Designation: A 801 – 04

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

This standard is issued under the fixed designation A 801; 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 currently manufactured and supplied commercially for use in magnetic components requiring high permeability at and above 15 kG (1.5 T) or high magnetic saturation. 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, cold-finished bars, and 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) 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:* [2]

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

A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing

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

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

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

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

3. Terminology

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

4. Ordering Information

4.1 Purchase orders for material under this specification shall include such of the following information to adequately describe the desired product.

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

4.1.2 Alloy 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),

4.1.5 Quantity (weight or number of 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,

4.1.8 Marking and packaging, and

4.1.9 Exceptions to this specification or special requirements.

[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] 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.

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4.2 *End Use*—Whenever practicable, the user should specify whether the material will be machined, blanked into flat pieces, wound into a core, punched into laminations, or photo-etched.

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, 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 E 1019.

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 Product*—Hot-rolled, hot-rolled and acid cleaned, and hot-rolled and mechanically cleaned.

6.1.3 *Cold-Finished Bars*—Centerless ground.

6.1.4 *Strip*—Cold-rolled.

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 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 A 34/A 34M. 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:

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

Alloy Type	UNS	Density g/cm^3 (kg/m^3)
1	R30005	8.12 (8120)
2	K92650	7.95 (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 A 341/A 341M, Test Method A 596/A 596M, or Test Method A 773/A 773M. 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.

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 Products*—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 Where any material fails to meet the requirements of this specification, the material shall be handled in accordance with the procedure mutually agreed upon by the producer and the user.

TABLE 2 DC Magnetic Property Requirements

Alloy Type 1 (UNS R30005)					
		Minimum Magnetic Flux Density kG, (T) for Magnetic Field Strengths of			
Product Form	Size	10 Oe (800 A/m)	20 Oe (1.6 kA/m)	50 Oe (4 kA/m)	100 Oe (8 kA/m)
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-billet	over 1 in. (25.4 mm)	15.0 (1.50)	17.5 (1.75)	19.5 (1.95)	21.5 (2.15)
Alloy Type 2 (UNS K92650)					
		Minimum Magnetic Flux Density kG, (T) for Magnetic Field Strengths of:			
Product Form	Size	50 Oe (4 kA/m)	100 Oe (8 kA/m)	150 Oe (12 kA/m)	200 Oe (16 kA/m)
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-billet	over 0.250 in. (6.35 mm)	11.0 (1.10)	17.5 (1.75)	19.5 (1.95)	21.0 (2.10)

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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 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)

[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)

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

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. Alloy 1 is typically heat treated at temperatures between 845 and 865°C. For some applications, annealing may be performed at temperatures as low as 715°C. The annealing temperature of Alloy 1 should never exceed 875°C 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 for the best magnetic performance. Alloy 2 may also be heat treated at temperatures as high as 975°C 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 at any rate thereafter to a temperature of at least 200°C 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.

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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, 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 X2.2 Typical DC Magnetic Properties

	Alloy Type I UNS R30005	Alloy Type 1 UNS R30005	Alloy Type 2 UNS K92650	Alloy Type 2 UNS K92650
Product form	Strip	Round Bar	Strip	Round Bar
Product size, in. (mm)	0.014 (0.35)	0.531 (13.5)	0.014 (0.35)	0.500 (12.7)
Heat treatment temperature,° C	845	845	845	925
Magnetic Field Strength, Oe (A/m)	Flux Density, kG (T)			
2 (160)	13.5 (1.35)	2.5 (0.25)	5.0 (0.50)	. . .
5 (400)	19.5 (1.95)	. . .	. . .	. . .
10 (800)	21.0 (2.10)	17.0 (1.70)	13.5 (1.35)	11.0 (1.10)
20 (1600)	22.0 (2.20)	20.0 (2.00)	17.0 (1.70)	14.0 (1.40)
50 (4000)	22.3 (2.23)	22.0 (2.20)	19.2 (1.92)	18.5 (1.85)
75 (6000)	22.5 (2.25)	22.5 (2.25)	21.0 (2.10)	19.5 (1.95)
100 (8000)	23.0 (2.30)	23.0 (2.30)	21.5 (2.15)	20.5 (2.05)
Coercive field strength, Oe (A/m)[A]	0.90 (72)	2.0 (160)	1.7 (140)	3.0 (240)
Residual induction, kG (T)[A]	14.5 (1.45)	10.0 (1.00)	8.5 (0.85)	6.0 (0.60)

[A] Coercive field strength and residual induction measured from a maximum magnetic field strength of 100 Oe (8000 A/m).

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TABLE X2.3 Typical 400 Hz ac Core Losses for Strip

Alloy Type 1 (UNS R30005)				
Heat Treatment Temperature, °C	Strip Thickness, in. (mm)	Core Loss, W/lb (W/kg) at Specified Maximum Flux Density		
		10 kG (1.0 T)	15 kG (1.5 T)	20 kG (2.0 T)
845	0.014 (0.36)	10 (22)	19 (42)	34 (75)
845	0.010 (0.25)	8 (18)	15 (33)	25 (55)
845	0.006 (0.15)	7 (15)	12 (26)	20 (44)
845	0.004 (0.10)	6 (13)	9 (20)	13 (29)
845	0.002 (0.05)	7 (15)	10 (22)	16 (35)
750	0.014 (0.36)	12 (26)	24 (53)	44 (97)
750	0.010 (0.25)	9 (20)	18 (40)	30 (66)
750	0.006 (0.15)	8 (18)	16 (35)	27 (60)
Alloy Type 2 (UNS K92650)				
Heat Treatment Temperature, °C	Strip Thickness, in. (mm)	Core Loss, W/lb (W/kg) at Specified Maximum Flux Density		
		10 kG (1.0 T)	15 kG (1.5 T)	19 kG (1.9 T)
845	0.014 (0.36)	17 (37)	35 (77)	65 (140)
845	0.010 (0.25)	13 (29)	25 (55)	50 (110)
845	0.014 (0.36)	18 (40)	37 (82)	68 (150)
845	0.010 (0.25)	15 (33)	27 (60)	55 (120)

TABLE X2.4 Typical Mechanical Properties

Alloy Type 1 (UNS R30005)					
Condition	0.2 % Yield Stress		Ultimate Tensile Strength		% Elongation in 2 in. (50 mm)
	ksi	MPa	ksi	MPa	
Cold-rolled strip	185	1280	195	1340	1
Strip annealed at 845°C	35	240	70	480	4
Strip annealed at 750°C	52	360	85	590	5
Strip annealed at 715°C	80	550	104	717	5
Bar annealed at 845°C	. . .	. . .	70	480	. . .
Alloy Type 2 (UNS K92650)					
Condition	0.2 % Yield Stress		Ultimate Tensile Strength		% Elongation in 2 in. (50 mm)
	ksi	MPa	ksi	MPa	
Cold-rolled strip	165	1140	167	1150	7
Strip annealed at 845°C	41	280	80	550	12
Strip annealed at 750°C	50	340	90	620	15

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