0003)	0.010 (0.0004)
0.16 to 0.254 (0.0061 to 0.0100)	0.013 (0.0005)	0.019 (0.00075)
0.257 to 0.356 (0.0101 to 0.0140)	0.025 (0.0010)	0.038 (0.0015)
0.358 to 0.635 (0.0141 to 0.0250)	0.038 (0.0015)	0.051 (0.0020)
0.638 to 1.52 (0.0251 to 0.0600)	0.051 (0.0020)	0.076 (0.0030)

[A] Measurements shall be made at least 0.375 in. (9.5 mm) from the edges of the cold rolled coil.

TABLE 5 Coil Width Tolerances for Cold-Rolled Strip

~~Specified Thickness, in. (mm)~~	~~Permissible Variations in Width, ±in. (±mm)~~	
	~~Width ≤6 in. (152 mm)~~	~~Width >6 in. (152 mm)~~
~~0.002 to 0.060 (0.05 to 1.52)~~	~~0.005 (0.13)~~	~~0.010 (0.25)~~

TABLE 5 Coil Width Tolerances for Cold-Rolled Strip

Specified Thickness, mm (in.)	Permissible Variations in Width ± mm (± in.)	
	Width ≤ 152 mm (6 in.)	Width > 152 mm (6 in.)
0.05 to 1.52 (0.002 to 0.060)	0.13 (0.005)	0.25 (0.010)

10.2 The producer may make claim for a rehearing. In this event, the user shall make samples that are representative of the rejected material available to the producer for evaluation.

11. Certification

11.1 When specified in the purchase order or contract, the user shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12. Packaging and Package Marking

12.1 Packaging shall be subject to agreement between the producer and user.

12.2 The material as furnished under this specification shall be identified by the name or symbol of the producer by melt number and size. Each heat supplied on a given order must be identified separately.

13. Keywords

13.1 core loss; iron-cobalt alloy; magnetic flux density; ~~magnetic saturation~~saturation flux density

APPENDIXES

(Nonmandatory Information)

X1. HEAT TREATMENT OF IRON-COBALT ALLOYS

X1.1 Most mechanical and magnetic properties of these alloys are dependent on the grain size after heat treatment. Producers generally evaluate magnetic property capability of a melt or an item by heat treating the magnetic test specimen representing the lot, using their recommended procedure.

X1.2 General heat-treatment procedure guidelines are as follows:

X1.2.1 Place material in a sealed (leak-free) retort or equivalent.

X1.2.2 Use a nonoxidizing, noncarburizing atmosphere such as dry hydrogen, argon, or equivalent, or a vacuum. Appropriate safety precautions must be taken when working with highly flammable atmospheres.

X1.2.3 Heat to the annealing temperature and hold for 4 ~~h.~~hours. Alloy 1 is typically heat treated at temperatures between 845 and ~~865°C.~~ 865°C (1553 and 1589°F). For some applications, annealing may be performed at temperatures as low as ~~715°C.~~ 715°C (1319°F). The annealing temperature of Alloy 1 should never exceed 875°C (1607°F) as the alloy is prone to exhibit poor magnetic properties if heated above this temperature. Exceptions to this high-temperature limit, if necessary, should be discussed with the producer. Alloy 2 is also typically heat treated between 845 and 865°C (1553 and 1589°F) for the best magnetic performance. Alloy 2 may also be heat treated at temperatures as high as 975°C (1787°F) without the same cautions concerning Alloy 1. For both alloys, the use of a relatively low heat treatment temperature or reduced heat treatment time provides higher strength but with a sacrifice in magnetic performance. The higher heat treatment temperatures, within the limits stated, generally provide the best magnetic performance but lower mechanical strength.

X1.2.4 Cool in the same atmosphere at a rate of 100 to ~~200°C/h to 500°C or lower and~~ 200°C (180 to 360°F) per hour until a temperature of 500°C (932°F) or lower is reached, then cool at any rate thereafter to a temperature of ~~at least~~ 200°C (392°F) or lower.

X1.3 There can be applications requiring lower heat-treating temperatures and shorter heat treatment times to achieve certain mechanical properties required by the end use. In these cases, the user must advise the producer of the mechanical and magnetic property requirements. These requirements are subject to mutual agreement between the producer and user.

X2. TYPICAL PHYSICAL, MAGNETIC, AND MECHANICAL PROPERTIES

X2.1 Typical physical, DC and AC magnetic properties, and mechanical properties are shown in ~~Tables X2.1-X2.4~~Table X2.1, Table X2.2, Table X2.3, and Table X2.4, respectively. Many of these properties depend on the particular product form and heat treatment used. The user should consult with the producer if such properties are of importance to the application. The data are provided for information only and are not requirements in this specification and need not be measured. All properties are for room temperature unless otherwise noted.

TABLE X2.1 Typical Physical Properties

		~~Alloy Type 1 UNS R30005~~	~~Alloy Type 2 UNS K92650~~
~~Density, g/cm^3 (kg/m^3)~~	~~8.12 (8120)~~	~~7.95 (7950)~~	
~~Electrical resistivity, μΩ - cm (μΩ - mm)~~	~~40 (400)~~	~~19 (190)~~	
Curie temperature, °C	940	925	
~~Saturation magnetostriction, 10^{-6}~~	~~60~~	~~36~~	
~~Saturation induction, kG (T)~~	~~23.8 (2.38)~~	~~23.6 (2.36)~~	
~~Modulus of elasticity, psi (GPa)~~	~~30 × 10^6 (207)~~	~~24 × 10^6 (166)~~	
~~Thermal conductivity, cal/cm · s · °C (W/m·K)~~	~~0.0712 (29.8)~~	~~0.131 (54.8)~~	
~~Thermal expansivity, 10^{-6}/°C~~			
	~~(20 to 100°C)~~	~~9.2~~	~~9.8~~
	~~(20 to 200°C)~~	~~9.5~~	~~10.1~~
	~~(20 to 300°C)~~	~~9.8~~	~~10.3~~
	~~(20 to 400°C)~~	~~10.1~~	~~10.6~~
	~~(20 to 500°C)~~	~~10.4~~	~~10.9~~
	~~(20 to 600°C)~~	~~10.5~~	~~11.2~~
	~~(20 to 700°C)~~	~~10.8~~	~~. . .~~
	~~(20 to 800°C)~~	~~11.3~~	~~. . .~~

TABLE X2.1 Typical Physical Properties

	Alloy Type 1 UNS R30005	Alloy Type 2 UNS K92650	
Density, g/cm^3, or, (kg/m^3)	8.12, or, (8120)	7.95, or, (7950)	
Electrical resistivity, μΩ - cm, or, (μΩ - mm)	40, or, (400)	19, or, (190)	
Curie temperature, °C (°F)	940 (1724)	925 (1697)	
Saturation magnetostriction, 10^{-6}	60	36	
Saturation flux density, T (kG)	2.38 (23.8)	2.36 (23.6)	
Modulus of elasticity, GPa (psi)	207 (30 × 10^6)	166 (24 × 10^6)	
Thermal conductivity, W/mK (cal/cm s ·°C)	29.8 (0.0712)	54.8 (0.131)	
Thermal expansivity, 10^{-6}/°C			
	(20 to 100°C)	9.2	9.8
	(20 to 200°C)	9.5	10.1
	(20 to 300°C)	9.8	10.3
	(20 to 400°C)	10.1	10.6
	(20 to 500°C)	10.4	10.9
	(20 to 600°C)	10.5	11.2
	(20 to 700°C)	10.8	...
	(20 to 800°C)	11.3	...