Designation: A1102 – 19

Standard Specification for Sintered Samarium Cobalt (SmCo) Permanent Magnets[1]

This standard is issued under the fixed designation A1102; 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 technically important, commercially available, magnetically hard sintered (fully dense) permanent magnets commonly known as samarium cobalt. These materials are available in two general composition families abbreviated "SmCo 1:5" and "SmCo 2:17." The numbers indicate the approximate atomic ratio of samarium to the sum of other constituents. (Refer to Appendix X3 for additional composition information.)

1.2 Samarium cobalt magnets have approximate magnetic properties of residual magnetic induction, B_r, from 0.78 T (7800 G) to 1.18 T (11 800 G) and intrinsic coercivity, H_{cJ}, typically greater than 800 kA/m (10 000 Oe). Special grades and isotropic (un-aligned) magnets can have properties outside these ranges (see Appendix X4). Specific magnetic hysteresis behavior (demagnetization curve) can be characterized using Test Method A977/A977M.

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

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, health, and 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A340 Terminology of Symbols and Definitions Relating to Magnetic Testing

A977/A977M Test Method for Magnetic Properties of High-Coercivity Permanent Magnet Materials Using Hysteresigraphs

2.2 *Other Standards:*

MMPA Standard No. 0100-00 Standard Specifications for Permanent Magnet Materials[3]

IEC 60404-8-1 Magnetic Materials Part 8: Specifications for Individual Materials Section 1 – Standard Specifications for Magnetically Hard Materials[4]

3. Terminology

3.1 The terms and symbols used in this specification, unless otherwise noted, are defined in Terminology A340.

3.2 Terms that are not defined in Terminology A340 but are in common usage and used herein are as follows.

3.2.1 Recoil permeability, $\mu_{(rec)}$, is the permeability corresponding to the slope of the recoil line. For reference see incremental, relative, and reversible permeabilities as defined in Terminology A340. In practical use, this is the slope of the normal hysteresis loop in the second quadrant and in proximity to the B-axis. The value of recoil permeability is dimensionless. Note that in producers' product literature recoil permeability is sometimes represented by the symbol μ_r, which is defined by Terminology A340 as relative permeability.

3.2.2 Magnetic characteristics change with temperature. Two key metrics of permanent magnet performance are residual induction, B_r, and intrinsic coercive field strength, H_{cJ}.

[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.

[3] Available from the Permanent Magnet Division of the SMMA (www.smma.org). It was previously available from The International Magnetics Association (IMA). The IMA had been the successor to the MMPA and both organizations (MMPA and IMA) no longer exist.

[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

The change in these characteristics over a defined and limited temperature range can be reversible, that is, nondestructive. This change is represented by values called reversible temperature coefficients. The symbol for reversible temperature coefficient of induction is $\alpha(B_r)$ and of (intrinsic) coercivity is $\alpha(H_{cJ})$. They are expressed in percent change per degree Celsius, %/°C, or the numerically equivalent percent per Kelvin, %/K. The change in magnetic characteristics is nonlinear, so it is necessary to specify the temperature range over which the coefficient applies.

3.2.3 The maximum recommended working temperature of a permanent magnet, T_w, is a semi-arbitrary value sometimes assigned by magnet manufacturers to their products. T_w is not normative. See Appendix X6 for a more complete discussion.

4. Classification

4.1 The classification of samarium cobalt permanent magnets is given in Table 1 and in Table X1.1 with cross-reference to MMPA Standard No. 0100-00 and IEC 60404-8-1.

5. Ordering Information

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

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

5.1.2 Reference to an applicable part drawing.

5.1.3 Magnetic property requirements, if they are more stringent than the minimum values listed in the tables.

5.1.4 Quantity required.

5.1.5 The required magnetization state of the provided material (unmagnetized, fully magnetized, magnetized and thermally stabilized, magnetized and then partially demagnetized). This information should appear on the part drawing whenever possible.

5.1.6 Certification of magnetic property evaluation.

5.1.7 Marking and packaging requirements.

TABLE 1 Samarium Cobalt Permanent Magnets: Minimum Magnetic Property Requirements[A]

ASTM Designation[B]	Maximum Energy Product $(BH)_{max}$		Residual Induction B_r		Coercive Field Strength H_{cB}		Intrinsic Coercive Field Strength H_{cJ}	
	kJ/m³	(MGOe)	mT	(G)	kA/m	(Oe)	kA/m	(Oe)
ANISOTROPIC SmCo 1:5								
S1-SA-115/1436	115	(14.4)	789	(7885)	567	(7125)	1436	(18050)
S1-SA-120/1600	120	(15.1)	800	(8000)	620	(7791)	1600	(20106)
S1-SA-129/2268	129	(16.2)	827	(8265)	643	(8075)	2268	(28500)
S1-SA-140/1200	140	(17.6)	860	(8600)	660	(8294)	1200	(15080)
S1-SA-143/2268	143	(18.0)	855	(8550)	665	(8360)	2268	(28500)
S1-SA-150/700	150	(18.8)	900	(9000)	600	(7540)	700	(8796)
S1-SA-160/1200	160	(20.1)	920	(9200)	660	(8294)	1200	(15080)
S1-SA-170/700	170	(21.4)	930	(9300)	600	(7540)	700	(8796)
S1-SA-179/1134	179	(22.5)	998	(9975)	722	(9073)	1134	(14250)
ANISOTROPIC SmCo 2:17								
S2-SA-140/1000	140	(17.6)	900	(9000)	620	(7791)	1000	(12566)
S2-SA-160/700	160	(20.1)	940	(9400)	600	(7540)	700	(8796)
S2-SA-172/529	172	(21.6)	950	(9500)	454	(5700)	529	(6650)
S2-SA-172/1966	172	(21.6)	950	(9500)	703	(8835)	1966	(24700)
S2-SA-180/1000	180	(22.6)	1000	(10000)	680	(8545)	1000	(12566)
S2-SA-180/1500	180	(22.6)	1000	(10000)	660	(8294)	1500	(18850)
S2-SA-186/756	186	(23.4)	998	(9975)	680	(8550)	756	(9500)
S2-SA-186/1966	186	(23.4)	1017	(10165)	737	(9263)	1966	(24700)
S2-SA-200/700	200	(25.1)	1050	(10500)	600	(7540)	700	(8796)
S2-SA-200/1500	200	(25.1)	1050	(10500)	700	(8796)	1500	(18850)
S2-SA-201/529	201	(25.2)	1036	(10355)	491	(6175)	529	(6650)
S2-SA-201/1966	201	(25.2)	1045	(10450)	779	(9785)	1966	(24700)
S2-SA-215/756	215	(27.0)	1045	(10450)	718	(9025)	756	(9500)
S2-SA-215/1512	215	(27.0)	1045	(10450)	779	(9785)	1512	(19000)
S2-SA-215/1814	215	(27.0)	1045	(10450)	779	(9785)	1814	(22800)
S2-SA-215/2268	215	(27.0)	1045	(10450)	779	(9785)	2268	(28500)
S2-SA-220/756	220	(27.6)	1088	(10878)	718	(9025)	756	(9500)
S2-SA-220/1500	220	(27.6)	1100	(11000)	600	(7540)	1500	(18850)
S2-SA-220/1890	220	(27.6)	1088	(10878)	801	(10070)	1890	(23750)
S2-SA-230/756	230	(28.9)	1107	(11068)	718	(9025)	756	(9500)
S2-SA-230/1134	230	(28.9)	1107	(11068)	824	(10355)	1134	(14250)
S2-SA-230/1512	230	(28.9)	1107	(11068)	824	(10355)	1512	(19000)
S2-SA-230/1890	230	(28.9)	1107	(11068)	824	(10355)	1890	(23750)
S2-SA-236/756	236	(29.7)	1112	(11115)	718	(9025)	756	(9500)
S2-SA-236/1134	236	(29.7)	1112	(11115)	832	(10450)	1134	(14250)
S2-SA-236/1512	236	(29.7)	1112	(11115)	832	(10450)	1512	(19000)

[A] Magnetic properties at 20 °C (68 °F).

[B] The ASTM designation conforms to the requirements of this specification and is of the form *MM-TT-XX/YY* where:

MM = material (S1 = samarium cobalt 1:5; S2 = samarium cobalt 2:17),
TT = type of processing and orientation (S = sintered; I = isotropic (non-oriented), A = anisotropic (oriented)),
XX = energy product in kJ/m³ rounded to the nearest integer, and
YY = intrinsic coercivity in kA/m rounded to the nearest integer.

5.1.8 Exceptions to this specification or special requirements such as plating, coating, or functional testing as mutually agreed upon by the producer and user.

6. Chemical Composition

6.1 Samarium cobalt magnets should be specified primarily by magnetic performance. Chemical composition can have an influence on both magnetic and physical characteristics but should only be specified when other options are insufficient to meet user requirements. Agreement on composition must be mutually arrived at by producer and user.

6.2 The general chemical constituents of samarium cobalt 1:5 magnets are samarium and cobalt. Samarium cobalt 2:17 magnets contain samarium, cobalt, iron, copper, and zirconium. Approximate chemical compositions are listed in Table X3.1 and are typical but not mandatory.

6.3 In some grades of samarium cobalt 1:5, praseodymium is used to substitute for a portion of the samarium to increase maximum energy product (see Table X3.1 and Appendix X4). In either the 1:5 or 2:17 grades, substitution of a portion of samarium by gadolinium (or a combination of gadolinium and dysprosium) will result in "temperature-stable" grades, those which exhibit less change in flux output as a function of temperature. These are generally made to customer specification and are not considered standard grades.

7. Physical and Mechanical Properties

7.1 Typical thermal and physical properties are listed in Table X2.1 in Appendix X2.

7.2 Physical density values are given for information purposes only and are not mandatory.

7.3 Samarium cobalt magnets are used for their magnetic characteristics. The end-use application should not rely on them for structural purposes due to low tensile and flexural strength. These materials are brittle, and can chip or break easily. Magnetic properties may also be affected by physical stress.

7.4 Strength testing of brittle materials such as samarium cobalt is difficult, expensive, and time-consuming and there may be considerable scatter in the measured values. Producers typically make these measurements at the onset of production and they are seldom repeated.

8. Magnetic Property Requirements

8.1 Magnetic properties are listed in Table 1.

8.2 The values of essential magnetic properties listed in the table are specified minimum values at 20 ± 2 °C (68 ± 4 °F), determined after magnetizing to saturation in closed magnetic circuit.

8.3 The specified values of magnetic properties are valid only for magnet test specimens with a uniform cross-section along the axis of magnetization. Properties for anisotropic (magnetically oriented) magnets are measured along the axis of preferred orientation.

8.4 Because of the nature of permanent magnet production, magnetic testing of each lot is recommended, especially for applications where the magnet performance is closely specified. Such magnetic property evaluations shall be conducted in the manner described below. Where the magnet shape is not suitable for magnetic testing, a specimen shall be cut from the magnet using appropriate slicing and grinding techniques, paying attention to any magnetic orientation within the magnet.

8.4.1 The magnetic properties shall be determined in accordance with Test Method A977/A977M, or by using a suitable, mutually agreed upon magnetometric method.

8.4.2 When magnets are being purchased in the fully magnetized condition, the testing shall determine the magnetic properties from the as-received magnetization state, followed by magnetization to saturation and testing of the magnetic properties from the fully magnetized condition.

8.4.3 When magnets are being purchased in the unmagnetized condition or in an unknown state of magnetization, the test laboratory shall magnetize the test specimen(s) to saturation in the same orientation as the received specimen's indicated direction of magnetization and measure the magnetic properties from this fully magnetized condition.

8.4.4 When magnets are being purchased in a calibrated, stabilized, or "knocked-down" condition, magnets should be handled with care to prevent exposure to externally applied fields. Refer to Appendix X6 for an explanation of these terms. During testing using Test Method A977/A977M, to avoid changing the magnetization state of the material prior to test, the measurement should proceed in the second quadrant only, without attempting to saturate the magnet specimen.

8.4.5 Other test methods may be utilized as agreed to between producer and user. Such tests may include the open circuit magnetic field strength Helmholtz test, field strength measurements in a defined magnetic circuit, or magnetic field strength measurements adjacent to the magnet surface.

9. Workmanship, Finish, and Appearance

9.1 Dimensions and tolerances shall be as specified on the magnet drawing and must be agreed upon between producer and user.

9.2 Though porosity and voids are uncommon in samarium cobalt magnets, their appearance shall not in themselves constitute reason for rejection unless agreed upon between producer and user. Allowable amounts of porosity and voids shall be documented in writing and included as part of the ordering or contracting process.

9.3 Magnets shall be free of adhered magnetic particles and surface residue which may interfere with assembly or proper device function.

9.4 Chips shall be acceptable if no more than 10 % of any surface identified as a magnetic pole surface is removed.

9.5 Cracks visible to the naked eye shall not be permitted unless otherwise agreed to by producer and user.

10. Sampling

10.1 A lot shall consist of parts of the same form and dimensions, produced from a single mixed powder batch or sintering run, and from an unchanged process, without discontinuity in production, and submitted for inspection at one time.

10.2 The producer and user shall agree upon a representative number of specimens for testing. Typically, a suitable number of parts, as mutually agreed upon between producer and user, shall be randomly selected from each lot. It is advisable to test a minimum of two parts from each lot, and more if there is reason to suspect that the magnetic properties are not uniform throughout the lot.

11. Rejection and Rehearing

11.1 Parts that fail to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer promptly and in writing. In case of dissatisfaction with the results of the test, the producer may make a claim for a rehearing.

11.2 The disposition of rejected parts shall be subject to agreement between the producer and user.

12. Certification

12.1 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 that the requirements have been met.

12.2 When specified in the purchase order or contract, a report of the test results shall, at a minimum, include:

12.2.1 Grade of material.

12.2.2 Lot or batch number.

12.2.3 Magnetic test results.

12.2.4 Results of any other tests stipulated in the purchase order or contract.

13. Packaging and Package Marking

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

13.2 Parts furnished under this specification shall be in a container identified by the name or symbol of the parts producer.

13.3 Magnetized parts shall be properly labeled as such for safe handling and shipping purposes.

13.3.1 Magnetized parts to be shipped via aircraft must be packaged in an appropriate manner to meet applicable requirements for air shipment. These requirements may vary depending upon local, national, and international laws. It is the responsibility of the producer to ensure packaging meets all relevant regulations. This may require rearranging the parts within the shipping container, adding sheets of steel or other magnetically soft shielding material, or both, or other specialized packaging procedures as determined by regulation, carrier policy, or by agreement between producer and user, to reduce the magnetic field external to the shipping container below the required levels.

14. Keywords

14.1 coercive field strength; magnetic field strength; magnetic flux density; magnetic properties; maximum energy product; permanent magnet; residual induction; samarium cobalt magnet; sintered rare earth magnet

APPENDIXES

(Nonmandatory Information)

X1. CLASSIFICATION

X1.1 See Table X1.1.