Designation: A1101 – 23

Standard Specification for Sintered and Fully Dense Neodymium Iron Boron (NdFeB) Permanent Magnets[1]

This standard is issued under the fixed designation A1101; 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 and fully dense neodymium iron boron ($Nd_2Fe_{14}B$, NdFeB, or "Neo") permanent magnets. These materials are available in a wide range of compositions with a commensurately large range of magnetic properties. The numbers in the $Nd_2Fe_{14}B$ name indicate the approximate atomic ratio of the key elements.

1.2 Anisotropic (aligned) sintered and fully dense neodymium iron boron magnets have approximate magnetic properties of residual magnetic induction, B_r, from 1.08 T (10 800 G) up to 1.5 T (15 000 G) and intrinsic coercive field strength, H_{cJ}, of 875 kA⁄m (11 000 Oe) to above 2785 kA⁄m (35 000 Oe). Fully dense but not sintered magnets include hot-deformed magnets using a plastic deformation technique, such as upsetting or extrusion, at elevated temperatures for the crystallographic alignment, as opposed to magnetic field alignment in sintered magnets. Special grades and isotropic (unaligned) 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.

[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] This standard is no longer actively maintained but it is still available from the Permanent Magnet Division of A3 (Association for Advancing Automation), http://www.automate.org.

[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.

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}. 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, and represent the average rate of change of the characteristic within the specified temperature range. 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 sintered neodymium iron boron permanent magnets is given in Table 1. The classification of hot-deformed neodymium iron boron permanent magnets is given in Table 2. Cross-reference to MMPA standard No. 0100-00 and IEC 60404-8-1 is provided in Appendix X1.

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.

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 Neodymium iron boron 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 composition of neodymium iron boron includes the elements neodymium, iron, and boron. Approximate chemical compositions are listed in Table X3.1 and are typical but not mandatory.

6.3 There are a number of additional elements included in the alloy to adjust magnetic, chemical, or mechanical properties. See Appendix X3 for additional information.

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 Neodymium iron boron 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 neodymium iron boron is difficult, expensive, time-consuming, and there may be considerable scatter in the measured values. Producers typically make a complete set of measurements at the onset of production and they are seldom repeated.

8. Magnetic Property Requirements

8.1 Magnetic properties of sintered neodymium iron boron permanent magnets are given in Table 1. Magnetic properties of hot-deformed neodymium iron boron permanent magnets are given in Table 2.

8.2 The values of magnetic properties listed in the table are specified minimum values at 20 °C ± 2 °C (68 °F ± 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. In the case of radially oriented magnets where the orientation axes vary along the curvature, care should be taken to minimize the error arising from the misalignment between the orientation and measurement field axis, for example, to use smaller circumferential length of the test specimen.

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.

TABLE 1 Sintered Neodymium Iron Boron Permanent Magnets: Classification and Minimum Magnetic Property[A] Requirements

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 $Nd_2Fe_{14}B$		
ND-SA-333/875	333 (41.8)	1 325 (13 250)	832 (10 450)	875 (11 000)
ND-SA-355/875	355 (44.6)	1 369 (13 690)	832 (10 450)	875 (11 000)
ND-SA-370/875	370 (46.5)	1 397 (13 970)	832 (10 450)	875 (11 000)
ND-SA-385/875	385 (48.4)	1 426 (14 260)	832 (10 450)	875 (11 000)
ND-SA-407/875	407 (51.1)	1 465 (14 650)	832 (10 450)	875 (11 000)
ND-SA-222/955	222 (27.9)	1 082 (10 820)	820 (10 300)	955 (12 000)
ND-SA-244/955	244 (30.7)	1 136 (11 360)	861 (10 820)	955 (12 000)
ND-SA-259/955	259 (32.5)	1 168 (11 680)	907 (11 400)	955 (12 000)
ND-SA-281/955	281 (35.3)	1 218 (12 180)	907 (11 400)	955 (12 000)
ND-SA-296/955	296 (37.2)	1 250 (12 500)	907 (11 400)	955 (12 000)
ND-SA-311/955	311 (39.1)	1 281 (12 810)	907 (11 400)	955 (12 000)
ND-SA-333/955	333 (41.8)	1 325 (13 250)	907 (11 400)	955 (12 000)
ND-SA-355/955	355 (44.6)	1 369 (13 690)	907 (11 400)	955 (12 000)
ND-SA-370/955	370 (46.5)	1 397 (13 970)	907 (11 400)	955 (12 000)
ND-SA-385/955	385 (48.4)	1 426 (14 260)	907 (11 400)	955 (12 000)
ND-SA-222/1114	222 (27.9)	1 082 (10 820)	820 (10 300)	1 114 (14 000)
ND-SA-244/1114	244 (30.7)	1 136 (11 360)	861 (10 820)	1 114 (14 000)
ND-SA-259/1114	259 (32.5)	1 168 (11 680)	885 (11 120)	1 114 (14 000)
ND-SA-281/1114	281 (35.3)	1 218 (12 180)	923 (11 600)	1 114 (14 000)
ND-SA-296/1114	296 (37.2)	1 250 (12 500)	947 (11 900)	1 114 (14 000)
ND-SA-311/1114	311 (39.1)	1 281 (12 810)	971 (12 200)	1 114 (14 000)
ND-SA-333/1114	333 (41.8)	1 325 (13 250)	1 004 (12 620)	1 114 (14 000)
ND-SA-355/1114	355 (44.6)	1 369 (13 690)	1 058 (13 300)	1 114 (14 000)
ND-SA-370/1114	370 (46.5)	1 397 (13 970)	1 058 (13 300)	1 114 (14 000)
ND-SA-385/1114	385 (48.4)	1 426 (14 260)	1 058 (13 300)	1 114 (14 000)
ND-SA-207/1353	207 (26.0)	1 045 (10 450)	792 (9 950)	1 353 (17 000)
ND-SA-222/1353	222 (27.9)	1 082 (10 820)	820 (10 300)	1 353 (17 000)
ND-SA-244/1353	244 (30.7)	1 136 (11 360)	861 (10 820)	1 353 (17 000)
ND-SA-259/1353	259 (32.5)	1 168 (11 680)	885 (11 120)	1 353 (17 000)
ND-SA-281/1353	281 (35.3)	1 218 (12 180)	923 (11 600)	1 353 (17 000)
ND-SA-296/1353	296 (37.2)	1 250 (12 500)	947 (11 900)	1 353 (17 000)
ND-SA-311/1353	311 (39.1)	1 281 (12 810)	971 (12 200)	1 353 (17 000)
ND-SA-333/1353	333 (41.8)	1 325 (13 250)	1 004 (12 620)	1 353 (17 000)
ND-SA-355/1353	355 (44.6)	1 369 (13 690)	1 038 (13 040)	1 353 (17 000)
ND-SA-370/1353	370 (46.5)	1 397 (13 970)	1 058 (13 300)	1 353 (17 000)
ND-SA-207/1592	207 (26.0)	1 045 (10 450)	792 (9 950)	1 592 (20 000)
ND-SA-222/1592	222 (27.9)	1 082 (10 820)	820 (10 300)	1 592 (20 000)
ND-SA-244/1592	244 (30.7)	1 136 (11 360)	861 (10 820)	1 592 (20 000)
ND-SA-259/1592	259 (32.5)	1 168 (11 680)	885 (11 120)	1 592 (20 000)
ND-SA-281/1592	281 (35.3)	1 218 (12 180)	923 (11 600)	1 592 (20 000)
ND-SA-296/1592	296 (37.2)	1 250 (12 500)	947 (11 900)	1 592 (20 000)
ND-SA-311/1592	311 (39.1)	1 281 (12 810)	971 (12 200)	1 592 (20 000)
ND-SA-333/1592	333 (41.8)	1 325 (13 250)	1 004 (12 620)	1 592 (20 000)
ND-SA-355/1592	355 (44.6)	1 369 (13 690)	1 038 (13 040)	1 592 (20 000)
ND-SA-207/1989	207 (26.0)	1 045 (10 450)	792 (9 950)	1 989 (25 000)
ND-SA-222/1989	222 (27.9)	1 082 (10 820)	820 (10 300)	1 989 (25 000)
ND-SA-244/1989	244 (30.7)	1 136 (11 360)	861 (10 820)	1 989 (25 000)
ND-SA-259/1989	259 (32.5)	1 168 (11 680)	885 (11 120)	1 989 (25 000)
ND-SA-281/1989	281 (35.3)	1 218 (12 180)	923 (11 600)	1 989 (25 000)
ND-SA-296/1989	296 (37.2)	1 250 (12 500)	947 (11 900)	1 989 (25 000)
ND-SA-311/1989	311 (39.1)	1 281 (12 810)	971 (12 200)	1 989 (25 000)
ND-SA-333/1989	333 (41.8)	1 325 (13 250)	1 004 (12 620)	1 989 (25 000)
ND-SA-207/2387	207 (26.0)	1 045 (10 450)	792 (9 950)	2 387 (30 000)
ND-SA-222/2387	222 (27.9)	1 082 (10 820)	820 (10 300)	2 387 (30 000)
ND-SA-244/2387	244 (30.7)	1 136 (11 360)	861 (10 820)	2 387 (30 000)
ND-SA-259/2387	259 (32.5)	1 168 (11 680)	885 (11 120)	2 387 (30 000)
ND-SA-281/2387	281 (35.3)	1 218 (12 180)	923 (11 600)	2 387 (30 000)
ND-SA-207/2785	207 (26.0)	1 045 (10 450)	792 (9 950)	2 785 (35 000)
ND-SA-222/2785	222 (27.9)	1 082 (10 820)	820 (10 300)	2 785 (35 000)
ND-SA-244/2785	244 (30.7)	1 136 (11 360)	861 (10 820)	2 785 (35 000)

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

[B] The ASTM designation conforms to the requirements of this specification. ASTM Designations are of the form *MM-TT-XX/YY*, where:

MM = material (ND = neodymium iron boron),
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.

TABLE 2 Hot-deformed Neodymium Iron Boron Permanent Magnets: Classification and Minimum Magnetic Property[A] Requirements

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 $Nd_2Fe_{14}B$								
ND-DR-240/1110	240	(30.2)	1 140	(11 400)	830	(10 430)	1 110	(13 949)
ND-DR-230/1590	230	(28.9)	1 080	(10 800)	810	(10 179)	1 590	(19 981)
ND-DR-270/1110	270	(33.9)	1 220	(12 200)	870	(10 933)	1 110	(13 949)
ND-DR-270/1430	270	(33.9)	1 220	(12 200)	880	(11 058)	1 430	(17 970)
ND-DR-300/1110	300	(37.7)	1 280	(12 800)	920	(11 561)	1 110	(13 949)
ND-DR-320/900	320	(40.2)	1 300	(13 000)	840	(10 556)	900	(11 310)
ND-DR-290/1430	290	(36.4)	1 270	(12 700)	920	(11 561)	1 430	(17 970)
ND-DR-310/1350	310	(39.0)	1 290	(12 900)	970	(12 189)	1 350	(16 965)
ND-DR-250/1800	250	(31.4)	1 170	(11 700)	900	(11 310)	1 800	(22 619)
ND-DA-330/1590	330	(41.5)	1 320	(13 200)	1 000	(12 566)	1 590	(19 981)
ND-DA-360/1570	360	(45.2)	1 370	(13 700)	1 050	(13 195)	1 570	(19 729)

[A] Magnetic properties at 20 °C (68 °F).
[B] The ASTM designation conforms to the requirements of this specification. ASTM Designations are of the form *MM-TT-XX/YY*, where:

MM = material (ND = neodymium iron boron),
TT = type of processing and orientation (S = sintered; D = hot-deformed; I = isotropic (non-oriented), A = axial (axially oriented); R = radial (radially oriented),
XX = energy product in kJ/m³ rounded to the nearest integer, and
YY = intrinsic coercivity in kA/m rounded to the nearest integer.

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 direction as the received specimen's indicated direction of orientation 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, the measurement should proceed in the second quadrant only, without attempting to saturate the magnet specimen, to avoid changing the magnetization state of the material prior to test.

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

9.2 Though porosity and voids are uncommon in sintered or hot-deformed neodymium iron boron 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 or hot-deformation 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; hot-deformed rare earth magnet; magnetic field strength; magnetic flux density; magnetic properties; maximum energy product; neodymium iron boron magnet; neo magnet; permanent magnet; residual induction; sintered rare earth magnet

APPENDIXES

(Nonmandatory Information)

X1. CLASSIFICATION

X1.1 See Table X1.1.

TABLE X1.1 Neodymium Iron Boron Permanent Magnets: Classification and Grade Cross Reference

NOTE 1—"..." indicates that there is no known published data.

ASTM	MMPA	IEC	
ASTM Designation[A]	MMPA Brief Designation	IEC Brief Designation	IEC Code Number
(none)	...	REFeB 170/190	R7-1-1
ND-SA-207/1592	...	REFeB 210/130	R7-1-2
ND-SA-244/1114	...	REFeB 250/120	R7-1-3
ND-SA-281/955	...	REFeB 290/80	R7-1-4
ND-SA-207/1592	...	REFeB 200/190	R7-1-5
ND-SA-244/1592	...	REFeB 240/180	R7-1-6
ND-SA-281/1114	...	REFeB 280/120	R7-1-7
ND-SA-311/955	...	REFeB 320/88	R7-1-8
ND-SA-207/2387	...	REFeB 210/240	R7-1-9
ND-SA-244/1592	...	REFeB 240/200	R7-1-10
ND-SA-311/1353	...	REFeB 310/130	R7-1-11
ND-SA-259/2387	...	REFeB 250/240	R7-1-12
ND-SA-259/1989	...	REFeB 260/200	R7-1-13
ND-SA-355/1592	...	REFeB 340/130	R7-1-14
ND-SA-370/875	...	REFeB 360/90	R7-1-15
ND-SA-370/1114	...	REFeB 380/100	R7-1-16
(none)	24/41	...	...
ND-SA-207/2387	26/32	...	...
ND-SA-207/1592	28/23	...	...
ND-SA-207/2387	28/32	...	...
ND-SA-222/1592	30/19	...	...
ND-SA-222/1989	30/27	...	...
ND-SA-244/1353	32/16	...	...
ND-SA-244/2387	32/31	...	...
ND-SA-259/1592	34/22	...	...
ND-SA-281/1592	36/19	...	...
ND-SA-281/1989	36/26	...	...
ND-SA-281/1353	38/15	...	...
ND-SA-281/1989	38/23	...	...
ND-SA-296/1353	40/15	...	...
ND-SA-296/1989	40/23	...	...
ND-SA-311/1353	42/15	...	...
ND-SA-333/1353	44/15	...	...
ND-SA-355/1592	48/11	...	...
ND-SA-370/955	50/11	...	...

[A] The ASTM designation conforms to the requirements of this specification. The ASTM cross-referenced grades are the closest approximation of the MMPA and IEC grades where they exist. MMPA and IEC designations are included for reference only. ASTM Designations are of the form *MM-TT-XX/YY* where:

MM = material (ND = neodymium iron boron),
TT = type of processing and orientation (S = sintered; I = isotropic (non-oriented), A = anisotropic (oriented)),
XX = energy product in kJ/m^3 rounded to the nearest integer, and
YY = intrinsic coercivity in kA/m rounded to the nearest integer.

X2. TYPICAL THERMAL, ELECTRICAL, AND MECHANICAL PROPERTIES

X2.1 See Table X2.1.