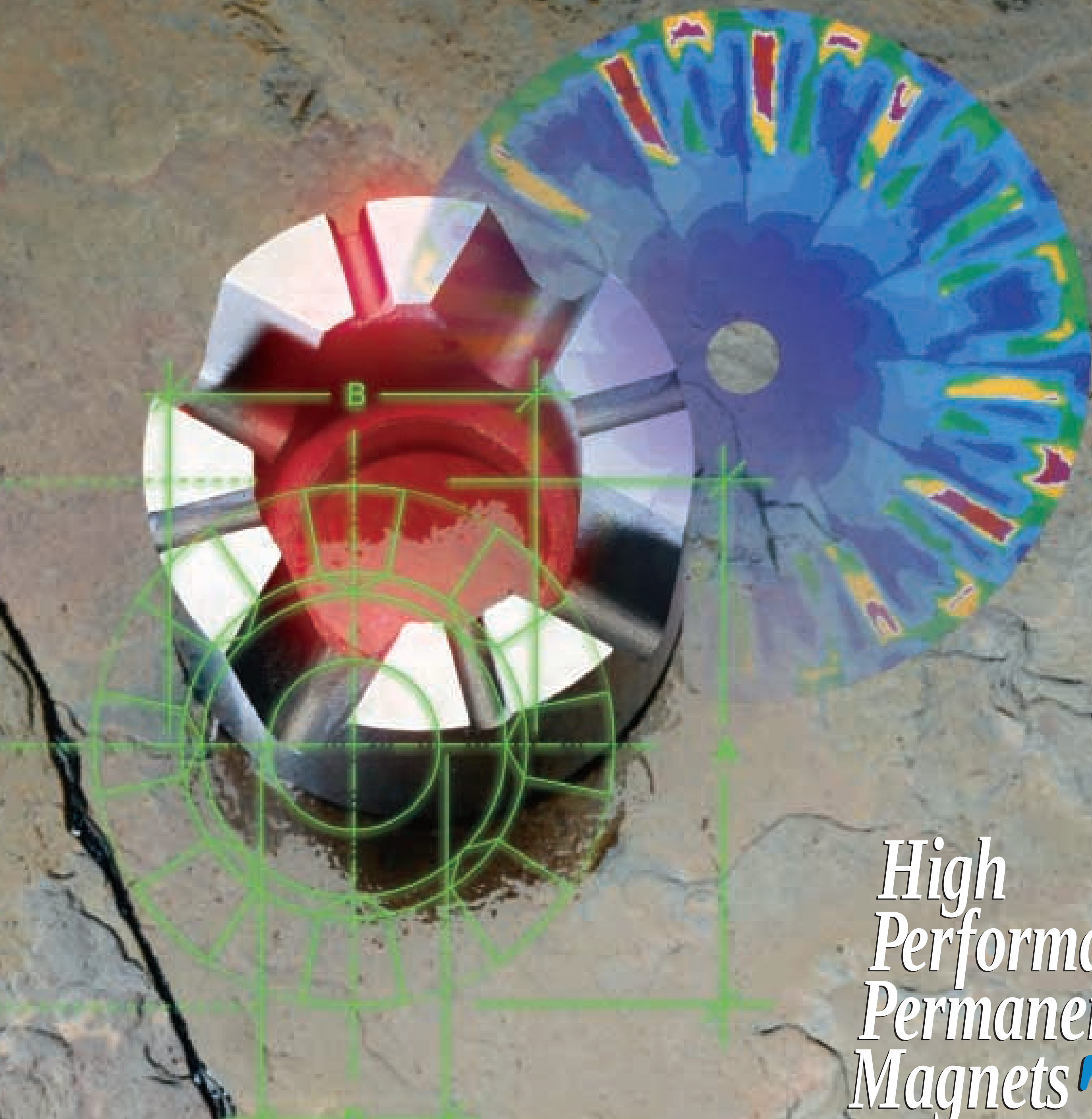
Magnet Sales & Manufacturing Inc.



High Performance Permanent Magnets 7

magnet
SALES &
MANUFACTURING
INC.

11248 PLAYA COURT, CULVER CITY, CA 90230-6162
800-421-6692 310-391-7213 IN CA FAX: 310-390-4357
HIGH PERFORMANCE PERMANENT MAGNETS, ELECTROMAGNETS, CUSTOM ASSEMBLIES

Welcome and thanks for requesting our High Performance Permanent Magnets catalog. I hope you will find it useful in understanding our capabilities and in locating your specific magnet requirements.

Founded in 1955, Magnet Sales & Manufacturing Inc. has worked to become a "one stop" quality magnet supplier. Our services include:

- Design assistance for magnet assemblies and electromagnetic components, including FEA modeling.
- Leading edge materials with exceptionally high magnetic properties.
- Large inventories of stock magnets in most materials, grades, shapes, and sizes.
- Machining of all magnet materials with short lead-times.
- Prototype to production quantities.
- High energy magnetizers (up to 64 Kilo Joules).
- CNC facilities for the manufacturing of metal components for magnet assemblies.
- Assembly and finishing of metal and magnet components.
- Inspection, test, and documentation.

Our Quality System has been audited to be in conformance with MIL-I-45208-A. We are a qualified "dock-to-stock" supplier for a number of companies. With a 34,000 square foot facility, all machining is done in house for greater control and reliability.

We look forward to an opportunity to be your partner.

Sincerely,

Anil Nanji
President

COMMUNICATING WITH OUR COMPANY

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OTHER CATALOGS

We have a large selection of magnets and have published a number of catalogs to help you locate your magnet requirements quickly. Some of these are:

Magnets for Material Handling
directed specifically for plant maintenance applications such as holding, lifting, cleaning and separating. Includes standard electromagnets.

Magnetic Ideas
directed towards the non-technical user, and includes a selection of all magnet materials, and a variety of magnets for office and plant use.

Flexible Magnets
directed specifically to the user of flexible magnetic strip or sheet. Includes standard punched parts and other finished items made from flexible magnet material.

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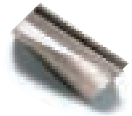


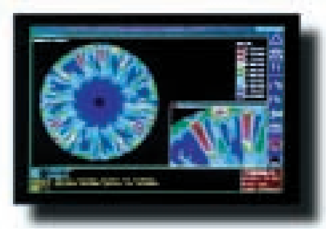


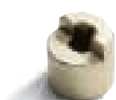

FROM ONE OF THE LARGEST INVENTORIES OF HIGH PERFORMANCE PERMANENT MAGNETS ANYWHERE. COAST TO COAST.

Our team of expert design engineers can help you select the magnet materials most appropriate for your application: Samarium Cobalts and Neodymium Iron Borons, Bonded Rare Earths, Alnicos, Ceramics, and Flexibles, spanning a range of properties to suit almost any application, including special high remanence or high coercivity grades. Standard shapes include rods, bars, rings, cylinders, discs, arcs, horseshoes and more. If it's not one of our six million magnets in stock, we'll make it - fast and at a competitive price. With stocking locations on both coasts.

WITH EXPERT DESIGN ASSISTANCE.

In response to the growing choice of available materials and increasingly complex magnet devices, we provide computerized finite element modeling of magnetic circuits. This allows for the rapid creation of computer based prototypes, shortening the cycle time from concept to final product. Our design engineering team has extensive experience in a variety of applications, including rotary and linear actuators, beam deflection, microwave components, high performance motors, thin film applications, instruments, magnetic couplings, klystrons, undulators, TWTs, magnetic resonance, shop and plant material handling, and cleaning and separating.



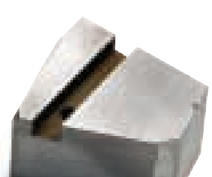


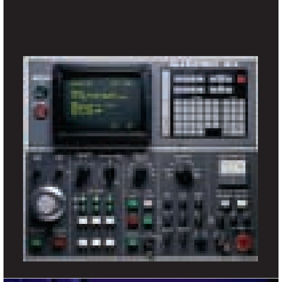


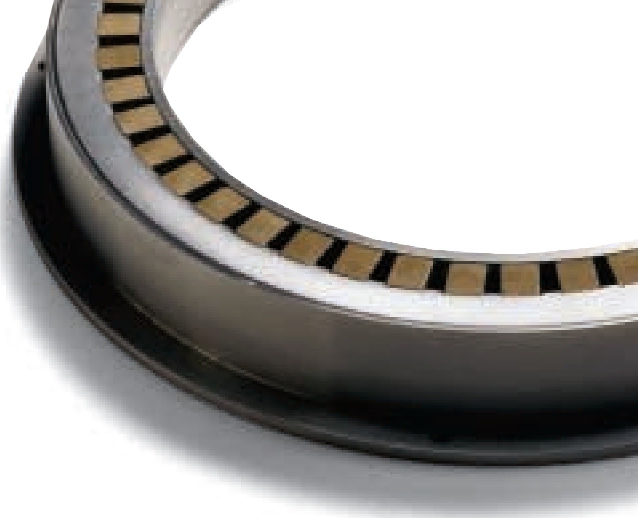








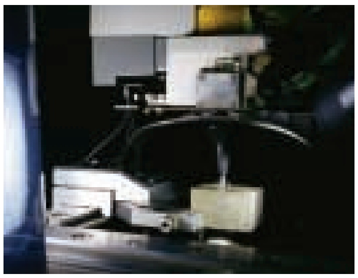


AND CUSTOM MACHINING AND ASSEMBLY.

We provide complete in-house machining and assembly capabilities to manufacture custom magnets, housings, and finished assemblies. Custom magnets are machined from raw stock to blueprint specifications. Equipment includes surface, I.D., and O.D. grinders, wire EDM, and production slicing and dicing. Prototypes and small production runs can be fabricated with short lead-times, sometimes in as little as a few days. State of the art horizontal and vertical CNC machining centers are used to rapidly produce metal components for finished magnet sub-assemblies. We routinely manufacture complex magnet assemblies with multiple component parts, providing detailed testing and documentation of results. Our high energy magnetizers are capable of handling large and hard to magnetize materials, assuring saturation and greater consistency.

QUALITY ASSURANCE AND CONTINUOUS IMPROVEMENT.

With a Quality System based on ISO 9002, and audited to conform to MIL-I-45208-A standards, we are the proud recipient of several certified supplier awards and participate in "dock-to-stock" programs. With statistical analysis, ongoing training, and a commitment to the tools of continuous improvement you can always count on us for continuing and reliable service.



MAGNET DESIGN

Design Engineering team, with design and applications experience in a wide variety of fields, including actuation, beam deflection, magnetic bearings, couplings, flywheels, high field structures, klystrons, microwave components, high performance motors, magnetic resonance for medical and geophysical applications, magnetic sensing, thin film applications, TWTs, undulators and wigglers, separation, magnetic holding, lifting, and more.

Finite Element Magnet Modeling, for proof of concept and approaching final magnet structure design.

Mechanical design assistance of magnet housing and holding structures, and CAD/CAM drawings of complex assembly details.

STOCK MAGNET MATERIALS

Neodymium Iron Boron *Leading edge materials with high remenance (> 13,000 Gauss), or high intrinsic coercivity (> 25,000 Oersteds). Energy products from 10 to 48 MGOe. In both sintered and bonded form. (See section 1 for stock grades, shapes, and sizes)*

Samarium Cobalt Materials *with energy products from 18 to 32 MGOe. (See section 1 for stock grades, shapes, and sizes)*

Ceramic *High remenance materials up to 4,200 Gauss, as well as standard Ceramic 5 and 8 grades. (See section 2 for stock grades, shapes, and sizes)*

Alnico *A large variety of shapes designed for many industrial applications, in grades 5, 5-7, 6, and 8. (See section 3 for stock grades, shapes, and sizes)*

Flexible *Low cost extruded materials with energy products from 0.6 to 1.6 MGOe. (See section 4 for stock grades, shapes, and sizes)*

CUSTOM FABRICATION

Complete manufacturing facilities, including surface, I.D., and O.D. grinding, honing, slicing, and wire EDM.

Magnet machining to print, maintaining tight tolerances on complex geometries.

MAGNETIZING

High capacity magnetizers up to 64 Kilo Joules, capable of saturating large magnets with high coercivities, as well as multiple pole magnetizing fixtures and the design of custom magnetizing fixtures.

METALWORKING

CNC metalworking facilities including vertical and horizontal machining centers, for manufacturing metal components of magnet assemblies.

CUSTOM MAGNET ASSEMBLIES

Assembly and finishing of magnet and metal components, for finished products such as magnetic couplings, yoke assemblies, magnetrons, holding magnets, motors, and more.

INSPECTION, TEST AND DOCUMENTATION

Mechanical inspection, with a MIL-I-45208-A qualified inspection facility.

Magnetic inspection including B-H curves, flux density, total flux, and dipole moment.

Statistical analysis of inspection results.

LEADTIMES AND MINIMUM ORDERS

Stock magnets can usually be shipped within 24 hours. Leadtimes for custom magnets vary with the complexity of the job, but are usually in the 2 to 4 week range, depending on capacity, complexity, and material availability. Orders can be scheduled to meet your requirements. Our minimum order is $100.

magnet SALES & MANUFACTURING INC.

CONTENTS

Air Gap : *A low permeability gap in the flux path of a magnetic circuit. Often air, but inclusive of other materials such as paint, aluminum, etc.*

Anisotropic Magnet : *A magnet having a preferred direction of magnetic orientation, so that the magnetic characteristics are optimum in one preferred direction.*

Closed Circuit : *This exists when the flux path external to a permanent magnet is confined within high permeability materials that compose the magnet circuit.*

Coercive Force, H_c : *The demagnetizing force, measured in Oersteds, necessary to reduce observed induction, B, to zero after the magnet has previously been brought to saturation.*

Curie Temperature, T_c : *The temperature at which the parallel alignment of elementary magnetic moments completely disappears, and the material is no longer able to hold magnetization.*

Demagnetization Curve: *The second quadrant of the hysteresis loop, generally describing the behavior of magnetic characteristics in actual use. Also known as the B-H curve.*

Eddy Currents : *Circulating electrical currents that are induced in electrically conductive elements when exposed to changing magnetic fields, creating an opposing force to the magnetic flux. Eddy currents can be harnessed to perform useful work (such as damping of movement), or may be unwanted consequences of certain designs which should be accounted for or minimized.*

Ferromagnetic Material : *A material whose permeability is very much larger than 1 (from 60 to several thousand times 1), and which exhibits hysteresis phenomena.*

Flux, ø : *The condition existing in a medium subjected to a magnetizing force. This quantity is characterized by the fact that an electromotive force is induced in a conductor surrounding the flux at any time the flux changes in magnitude. The cgs unit of flux is the maxwell.*

Fringing Fields : *Leakage flux particularly associated with edge effects in a magnetic circuit.*

Gauss : *Lines of magnetic flux per square centimeter, cgs unit of flux density, equivalent to lines per square inch in the English system, and webers per square meter or Tesla in the SI system.*

Hysteresis Loop : *A closed curve obtained for a material by plotting corresponding values of magnetic induction, B, (on the abscissa) against magnetizing force, H, (on the ordinate).*

Induction, B : *The magnetic flux per unit area of a section normal to the direction of flux. Measured in Gauss, in the cgs system of units.*

Intrinsic Coercive Force, H_{ci} : *Measured in Oersteds in the cgs system, this is a measure of the material's inherent ability to resist demagnetization. It is the demagnetization force corresponding to zero intrinsic induction in the magnetic material after saturation. Practical consequences of high H_{ci} values are seen in greater temperature stability for a given class of material, and greater stability in dynamic operating conditions.*

Irreversible Loss : *Defined as the partial demagnetization of a magnet caused by external fields or other factors. These losses are only recoverable by remagnetization. Magnets can be stabilized to prevent the variation of performance caused by irreversible losses.*

Isotropic Magnet : *A magnet material whose magnetic properties are the same in any direction, and which can therefore be magnetized in any direction without loss of magnetic characteristics.*

Keeper : *A piece of soft iron that is placed on or between the poles of a magnet, decreasing the reluctance of the air gap and thereby reducing the flux leakage from the magnet.*

Knee of the Demagnetization Curve : *The point at which the B-H curve ceases to be linear. All magnet materials, even if their second quadrant curves are straight line at room temperature, develop a knee at some temperature. Alnico 5 exhibits a knee at room temperature. If the operating point of a magnet falls below the knee, small changes in H produce large changes in B, and the magnet will not be able to recover its original flux output without remagnetization.*

Leakage Flux : *That portion of the magnetic flux that is lost through leakage in the magnetic circuit due to saturation or air-gaps, and is therefore unable to be used.*

Length of Air-Gap, L_g : *The length of the path of the central flux line in the air-gap.*

Load Line : *A line drawn from the origin of the Demagnetization Curve with a slope of -B/H, the intersection of which with the B-H curve represents the operating point of the magnet. Also see Permeance Coefficient.*

Magnetic Circuit : *An assembly consisting of some or all of the following: permanent magnets, ferromagnetic conduction elements, air gaps, electrical currents.*

Magnetic Flux, ø : *The total magnetic induction over a given area. When the magnetic induction, B, is uniformly distributed over an area A, $ø = BA$. The general equation is $ø = \iint B \cdot dA$.*

Magnetizing Force, H : *The magnetomotive force per unit length at any point in a magnetic circuit. Measured in oersteds in the cgs system.*

Magnetomotive Force, F : *Analogous to voltage in electrical circuits, this is the magnetic potential difference between any two points.*

Maximum Energy Product, BH_{max} : *The point on the Demagnetization Curve where the product of B and H is a maximum and the required volume of magnet material required to project a given energy into its surroundings is a minimum. Measured in Mega Gauss Oersteds, MGOe.*

North Pole : *That pole of a magnet which, when freely suspended, would point to the north magnetic pole of the earth. The definition of polarity can be a confusing issue, and it is often best to clarify by using "north seeking pole" instead of "north pole" in specifications.*

Oersted, Oe : *A cgs unit of measure used to describe magnetizing force. The English system equivalent is Ampere Turns per Inch, and the SI system's is Ampere Turns per Meter.*

Orientation Direction : *The direction in which an anisotropic magnet should be magnetized in order to achieve optimum magnetic properties. Also known as the "axis", "easy axis", or "angle of inclination".*

Paramagnetic Material : *A material having a permeability slightly greater than 1.*

Permeance : *The inverse of reluctance, analogous to conductance in electrical circuits.*

Permeance Coefficient, P_c : *Ratio of the magnetic induction, B_d, to its self demagnetizing force, H_d. $P_c = B_d/H_d$. This is also known as the "load line" or operating point of the magnet, and is useful in estimating the flux output of the magnet in various conditions. As a first order approximation, $B_d/H_d = L_m/L_g$, where Lm is the length of the magnet, and L_g is the length of an air gap that the magnet is subjected to. P_c is therefore a function of the geometry of the magnetic circuit.*

Pole Pieces : *Ferromagnetic materials placed on magnetic poles used to shape and alter the effect of lines of flux.*

Relative Permeability, μ_r : *The ratio of permeability of a medium to that of a vacuum; $\mu_r = \mu/\mu_o$. In the cgs system, $\mu_o = 1$ in a vacuum by definition. The permeability of air is also for all practical purposes equal to 1 in the cgs system.*

Reluctance, R : *Analogous to resistance in an electrical circuit, reluctance is related to the magnetomotive force, F, and the magnetic flux, ø by the equation R = F/ø, (paralleling Ohm's Law) where F is the magnetomotive force, and ø is the magnetic flux, (in cgs units).*

Remenance, B_d : *The magnetic induction which remains in a magnetic circuit after the removal of an applied magnetizing force. If there is an air gap in the circuit, the remanence will be less than the residual induction, B_r.*

Residual Induction, B_r : *This is the point at which the hysteresis loop crosses the B axis at zero magnetizing force, and represents the maximum flux output from the given magnet material. By definition, this point occurs at zero air gap, and therefore cannot be seen in practical use of magnet materials.*

Return Path : *Conduction elements in a magnetic circuit which provide a low reluctance path for the magnetic flux.*

Reversible Temperature Coefficient : *A measure of the reversible changes in flux caused by temperature variations.*

Saturation : *The condition under which all elementary magnetic moments have become oriented in one direction. A ferromagnetic material is saturated when an increase in the applied magnetizing force produces no increase in induction. Saturation flux densities for steels are in the range of 16,000 to 20,000 Gauss.*

Stabilization : *Exposure of a magnet to demagnetizing influences expected to be encountered in use in order to prevent irreversible losses during actual operation. Demagnetizing influences can be caused by high or low temperatures, or by external magnetic fields.*

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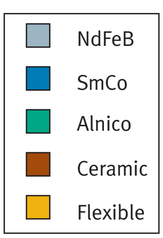
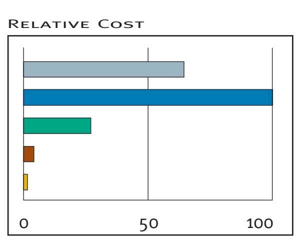
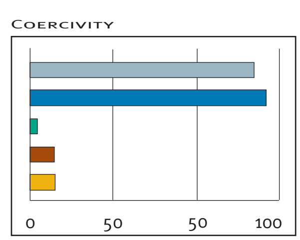
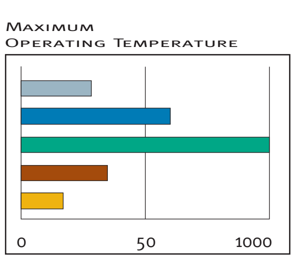
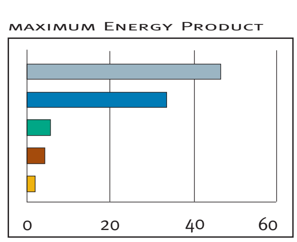
MAGNET MATERIAL QUICK REFERENCE COMPARISON CHARTS

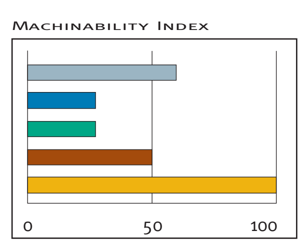












1.0 INTRODUCTION

Magnets are an important part of our daily lives, serving as essential components in everything from electric motors, loudspeakers, computers, compact disc players, microwave ovens and the family car, to instrumentation, production equipment, and research. Their contribution is often overlooked because they are built into devices and are usually out of sight.

Magnets function as transducers, transforming energy from one form to another, without any permanent loss of their own energy. General categories of permanent magnet functions are:

- *Mechanical to mechanical* - such as attraction and repulsion.
- *Mechanical to electrical* - such as generators and microphones.
- *Electrical to mechanical* - such as motors, loudspeakers, charged particle deflection.
- *Mechanical to heat* - such as eddy current and hysteresis torque devices.
- *Special effects* - such as magneto resistance, Hall effect devices, and magnetic resonance.

The following sections will provide a brief insight into the design and application of permanent magnets. The Design Engineering team at Magnet Sales & Manufacturing Inc. will be happy to assist you further in your applications.

2.0 MODERN MAGNET MATERIALS

There are four classes of modern commercialized magnets, each based on their material composition. Within each class is a family of grades with their own magnetic properties. These general classes are:

- *Neodymium Iron Boron*
- *Samarium Cobalt*
- *Ceramic*
- *Alnico*

Neodymium Iron Boron and Samarium Cobalt are collectively known as Rare Earth magnets because they are both composed of materials from the Rare Earth group of elements. Neodymium Iron Boron (general composition $Nd_2Fe_{14}B$, often abbreviated to NdFeB) is the most recent commercial addition to the family of modern magnet materials. At room temperatures, NdFeB magnets exhibit the highest properties of all magnet materials. Samarium Cobalt is manufactured in two compositions: Sm_1Co_5 and Sm_2Co_{17}, often referred to as the SmCo 1:5 or SmCo 2:17 types. 2:17 types, with higher H_{ci} values, offer greater inherent stability than the 1:5 types. Ceramic, also known as Ferrite, magnets (general composition $BaFe_2O_3$ or $SrFe_2O_3$) have been commercialized since the 1950s and continue to be extensively used today due to their low cost. A special form of Ceramic magnet is "Flexible" material, made by bonding Ceramic powder in a flexible binder. Alnico magnets (general composition Al-Ni-Co) were commercialized in the 1930s and are still extensively used today.

These materials span a range of properties that accommodate a wide variety of application requirements. The following pages are intended to give a broad but practical overview of factors that must be considered in selecting the proper material, grade, shape, and size of magnet for a specific application. The chart below shows typical values of the key characteristics for selected grades of various materials for comparison. These values will be discussed in detail in the following pages.

TABLE 2.1 MAGNET MATERIAL COMPARISONS

Material	Grade	B_r	H_c	H_{ci}	BH_{max}	T_{max} (°C)*
NdFeB	39H	12,800	12,300	21,000	40	150
SmCo	26	10,500	9,200	10,000	26	300
NdFeB	B10N	6,800	5,780	10,300	10	150
Alnico	5	12,500	640	640	5.5	540
Ceramic	8	3,900	3,200	3,250	3.5	300
Flexible	1	1,600	1,370	1,380	0.6	100

* T_{max} *(maximum practical operating temperature) is for reference only. The maximum practical operating temperature of any magnet is dependent on the circuit the magnet is operating in.*

3.0 UNITS OF MEASURE

Three systems of units of measure are common: the cgs (centimeter, gram, second), SI (meter, kilogram, second), and English (inch, pound, second) systems. This catalog uses the cgs system for magnetic units, unless otherwise specified.

TABLE 3.1 UNIT OF MEASURE SYSTEMS

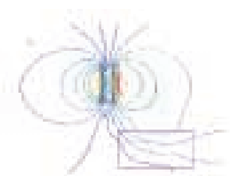
Unit	Symbol	cgs System	SI System	English System
Flux	ø	Maxwell	weber	Maxwell
Flux Density	B	Gauss	Tesla	lines/in^2
Magnetomotive Force	F	gilbert	ampere turn	ampere turn
Magnetizing Force	H	Oersted	ampere turns/m	ampere turns/in
Length	L	cm	m	in
Permeability of a vacuum	μ_v	1	$0.4\pi \times 10^{-6}$	3.192

TABLE 3.2 CONVERSION FACTORS

Multiply	By	To obtain
inches	2.54	centimeters
lines/in^2	0.155	Gauss
lines/in^2	1.55×10^{-5}	Tesla
Gauss	6.45	lines/in^2
Gauss	10^{-4}	Tesla
Gilberts	0.79577	ampere turns
Oersteds	79.577	ampere turns/m
Ampere turns	0.4π	Gilberts
Ampere turns/in	0.495	Oersteds
Ampere turns/in	39.37	Ampere turns/m

4.0 DESIGN CONSIDERATIONS

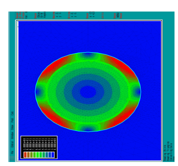
Basic problems of permanent magnet design revolve around estimating the distribution of magnetic flux in a magnetic circuit, which may include permanent magnets, air gaps, high permeability conduction elements, and electrical currents. Exact solutions of magnetic fields require complex analysis of many factors, although approximate solutions are possible based on certain simplifying assumptions. Obtaining an optimum magnet design often involves experience and tradeoffs.



Model of bar magnet with soft iron block nearby

4.1 Finite Element Analysis

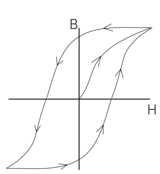
Finite Element Analysis (FEA) modeling programs are used to analyze magnetic problems in order to arrive at more exact solutions, which can then be tested and fine tuned against a prototype of the magnet structure. Using FEA models flux densities, torques, and forces may be calculated. Results can be output in various forms, including plots of vector magnetic potentials, flux density maps, and flux path plots. The Design Engineering team at Magnet Sales & Manufacturing Inc. has extensive experience in many types of magnetic designs and is able to assist in the design and execution of FEA models.



Finite Element model

4.2 The B-H Curve

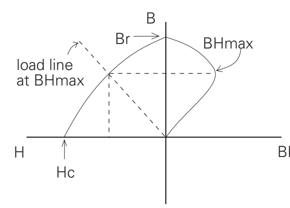
The basis of magnet design is the **B-H curve**, *or hysteresis loop, which characterizes each magnet material. This curve describes the cycling of a magnet in a closed circuit as it is brought to saturation, demagnetized, saturated in the opposite direction, and then demagnetized again under the influence of an external magnetic field.*



Hysteresis Loop

The second quadrant of the B-H curve, commonly referred to as the "Demagnetization Curve", describes the conditions under which permanent magnets are used in practice. A permanent magnet will have a unique, static operating point if air-gap dimensions are fixed and if any adjacent fields are held constant. Otherwise, the operating point will move about the demagnetization curve, the manner of which must be accounted for in the design of the device.

The three most important characteristics of the B-H curve are the points at which it intersects the B and H axes (at B_r - the residual induction - and H_c - the coercive force - respectively), and the point at which the product of B and H are at a maximum (BH_{max} - the maximum energy product). **B_r** *represents the maximum flux the magnet is able to produce under closed circuit conditions. In actual useful operation permanent magnets can only approach this point.* **H_c** *represents the point at which the magnet becomes demagnetized under the influence of an externally applied magnetic field.* **BH_{max}** *represents the point at which the product of B and H, and the energy density of the magnetic field into the air gap surrounding the magnet, is at a maximum. The higher this product, the smaller need be the volume of the magnet. Designs should also account for the variation of the B-H curve with temperature. This effect is more closely examined in the section entitled "Permanent Magnet Stability".*



The Demagnetization Curve

When plotting a B-H curve, the value of B is obtained by measuring the total flux in the magnet (ø) and then dividing this by the magnet pole area (A) to obtain the flux density (B=ø/A). The total flux is composed of the flux produced in the magnet by the magnetizing field (H), and the intrinsic ability of the magnet material to produce more flux due to the orientation of the domains. The flux density of the magnet is therefore composed of two components, one equal to the applied H, and the other created by the intrinsic ability of ferromagnetic materials to produce flux. The intrinsic flux density is given the symbol B_i where total flux $B = H + B_i$, or, $B_i = B - H$. In normal operating conditions, no external magnetizing field is present, and the magnet operates in the second quadrant, where H has a negative value. Although strictly negative, H is usually referred to as a positive number, and therefore, in normal practice, $B_i = B + H$. It is possible to plot an intrinsic as well as a normal B-H curve. The point at which the intrinsic curve crosses the H axis is the intrinsic coercive force, and is given the symbol H_{ci}. High H_{ci} values are an indicator of inherent stability of the magnet material. The normal curve can be derived from the intrinsic curve and vice versa. In practice, if a magnet is operated in a static manner with no external fields present, the normal curve is sufficient for design purposes. When external fields are present, the normal and intrinsic curves are used to determine the changes in the intrinsic properties of the material.

4.3 Magnet Calculations

In the absence of any coil excitation, the magnet length and pole area may be determined by the following equations:

$$L_m = \frac{B_g L_g}{H_m} \qquad \textit{Equation 1}$$

and

$$A_m = \frac{B_g A_g}{B_m} \qquad \textit{Equation 2}$$

where B_m = *the flux density at the operating point,*
H_m = *the magnetizing force at the operating point,*
A_g, = *the air-gap area,*
L_g = *the air-gap length,*
B_g = *the gap flux density,*
A_m = *the magnet pole area,*
and L_m = *the magnet length.*

Combining the two equations, the permeance coefficient P_c *may be determined as follows:*

$$P_c = \frac{B_m}{H_m} = \frac{A_g L_m}{A_m L_g} \qquad \textit{Equation 3}$$

Strictly,

$$P_c = \frac{B_m}{H_m} = \mu\left(\frac{A_g L_m}{A_m L_g}\right)k$$

where μ is the permeability of the medium, and k is a factor which takes account of leakage and reluctance that are functions of the geometry and composition of the magnetic circuit.

(The intrinsic permeance coefficient $P_{ci} = B_i/H$*. Since the normal permeance coefficient* $P_c = B/H$*, and* $B = H + B_i$*,* $P_c = (H + B_i)/H$ *or* $P_c = 1 + B_i/H$*. Even though the value of H in the second quadrant is actually negative, H is conventionally referred to as a positive number. Taking account of this convention,* $P_c = 1 - B_i/H$*, or* $B_i/H = P_{ci} = P_c + 1$*. In other words, the intrinsic permeance coefficient is equal to the normal permeance coefficient plus 1. This is a useful relationship when working on magnet systems that involve the presence of external fields.)*

The permeance coefficient is a useful first order relationship, helpful in pointing towards the appropriate magnet material, and to the approximate dimensions of the magnet. The objective of good magnet design is usually to minimize the required volume of magnet material by operating the magnet at BH_{max}*. The permeance coefficient at which* BH_{max} *occurs is given in the charts starting on page* xiv.

We can compare the various magnet materials for general characteristics using Equation 3.

Consider that a particular field is required in a given air-gap, so that the parameters B_g*,* H_g *(air-gap magnetizing force),* A_g*, and* L_g *are known.*

- *Alnico 5 has the ability to provide very high levels of flux density* B_m*, which is often desirable in high performance electromechanical devices. This is accompanied, however, by a low coercivity* H_m*, and so some considerable magnet length will be required.*
- *Alnico 8 operates at a higher magnetizing force,* H_m*, needing a smaller length* L_m*, but will yield a lower* B_m*, and would therefore require a larger magnet area* A_m*.*
- *Rare Earth materials offer reasonable to high values of flux density at very high values of magnetizing force. Consequently, very short magnet lengths are needed, and the required volume of this material will be small.*
- *Ceramic operates at relatively low flux densities, and will therefore need a correspondingly greater pole face area,* A_m*.*

The permeance coefficient method using the demagnetization curves allows for initial selection of magnet material, based upon the space available in the device, this determining allowable magnet dimensions.

4.3.1 Calculation Of Flux Density On A Magnet's Central Line

For magnet materials with straight line normal demagnetization curves such as Rare Earths and Ceramics, it is possible to calculate with reasonable accuracy the flux density at a distance X from the pole surface (where X>0) on the magnet's centerline under a variety of conditions.

a. Cylindrical Magnets

$$B_x = \frac{B_r}{2}\left(\frac{(L+X)}{\sqrt{R^2+(L+X)^2}} - \frac{X}{\sqrt{R^2+X^2}}\right) \qquad \textit{Equation 4}$$

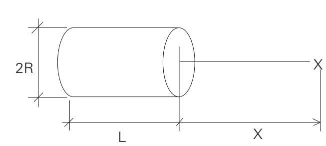


Table 4.1 shows flux density calculations using Equation 4 for a magnet 0.500" in diameter by 0.250" long at a distance of 0.050" from the pole surface, for various materials. Note that you may use any unit of measure for dimensions; since the equation is a ratio of dimensions, the result is the same using any unit system. The resultant flux density is in units of Gauss.

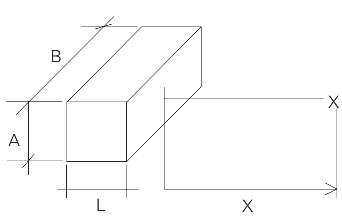
TABLE 4.1 FLUX DENSITY VS. MATERIAL

MATERIAL AND GRADE	RESIDUAL FLUX DENSITY B_r	FLUX AT DIST 0.050" FROM SURFACE
Ceramic 1	2,200	629
Ceramic 5	3,950	1,130
SmCo 18	8,600	2,460
SmCo 26	10,500	3,004
NdFeB 35	12,300	3,518
NdFeB 42H	13,300	3,804

b. Rectangular Magnets

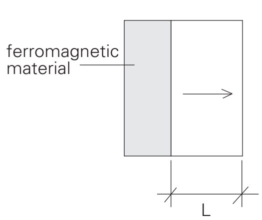
$$B_x = \frac{B_r}{\pi}\left(\tan^{-1}\frac{AB}{2X\sqrt{4X^2+A^2+B^2}} - \tan^{-1}\frac{AB}{2(L+X)\sqrt{4(L+X)^2+A^2+B^2}}\right)$$

Equation 5
(where all angles are in radians)



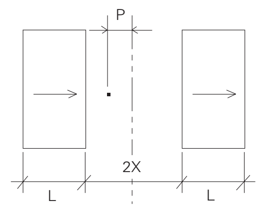
c. For a Magnet on a Steel Back plate

Substitute 2L for L in the above formulae. (Equation 6)



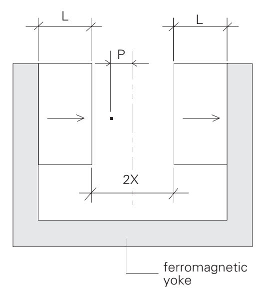
d. For Identical Magnets Facing Each Other in Attracting Positions

The value of B_X at the gap center is double the value of B_X in case 3. At a point P, B_P is the sum of $B_{(X+P)}$ and $B_{(X-P)}$, where (X+P) and (X-P) substitute for X in case 3. (Equation 7)



e. For Identical, Yoked Magnets Facing Each Other in Attracting Positions

Substitute 2L for L in case 4, and adopt the same procedure to calculate B_P. (Equation 8)



4.3.2 Force Calculations

The attractive force exerted by a magnet to a ferromagnetic material may be calculated by:

$$F = 0.577B^2A$$ *Equation 9*

where F is the force in pounds, B is the flux density in Kilogauss, and A is the pole area in square inches. Calculating B is a complicated task if it is to be done in a rigorous manner. However, it is possible to approximate the holding force of certain magnets in contact with a piece of steel using the relationship:

$$F \approx 0.58B_r^2L_m\sqrt{A}$$ *Equation 10*

where B_r is the residual flux density of the material, A is the pole area in square inches, and L_m is the magnetic length.

This formula is only intended to give an order of magnitude for the holding force which is available from a magnet with one pole in direct contact with a flat, machined, steel surface. The formula can only be used with straight line demagnetization curve materials - i.e. for Rare Earth and Ceramic materials - and where the magnet length, L_m, is kept within the bounds of normal, standard magnet configurations.

5.0 PERMANENT MAGNET STABILITY

The ability of a permanent magnet to support an external magnetic field results from small magnetic domains "locked" in position by crystal anisotropy within the magnet material. Once established by initial magnetization, these positions are held until acted upon by forces exceeding those which lock the domains. The energy required to disturb the magnetic field produced by a magnet varies for each type of material. Permanent magnets can be produced with extremely high coercive forces (H_c) which will maintain domain alignment in the presence of high external magnetic fields. Stability can be described as the repeated magnetic performance of a material under specific conditions over the life of the magnet.

Factors affecting magnet stability include time, temperature, reluctance changes, adverse fields, radiation, shock, stress, and vibration.

5.1 Time

The effect of time on modern permanent magnets is minimal. Studies have shown that permanent magnets will see changes immediately after magnetization. These changes, known as "magnetic creep", occur as less stable domains are affected by fluctuations in thermal or magnetic energy, even in a thermally stable environment. This variation is reduced as the number of unstable domains decreases. Rare Earth magnets are not as likely to experience this effect because of their extremely high coercivities. Long term time versus flux studies have shown that a newly magnetized magnet will lose a minor percent of its flux as a function of age. Over 100,000 hours, these losses are in the range of essentially zero for Samarium Cobalt materials to less than 3% for Alnico 5 materials at low permeance coefficients.

5.2 Temperature

Temperature effects fall into three categories:

- *Reversible losses.*
- *Irreversible but recoverable losses.*
- *Irreversible and unrecoverable losses.*

5.2.1. Reversible losses.

These are losses that are recovered when the magnet returns to its original temperature. Reversible losses cannot be eliminated by magnet stabilization. Reversible losses are described by the Reversible Temperature Coefficients (T_c), shown in table 5.1. T_c is expressed as % per degree Centigrade. These figures vary for specific grades of each material but are representative of the class of material as a whole. It is because the temperature coefficients of B_r and H_c are significantly different that the demagnetization curve develops a "knee" at elevated temperatures.

Table 5.1 Reversible Temperature Coefficients of B_r and H_c

Material	T_c of B_r	T_c of H_c
NdFeB	-0.12	-0.60
SmCo	-0.04	-0.30
Alnico	-0.02	+0.01
Ceramic	-0.20	+0.30

5.2.2. Irreversible but recoverable losses

These losses are defined as partial demagnetization of the magnet from exposure to high or low temperatures. These losses are only recoverable by remagnetization, and are not recovered when the temperature returns to its original value. These losses occur when the operating point of the magnet falls below the knee of the demagnetization curve. An efficient permanent magnet design should have a magnetic circuit in which the magnet operates at a permeance coefficient above the knee of the demagnetization curve at expected elevated temperatures. This will prevent performance variations at elevated temperatures.

5.2.3. Irreversible and unrecoverable losses

Metallurgical changes occur in magnets exposed to very high temperatures and are not recoverable by remagnetization. Table 5.2 shows critical temperatures for the various materials, where

- **T_{Curie}**, *is the Curie temperature at which the elementary magnetic moments are randomized and the material is demagnetized; and*
- **T_{max}**, *is the maximum practical operating temperatures† in air, for general classes of major materials. Different grades of each material exhibit values differing slightly from the values shown here.*

†Note that the maximum practical operating temperature is dependent on the operating point of the magnet in the circuit. The higher the operating point on the Demagnetization Curve, the higher the temperature at which the magnet may operate.

Table 5.2 Critical Temperatures for Various Materials

Material	T_{Curie}	T_{max}
Neodymium Iron Boron	310 (590)	150 (302)
Samarium Cobalt	750 (1382)	300 (572)
Alnico	860 (1580)	540 (1004)
Ceramic	460 (860)	300 (572)

(Temperatures are shown in degrees Centigrade with the Fahrenheit equivalent in parentheses.)

Flexible materials are not included in this table since the binders which are used to render the magnet flexible break down before metallurgical changes occur in the magnetic ferrite powder which provides flexible magnets with their magnetic properties.

Partially demagnetizing a magnet by exposure to elevated temperatures in a controlled manner stabilizes the magnet with respect to temperature. The slight reduction in flux density improves a magnet's stability because domains with low commitment to orientation are the first to lose their orientation. A magnet thus stabilized will exhibit constant flux when exposed to equivalent or lesser temperatures. Moreover, a batch of stabilized magnets will exhibit lower variation of flux when compared to each other since the high end of the bell curve which characterizes normal variation will be brought in closer to the rest of the batch.

5.3 Reluctance Changes

These changes occur when a magnet is subjected to permeance changes such as changes in air gap dimensions during operation. These changes will change the reluctance of the circuit, and may cause the magnet's operating point to fall below the knee of the curve, causing partial and/or irreversible losses. The extent of these losses depend upon the material properties and the extent of the permeance change. Stabilization may be achieved by pre-exposure of the magnet to the expected reluctance changes.

5.4 Adverse Fields

External magnetic fields in repulsion modes will produce a demagnetizing effect on permanent magnets. Rare Earth magnets with coercive forces exceeding 15 KOe are difficult to affect in this manner. However, Alnico 5, with a coercive force of 640 Oe will encounter magnetic losses in the presence of any magnetic repelling force, including similar magnets. Applications involving Ceramic magnets with coercive forces of approximately 4 KOe should be carefully evaluated in order to assess the effect of external magnetic fields.

5.5 Radiation

Rare Earth materials are commonly used in charged particle beam deflection applications, and it is necessary to account for possible radiation effects on magnetic properties. Studies (A.F. Zeller and J.A. Nolen, National Superconducting Cyclotron Laboratory, 09/87, and E.W. Blackmore, TRIUMF, 1985) have shown that SmCo and especially Sm_2Co_{17} *withstand radiation 2 to 40 times better than NdFeB materials. SmCo exhibits significant demagnetization when irradiated with a proton beam of* 10^9 *to* 10^{10} *rads. NdFeB test samples were shown to lose all of their magnetization at a dose of* 7×10^7 *rads, and 50% at a dose of* 4×10^6 *rads. In general, it is recommended that magnet materials with high* H_{ci} *values be used in radiation environments, that they be operated at high permeance coefficients,* P_c*, and that they be shielded from direct heavy particle irradiation. Stabilization can be achieved by pre-exposure to expected radiation levels.*

5.6 Shock, Stress, and Vibration

Below destructive limits, these effects are very minor on modern magnet materials. However, rigid magnet materials are brittle in nature, and can easily be damaged or chipped by improper handling. Samarium Cobalt in particular is a fragile material and special handling precautions must be taken to avoid damage. Thermal shock when Ceramics and Samarium Cobalt magnets are exposed to high temperature gradients can cause fractures within the material and should be avoided.

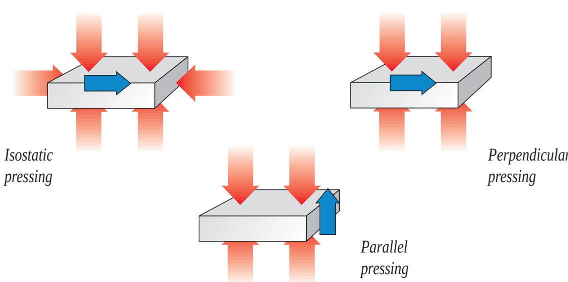
6.0 MANUFACTURING METHODS

Permanent magnets are manufactured by one of the following methods:

- *Sintering, (Rare Earths, Ceramics, and Alnicos)*
- *Pressure Bonding or Injection Molding, (Rare Earths and Ceramics)*
- *Casting, (Alnicos)*
- *Extruding, (Bonded Neodymium and Flexible)*
- *Calendering (Flexible)*

The sintering process involves compacting fine powders at high pressure in an aligning magnetic field, then sintering to fuse into a solid shape. After sintering, the magnet shape is rough, and will need to be machined to achieve close tolerances. The intricacy of shapes that can be thus pressed is limited.

Rare Earth magnets may be die pressed (with pressure being applied in one direction) or isostatically pressed (with equal pressure being applied in all directions). Isostatically pressed magnets achieve higher magnetic properties than die pressed magnets. The aligning magnetic field for die pressed magnets can be either parallel or perpendicular to the pressing direction. Magnets pressed with the aligning field perpendicular to the pressing direction achieve higher magnetic properties than the parallel pressed form.



Both Rare Earth and Ceramic magnets can also be manufactured by pressure bonding or injection molding the magnet powders in a carrier matrix. The density of magnet material in this form is lower than the pure sintered form, yielding lower magnetic properties. However, bonded or injection molded magnets may be made with close tolerances "off tool" and in relatively intricate shapes.

Alnico is manufactured in a cast or sintered form. Alnicos may be cast in large or complex shapes (such as the common horseshoe), while sintered Alnico magnets are made in relatively small sizes (normally one ounce or less) and in simple shapes.

Flexible Rare Earth or Ceramic magnets are made by calendering or extruding magnet powders in a flexible carrier matrix such as vinyl. Magnet powder densities and therefore magnetic properties in this form of manufacture are even lower than the bonded or injection molded form. Flexible magnets are easily cut or punched to shape.

7.0 PHYSICAL CHARACTERISTICS AND MACHINING OF PERMANENT MAGNETS

Sintered Samarium Cobalt and Ceramic magnets exhibit small cracks within the material that occur during the sintering process. Provided that cracks do not extend more than halfway through a section, they do not normally affect the operation of the magnet. This is also true for small chips that may occur during machining and handling of these magnets, especially on sharp edges. Magnets may be tumbled to break edges: this is done to avoid "feathering" of sharp edges due to the brittle nature of the materials. Tumbling can achieve edge breaks of 0.003" to 0.010". Although Neodymium Iron Boron is relatively tough as compared to Samarium Cobalt and Ceramic, it is still brittle and care must be taken in handling. Because of these inherent material characteristics, it is not advisable to use any permanent magnet material as a structural component of an assembly.

Rare Earth, Alnico, and Ceramic magnets are machined by grinding, which may considerably affect the magnet cost. Maintaining simple geometries and wide tolerances is therefore desirable from an economic point of view. Rectangular or round sections are preferable to complex shapes. Square holes (even with large radii), and very small holes are difficult to machine and should be avoided. Magnets may be ground to virtually any specified tolerance. However, to reduce costs, tolerances of less than ±0.001" should be avoided if possible.

Cast Alnico materials exhibit porosity as a natural consequence of the casting process. This may become a problem with small shapes which are machined out of larger castings. The voids occupy a small portion of the larger casting, but can account for a large portion of the smaller fabricated magnets. This may cause a problem where uniformity or low variation is critical, and it may be advisable either to use a sintered Alnico, or another material. In spite of its slightly lower magnetic properties, sintered Alnico may yield a higher or more uniform net density, resulting in equal or higher net magnetic output.

In applications where the cosmetic qualities of the magnet are of a concern, special attention should be placed on selecting the appropriate material, since cracks, chips, pores, and voids are common in rigid magnet materials.

Magnet Sales & Manufacturing Inc. has extensive experience in the machining and handling of all permanent magnet materials. In house machining facilities allow the ability to deliver prototype to production quantities with short lead times.

8.0 COATINGS

Samarium Cobalt, Alnico, and Ceramic materials are corrosion resistant, and do not require to be coated against corrosion. Alnico is easily plated for cosmetic qualities, and Ceramics may be coated to seal the surface which will otherwise be covered by a thin film of ferrite powder (although not a problem for most applications).

Neodymium Iron Boron magnets are susceptible to corrosion and consideration should be given to the operating environment to determine if coating is necessary. Nickel or tin plating may be used for Neodymium Iron Boron magnets, however, the material must be properly prepared and the plating process properly controlled for successful plating. Plating houses experienced in the plating of NdFeB materials are difficult to locate, and must be furnished with the necessary information for proper preparation and control of the process. Aluminum chromate or cadmium chromate vacuum deposition has been successfully tested, with coating thickness as low as 0.0003". Teflon and other organic coatings are relatively inexpensive and have also been successfully tested. A further option for critical applications is to apply two types of protective coatings or to encase the magnet in a stainless steel or other housing to reduce the chances of corrosion.

9.0 ASSEMBLY CONSIDERATIONS

Magnet Sales & Manufacturing Inc. has manufacturing capabilities to manufacture complex magnet pole pieces and housings to provide a complete magnet assembly. The following points should be considered when designing magnet assemblies.

9.1 Affixing Magnets to Housings

Magnets can be successfully affixed to housings using adhesives. Cyanoacrylate adhesives which are rated to temperatures up to 350°F with fast cure times are most commonly used. Fast cure times avoid the need for fixtures to hold the magnets in place while the bond cures. Adhesives with higher temperature ratings are also available, but these require oven curing, and fixturing of the magnets to hold them in place. If magnet assemblies are to be used in a vacuum, potential outgassing of the adhesives should be considered.

9.2 Housing Design

Magnet Sales & Manufacturing is equipped with state of the art CNC and EDM equipment allowing the manufacture of complex housings. Effective magnet locating sections should be included in housing designs to support and locate magnets precisely.

9.3 Mechanical Fastening

When arrays of magnets must be assembled, especially when the magnets must be placed in repelling positions, it is very important to consider safety issues. Modern magnet materials such as the Rare Earths are extremely powerful, and when in repulsion they can behave as projectiles if adhesives were to break down. We strongly recommend that in these situations mechanical fastening be included in the design in addition to adhesives. Potential methods of mechanical retention include encasement, pinning, or strapping the magnets in place with non magnetic metal components. The Design Engineering team at Magnet Sales & Manufacturing is experienced in magnet housing and fastening designs, and we will be pleased to assist in arriving at an appropriate design.

9.4 Potting

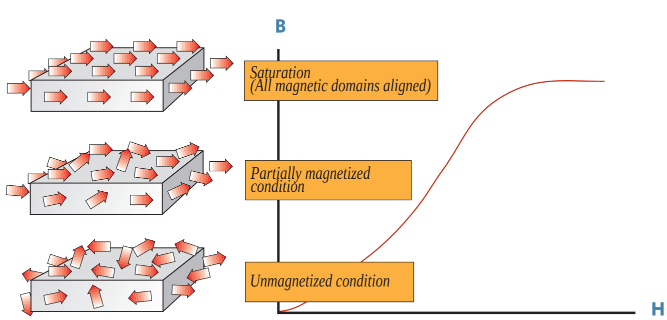
Magnet assemblies may be potted to fill gaps or to cover entire arrays of magnets. Potting compounds cure to hard and durable finishes, and are available to resist a variety of environments, such as elevated temperatures, water flow, etc. When cured, the potting compounds may be machined to provide accurate finished parts.

9.5 Welding

Assemblies which are required to be hermetically sealed can be welded using either laser welding (which is not affected by the presence of magnetic fields) or TIG welding (using appropriate shunting elements to reduce the effect of magnetic fields on the weld arc). Special care should be taken when welding magnetic assemblies so that heat dissipation of the weld does not affect the magnets.

10.0 MAGNETIZATION

Permanent magnet materials are believed to be composed of small regions or "domains" each of which exhibit a net magnetic moment. An unmagnetized magnet will possess domains which are randomly oriented with respect to each other, providing a net magnetic moment of zero. Thus a magnet when demagnetized is only demagnetized from the observer's point of view. Magnetizing fields serve to align randomly oriented domains to give a net, externally observable field.



10.1 Objective of Magnetization

The objective of magnetization is initially to magnetize a magnet to saturation, even if it will later be slightly demagnetized for stabilization purposes. Saturating the magnet and then demagnetizing it in a controlled manner ensures that the domains with the least commitment to orientation will be the first to lose their orientation, thereby leading to a more stable magnet. Not achieving saturation, on the other hand, leads to orientation of only the most weakly committed domains, hence leading to a less stable magnet.

Anisotropic magnets must be magnetized parallel to the direction of orientation to achieve optimum magnetic properties. Isotropic magnets can be magnetized through any direction with little or no loss of magnetic properties. Slightly higher magnetic properties are obtained in the pressing direction.

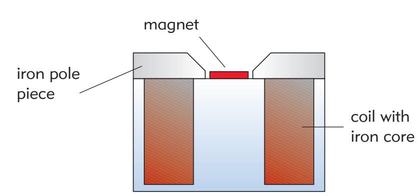
10.2 Magnetizing Equipment

Magnetization is accomplished by exposing the magnet to an externally applied magnetic field. This magnetic field may be created by other permanent magnets, or by currents flowing in coils. Using permanent magnets for magnetization is only practical for low coercivity or thin sections of materials. Removal of the magnetized specimen from the permanent magnet magnetizer can be problematic since the field cannot be turned off, and fringing fields may adversely affect the magnetization of the specimen.

The two most common types of magnetizing equipment are the DC and capacitor discharge magnetizers.

10.2.1 DC Magnetizers

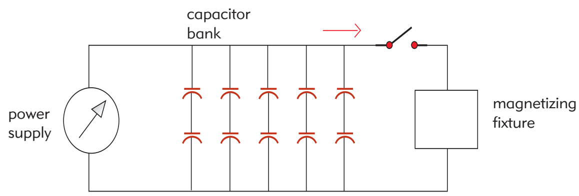
DC magnetizers employ large coils through which a current is applied for a short duration by closing a switch. The current flowing through the coil produces a magnetic field which is usually directed by the use of iron cores and pole pieces, and magnets are placed in the gap between the pole pieces. DC magnetizers are only practical for magnetizing Alnico materials which have a low magnetizing force requirement, or small sections of Ceramic materials.



DC Magnetizer

10.2.2 Capacitor Discharge Magnetizers

Capacitor discharge magnetizers employ capacitor banks which are charged, then discharged through a coil. Provided the coil has an resistance, R, which is greater than $2\sqrt{L/C}$, where L is the inductance and C the capacitance, the current flowing though the coil



Capacitor Discharge Magnetizer

will be unidirectional. Extremely high magnetizing fields (in the range of 100 KOe) can be achieved using special coils and power supplies.

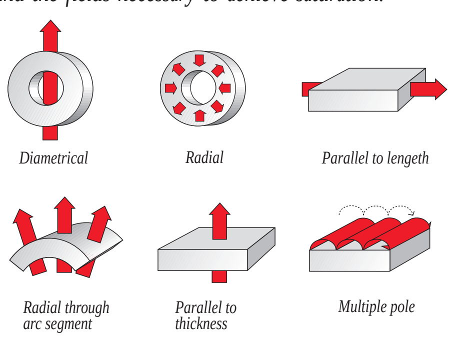
10.3 Saturation Fields Required

Some Rare Earth magnets require very high magnetizing fields in the 20 to 50 KOe range. These fields are difficult to produce requiring large power supplies in conjunction with carefully designed magnetizing fixtures. Isotropic bonded Neodymium materials require fields in the high 60 KOe range to be fully saturated. However, 98% of saturation may be achieved by fields in the 30 KOe range. Ceramics require fields in the order of 10 KOe, while Alnicos require fields in the range of 3 KOe for saturation. Because of the ease by which Alnico 5 can become inadvertently demagnetized, it is preferable for this material to be magnetized just prior to or even after final assembly of the magnet into the device.

10.4 Multiple Pole Magnetization

In certain cases, it may be desirable to magnetize a magnet with more than one pole on a single pole surface. This may be accomplished by constructing special magnetizing fixtures. Multiple pole magnetizing fixtures are relatively simple to build for Alnico and Ceramic, but require great care in design and construction for Rare Earth materials.

Magnetizing with multiple poles will sometimes eliminate the need for several discrete magnets, reducing assembly costs, although a cost will be incurred for building an appropriate magnetizing fixture. Multiple pole fixtures for Rare Earth magnets may cost several thousand dollars to build, depending on the size of the magnet, the number of poles required, and the fields necessary to achieve saturation.



Magnetizing Paterns

10.5 The Orientation Direction

Some applications require magnets oriented in a particular direction with a high degree of accuracy. This direction may or may not coincide with a geometrical plane of the magnet. For anisotropic materials the orientation direction can normally be held within 3 degrees of the nominal with no special precautions. However, more precise requirements may need special measurement and testing. This is achieved by the use of Helmholtz coils which measure the total flux in various axes, and thence calculating the resultant magnetic moment vector. Materials must be cut and machined taking into account the actual angle of orientation to achieve the required accuracy. Isotropic materials may be magnetized in any direction, and therefore pose no problem in this regard.

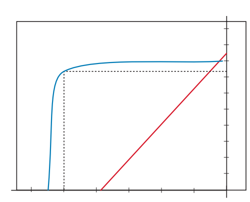
11.0 MEASUREMENT AND TESTING

It is important that incoming inspection of magnetic characteristics be clearly and properly specified. End point characteristics (such as B_r or H_c) cannot be directly observed, therefore inspection personnel should not expect to measure 8,500 Gauss on a SmCo 18 magnet even though the B_r is specified at 8,500 Gauss.

A test method or combination of test methods should be based upon the criticality of the requirement, and the cost and ease of performing tests. Ideally, the test results should be able to be directly translated into functional performance of the magnet. A sampling plan should be specified which inspects the parameters which are critical to the application. A brief description of some common test methods follows below.

11.1 B-H Curves

B-H curves may be plotted with the use of a permeameter. These curves completely characterize the magnetic properties of the material at a specific temperature. In order to plot a B-H curve, a sample of specific size must be used, then cycled through a magnetization/demagnetization cycle. This test is expensive to perform due to the length of time required to complete. The test is destructive to the sample piece in many cases, and is not practical to perform on a large sample of finished magnets. However, when magnets are machined from a larger block, the supplier may be requested to provide B-H curves for the starting raw stock of magnet material.



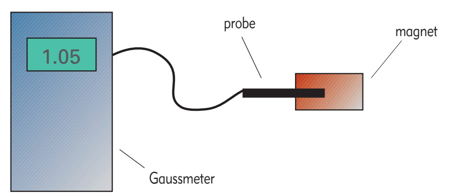
Demagnetization Curves

11.2 Total Flux

Using a test set up consisting of a Helmholtz coil pair connected to a fluxmeter, total flux measurements can be made to obtain total dipole moments, and interpolated to obtain close estimates of B_r, H_c, and BH_{max}. The inside diameter of the coils should be at least three times the largest dimension of the magnet for accurate results. The angle of orientation of the magnet can also be determined using this method. This is a quick and reliable test, and one that is not overly sensitive to magnet placement within the coil.

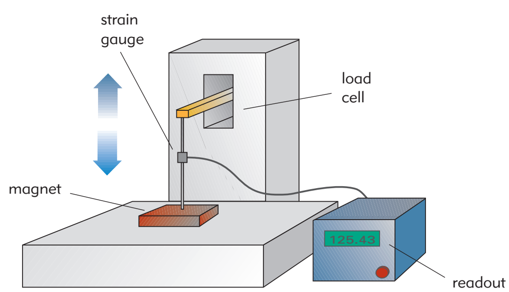
11.3 Flux Density

Flux density measurements are made using a gaussmeter and an appropriate probe. The probe contains a Hall Effect device whose voltage output is proportional to the flux density encountered. Two types of probe construction (axial, where the lines of flux travel parallel to the probe holder, and transverse where the lines of flux travel perpendicular to the probe holder, are measured) allow the measurement of flux density of magnets in various configurations. The placement of the probe with respect to the magnet is critical in order to obtain comparable measurements from magnet to magnet. This is accomplished by building a holding fixture for the magnet and probe, so that their positions are fixed relative to each other.



11.4 Pull Tests

This is a commonly used test for magnets. The pull of the magnet is proportional to B^2*, and is therefore very sensitive to the value of B. Variations in B occur due to variations in the inherent properties of the magnet itself, as well as environmental effects such as temperature, composition and condition of the material that the magnet is being tested on, measurement equipment, and operator. Since B decays exponentially from a zero air gap, small inadvertently introduced air gaps between the magnet and the test material can have a large effect on the measured pull. It is therefore recommended that pull be tested at a positive air gap. Performing pull tests at a number of air gaps, and plotting results as air gap vs. √(pull), provides a more accurate description of the pull characteristics of the magnet. Extrapolating from this pull at zero air gap may be calculated.*



11.5 Other Functional Tests

These should be determined according to the application and after discussion with the supplier. They may involve complex tests such as a profile of flux density along a specified axis, flux uniformity requirements within a defined volume, or relatively simple tests such as a torque test.

12.0 HANDLING AND STORAGE

Handle magnets with care!
Personnel wearing pacemakers should not handle magnets.
Magnets should be kept away from sensitive electronic equipment.
Modern magnet materials are extremely strong magnetically and somewhat weak mechanically. Any person required to handle magnets should be appropriately trained about the potential dangers of handling magnets. Injury is possible to personnel, and magnets themselves can easily get damaged if allowed to snap towards each other, or if nearby metal objects are allowed to be attracted to the magnets.

Materials with low coercive forces such as Alnico 5 must be carefully handled and stored when received in a magnetized condition. When stored, these magnets should be maintained on a "keeper" which provides a closed loop protecting the magnet from adverse fields. Bringing together like poles in repulsion would lead to irreversible, though remagnetizable, losses.

Samarium Cobalt should be carefully handled and stored due to the extremely brittle nature of the material.

Uncoated Neodymium magnets should be stored so as to minimize the risk of corrosion.

In general, it is preferable to store magnetized materials under vacuum sealed film so that the magnets do not collect ferromagnetic dust particles over time, since cleaning this accumulated dust is time consuming.

13.0 QUICK REFERENCE SPECIFICATION CHECKLIST

When requesting design assistance, information should establish adverse environmental conditions to which the magnet may be subjected - for example unusual temperatures, humidity, radiation, demagnetizing fields produced by other parts of the magnetic circuit, etc. The various magnet materials react differently under different environmental conditions, and it is most likely that a material can be selected which will maximize the chances of success, provided that all relevant information is conveyed.

The following checklist may be helpful in constructing and communicating specifications for permanent magnets:

Material type
Nominal, minimum and/or maximum magnetic properties
(B_r, H_c, H_{ci}, BH_{max})
Geometry and tolerances of magnet
Orientation direction (and tolerance of orientation direction if critical)
Whether to be supplied magnetized or not
Marking requirements
Coating requirements
Acceptance tests or performance requirements
Inspection sampling plan
Packaging and identification

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Material & Grade	B_r (Gauss)	H_c (Oersted)	H_{ci} (Oersted)	BH_{max} MGOe	Recoil Perm.	Slope @ BH_{max}	Curie Temp(°C)	*Max. Op. Temp (°C)	Temp. Coeff. $\Delta B_r/B_r$/°C (%)	Density (Lb/in^3)	Rel. Cost by Wt.
NdFeB											
4SB	3460	3,460	9,600	2.8	1.25	1.2	350	150	-0.10	0.217	40
B10N	6,800	5,780	10,300	10	1.25	1.2	350	150	-0.10	0.217	60
24	9,800	7,500	8,000	24	1.10	1.3	300	80	-0.12	0.275	60
24UH	10,000	9,600	41,000	24	1.10	1.0	310	210	-0.10	0.271	80
27	10,850	9,650	13,500	27	1.10	1.0	315	80	-0.12	0.267	70
27H	10,600	10,100	17,000	27	1.05	1.0	310	150	-0.11	0.271	80
28	10,800	10,100	17,000	28	1.09	1.0	310	150	-0.09	0.271	70
28UH	10,900	10,400	25,000	28	1.05	1.0	310	190	-0.11	0.271	80
30	11,400	10,400	13,500	30	1.09	1.0	315	150	-0.12	0.267	70
30H	11,200	10,700	17,000	30	1.05	1.0	310	150	-0.11	0.271	80
32SH	11,600	11,100	31,000	32	1.10	1.0	310	180	-0.10	0.271	90
35	12,300	11,300	14,000	35	1.09	1.1	310	150	-0.10	0.271	70
35SH	12,200	11,700	26,000	36	1.05	1.0	310	160	-0.10	0.271	80
38H	12,550	11,700	17,000	38.5	1.05	1.0	365	130	-0.10	0.271	90
39H	12,800	12,300	21,000	40	1.10	1.0	310	150	-0.10	0.271	80
40	12,900	12,400	12,000	40	1.05	1.0	310	130	-0.11	0.271	80
42	13,050	12,500	14,000	41	1.05	1.0	365	120	-0.10	0.271	90
42H	13,300	12,700	17,000	43	1.10	1.0	310	120	-0.10	0.271	80
45	13,550	11,750	11,000	44	1.05	1.1	310	100	-0.10	0.271	90
45H	13,500	12,900	15,000	45	1.10	1.0	310	100	-0.11	0.271	90
48	14,100	12900	13,500	48	1.10	1.1	310	80	-0.11	0.271	90
SmCo											
B15S	7,950	6,100	10,500	14	1.05	1.1	720	150	-0.04	0.253	90
18	8,600	7,200	9,000	18	1.08	1.0	775	250	-0.04	0.300	100
22	9,850	8,750	12,000	22	1.02	1.0	820	250	-0.03	0.303	110
26	10,500	9,200	10,000	26	1.08	1.0	825	350	-0.03	0.303	120
26H	10,600	9,250	11,500	27	1.02	1.0	820	350	-0.03	0.303	120
26HS	10,600	9,800	18,000	27	1.02	1.0	820	380	-0.03	0.303	130
27H	11,000	10,300	26,000	28	1.10	1.0	820	350	-0.03	0.303	130
28	10,700	10,300	18,000	28	1.05	1.0	820	350	-0.03	0.303	130
32H	11,600	9,500	14,000	31	1.02	1.1	820	350	-0.03	0.303	140

** These maximum operating temperatures apply under certain conditions and are for reference only.
If your application will approach these temperatures, please consult with our engineers.*

MAGNET MATERIAL CHARACTERISTICS

Material & Grade	B_r (Gauss)	H_c (Oersted)	H_{ci} (Oersted)	BH_{max} MGOe	Recoil Perm.	Slope @ BH_{max}	Curie Temp(°C)	*Max. Op. Temp (°C)	Temp. Coeff. $\Delta B_r/B_r/°$ (C%)	Density (Lb/in³)	Rel. Cost by Wt.
Ceramic											
1	2,200	1,900	3,250	1.1	1.15	1.2	450	300	-0.18	0.180	2
5	3,950	2,400	2,450	3.6	1.06	1.1	450	300	-0.20	0.180	3
8	3,900	3,200	3,250	3.5	1.06	1.0	450	300	-0.20	0.180	4
10	4,200	2,950	3,050	4.2	1.06	1.1	450	300	-0.20	0.180	8
Alnico											
5 Cast	12,500	640	640	5.5	3.70	18.0	860	540	-0.013	0.265	15
5-7 Cast	13,500	740	740	7.5	3.60	16.0	860	540	-0.013	0.265	30
6 Cast	10,500	780	800	3.9	2.40	7.0	860	540	-0.013	0.265	20
8 Cast	8,300	1,650	1,650	5.5	2.00	5.0	860	540	-0.013	0.265	18
2 Sintered	6,600	550	550	1.4	5.60	12.3	810	540	-0.015	0.247	8
5 Sintered	10,800	600	600	3.8	5.20	18.4	860	540	-0.007	0.253	10
8 Sintered	7,000	1,900	1,900	5.0	1.90	5.0	860	540	-0.013	0.253	10
Flexible											
Standard	1,725	1,325	1,340	0.6	1.06	1.2	**	100	-0.19	0.133	1
HF1	2,200	2,000	2,400	1.1	1.06	1.0	**	100	-0.19	0.140	2
HF2	2,450	2,200	2,400	1.4	1.06	1.0	**	100	-0.19	0.140	2.5
HF3	2,650	2,200	2,400	1.6	1.06	1.0	**	100	-0.19	0.140	3

** These maximum operating temperatures apply under certain conditions and are for reference only. If your application will approach these temperatures, please consult with our engineers.*

*** Due to the bonding agents used, flexible magnets may not operate at temperatures above 120°C.*

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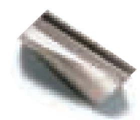
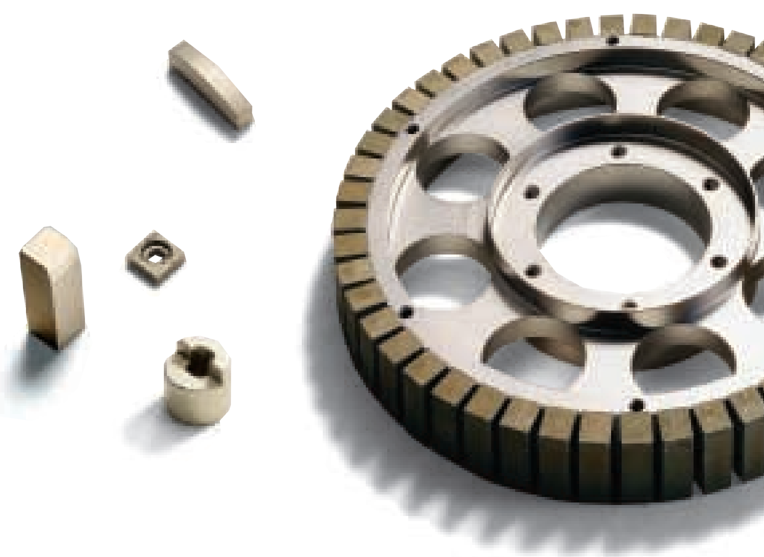


Alloys of the Lanthanide group of elements, Rare Earths are the most advanced commercialized permanent magnet materials. Collectively known as Rare Earths are the Neodymium Iron Boron (NdFeB) types and Samarium Cobalt (SmCo) types. Within each of these classes of Rare Earth magnets are a number of different grades which span a wide range of properties and application requirements.

Both NdFeB and SmCo are available in sintered as well as bonded forms. The bonded form of the material can be produced with close tolerances off tool, with little or no finishing required. The sintered form usually requires some finishing operations in order to hold close mechanical tolerances.



Rare Earth magnets are brittle, and machining operations should be performed prior to magnetization, using diamond tools. SmCo materials are far more brittle than NdFeB, and great care must be taken in machining them. We are equipped to fabricate these materials to blueprint specifications.

All the Rare Earth materials shown in this section except the bonded NdFeB B10N material are anisotropic, and can only be magnetized in the orientation direction. B10N material is isotropic and can be magnetized in any direction, and with multiple poles, although special magnetizing fixtures are required for this. In general, magnetizing fields of about 30 KOe are required to saturate NdFeB, while fields of up to 45 KOe are required to saturate some of the higher energy SmCo materials.

Comparison of NdFeB and SmCo Magnets

Material	Energy Products	Mechanical Strength	Density (Lbs/in3)	Corrosion Resistance	Temp Stability	Cost
NdFeB	24 to 48	Medium	0.275	Low	Low to Med.	Lower
SmCo	18 to 32	Low	0.300	High	High	Higher

TOLERANCES

1. Blocks

Tolerances on "as sintered" die pressed blocks are the greater of ± 3% or ± 0.045".
Tolerances on "as sintered" isostatically pressed blocks are the greater of ± 5% or ± 0.125".
Tolerances on "finished" blocks are the greater of ± 1.5% or ± 0.015" on cross sectional dimensions, and ± 0.005" on the orientation direction.

2. Rods

Tolerances on "as sintered" isostatically pressed rods are the greater of ± 5% or ± 0.125".
Tolerances on "finished" rods are the greater of ± 1% or ± 0.010" on diameters, and ± 1.5% or ± 0.015" on the length.

3. Discs and Rings

Tolerances on diameters are the greater of ± 1.5% or ± 0.010", and the greater of ± 1% or ± 0.005" on lengths.

4. Bonded Rare Earth Magnets

Tolerances are the greater of ± 0.5% or ± 0.005" on all dimensions.

SHAPES, SIZES, AND GRADES AVAILABLE

In addition to the stock shapes, sizes, and grades listed in the catalog, others are available. Please inquire. Non standard shapes and sizes can be fabricated to blueprint specifications from raw stock.

ASSEMBLIES

We are able to manufacture metal and other components of finished sub assemblies using our CNC machining facilities.

Assemblies using metal or other components and magnets can be fabricated by adhering magnets with adhesives to suit a range of environments, by mechanically fastening magnets, or by a combination of these methods. Due to the relatively brittle nature of these magnet materials, press fits are not recommended.

When multiple magnets are assembled in repelling positions, it is advisable to use mechanical fastening in addition to adhesives, since if adhesives were to give way, repelling magnets may dislodge and endanger personnel using them. Our design engineering team will be happy to assist you in designing housings for your magnet assemblies.

SURFACE TREATMENTS

The corrosion resistance of SmCo is considered "good" while that of NdFeB is considered "poor". Painting, coating, or plating is therefore highly recommended for NdFeB. Plating NdFeB is a difficult process, and commercial platers are unlikely to be able to achieve plating with good adhesion. We are able to plate NdFeB using vacuum deposition techniques, with cadmium chromate or aluminum chromate materials. Tin plating, or nickel plating is also possible, although longer lead times or higher volumes may be required for these. A variety of non metallic coatings have also been successfully developed for NdFeB, exhibiting good corrosion resistance characteristics. For especially harsh environments, it may be advisable to use a combination of coating techniques, or to encapsulate the material in a sealed housing.

MACHINING

SmCo is extremely brittle, and highly prone to chipping and cracking. Special machining techniques must be used to machine this material. Some machining operations may be performed on NdFeB materials using carbide tools, although surface finishes thus obtained may be less than optimal.

We are fully equipped to machine both these materials to your blueprint specifications.

Bonded NdFeB is easily machined. Coolants must be used while machining this material in order to avoid spontaneous combustion of powder. Machining this material removes a layer of protective coating, and re-coating for corrosion resistance may be necessary.

MAGNETIZING AND HANDLING

Rare Earths require extremely high magnetizing fields and special consideration must be given to this when designing complex assemblies, if it is intended to magnetize after assembly. Consult us if you foresee any problems. Due to their very high coercivities, these materials, unlike Alnicos, may be magnetized prior to assembly without any loss of magnetization.

Rare Earth materials are mechanically weak, and magnetically very strong. They must therefore be handled very carefully to avoid damage and injury to personnel handling the magnets. Receiving and assembly personnel should be warned about the dangers of handling magnetized Rare Earth magnets.

Isotropic bonded NdFeB materials can be magnetized in any direction, or with multiple poles. Special magnetizing fixtures are required in order to achieve multiple pole magnetization. Such multiple pole fixtures may cost several thousand dollars depending on complexity of design and production rate requirements.

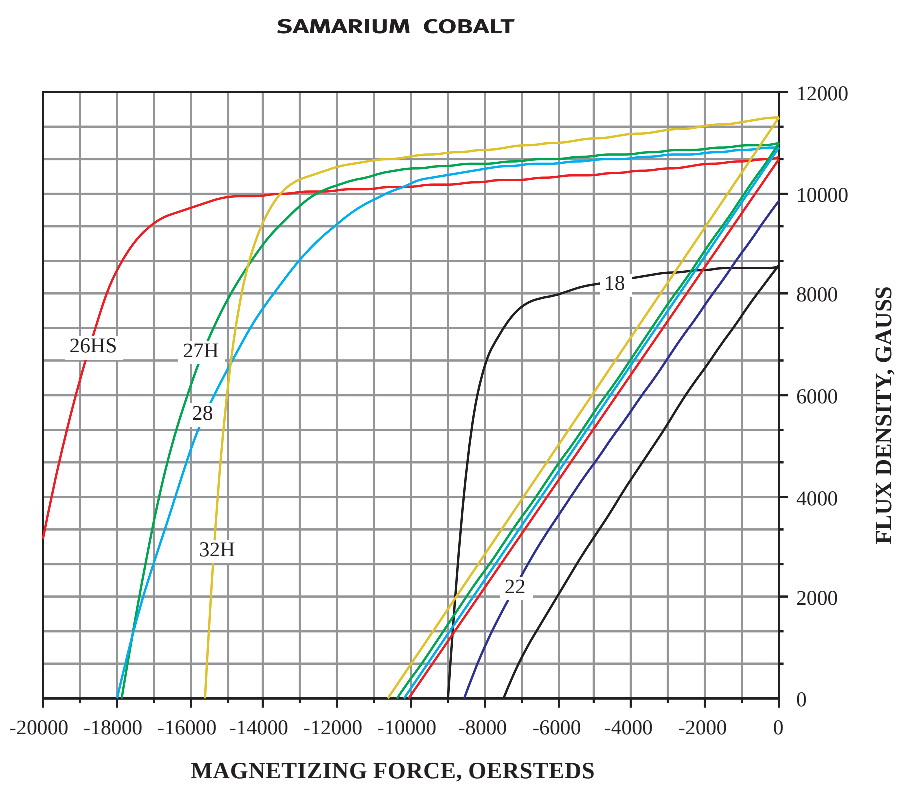
TEMPERATURE EFFECTS

SmCo magnets withstand higher temperatures than do NdFeB magnets. Magnetic properties of NdFeB deteriorate rapidly above about 130 degrees Centigrade, depending on the grade of material, and the permeance coefficient of the magnet in operation. The higher the permeance coefficient the magnet operates at, the higher the *temperature it will withstand. High H_{ci} NdFeB materials operating at a high permeance coefficient can operate to about 180 degrees Centigrade.*

SmCo magnets can operate at temperatures up to 350 degrees Centigrade, again depending upon the grade and permeance coefficient. Sm_2Co_{17} materials exhibit superior temperature characteristics as compared to the Sm_1Co_5 types.

COMMON APPLICATIONS FOR RARE EARTH MAGNETS

Holding systems requiring very high holding forces, high performance stepper, DC, servo, linear, and voice coil motors, magnetic bearings, magnetic couplings, loudspeakers, headphones, microphones, magnetic separation, instrumentation, switches, relays, magnetic resonance, sputtering, vacuum deposition, charges particle beam guidance, particle accelerators, undulators, wigglers.



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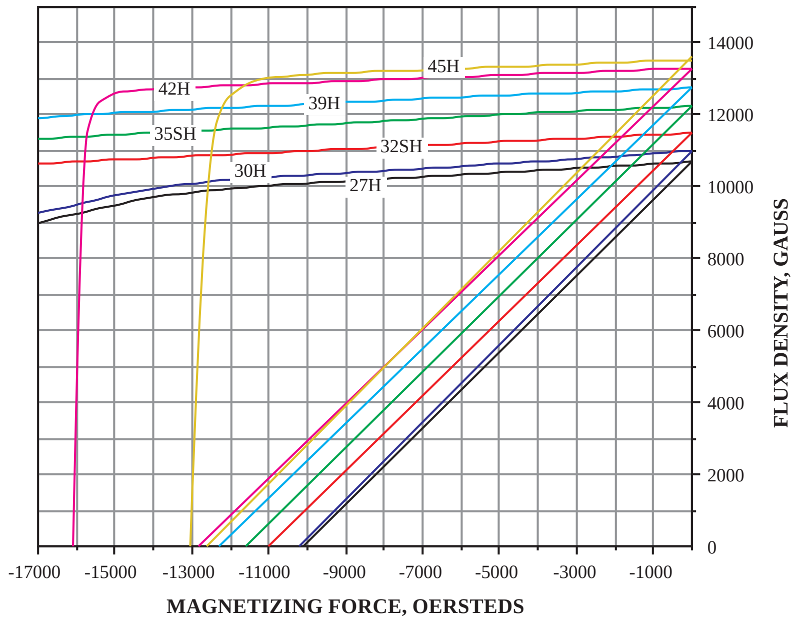
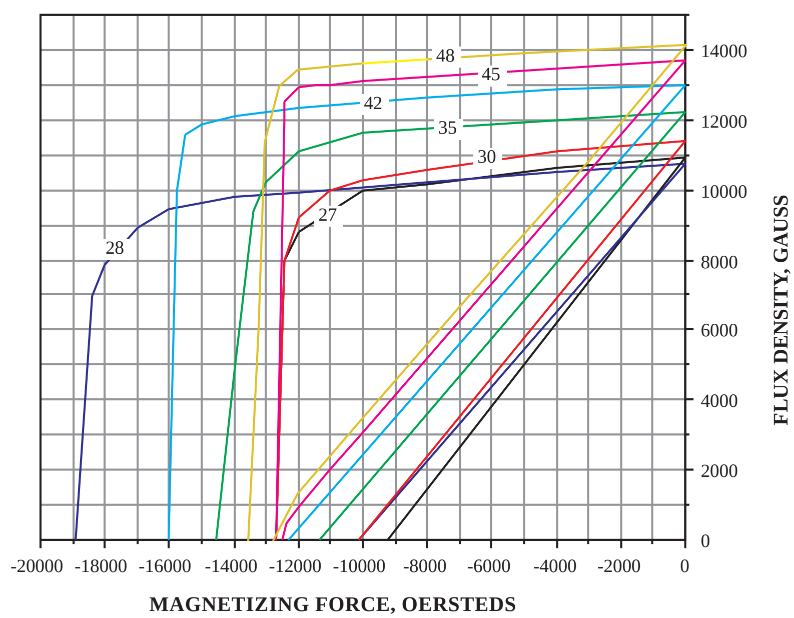
HIGH COERCIVITY NEODYMIUM IRON BORON



STANDARD NEODYMIUM IRON BORON



magnet SALES & MANUFACTURING INC.

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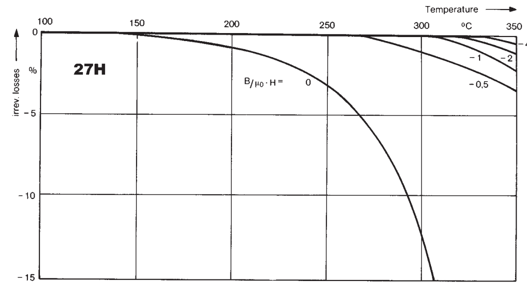
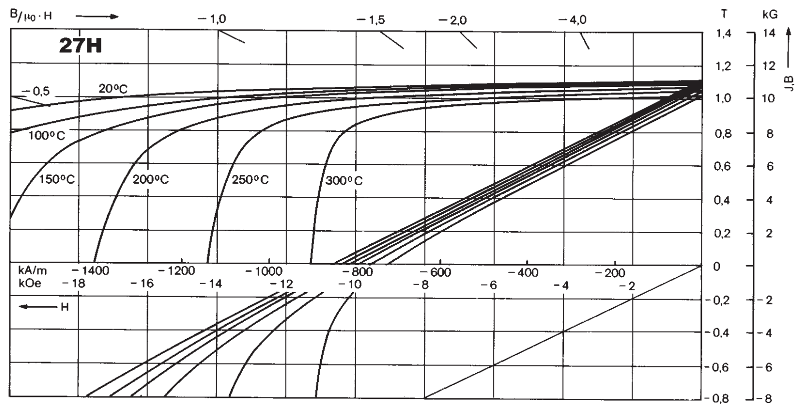
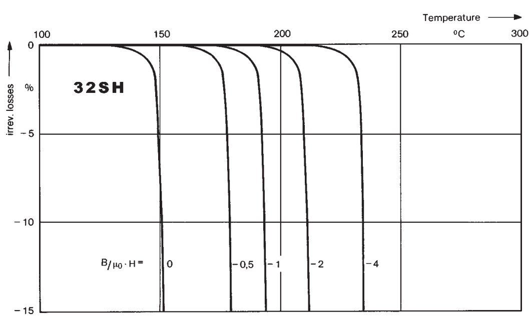
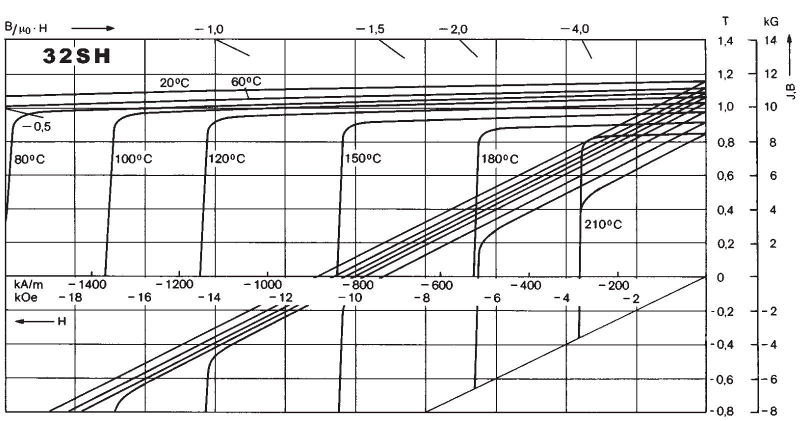
SmCo 27H	TYPICAL	MINIUM
B_r (Gauss)	11,000	10,300
H_c (Oersteds)	10,300	9,000
H_{ci} (Oersteds)	26,000	20,000
BH_{max} (MGOe)	28	24

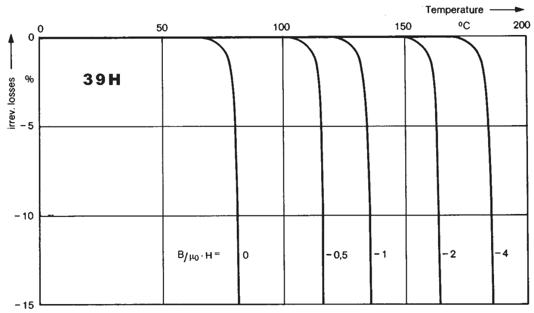




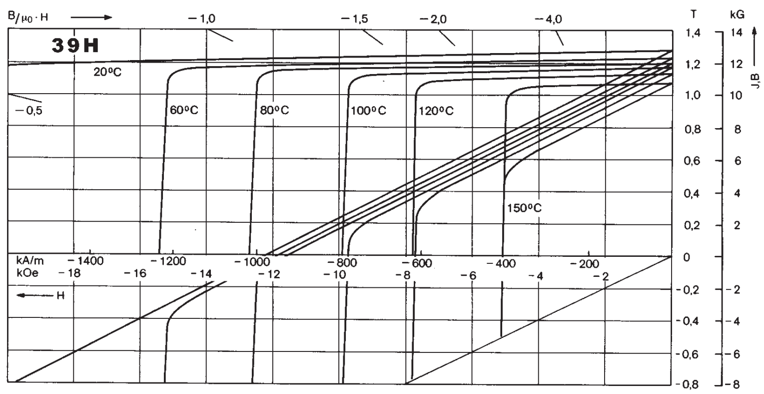


NdFeB 32SH	TYPICAL	MINIUM
B_r (Gauss)	11,600	11,000
H_c (Oersteds)	11,100	10,300
H_{ci} (Oersteds)	31,000	27,000
BH_{max} (MGOe)	32	28

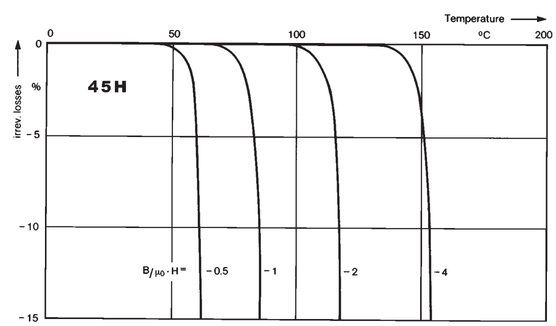


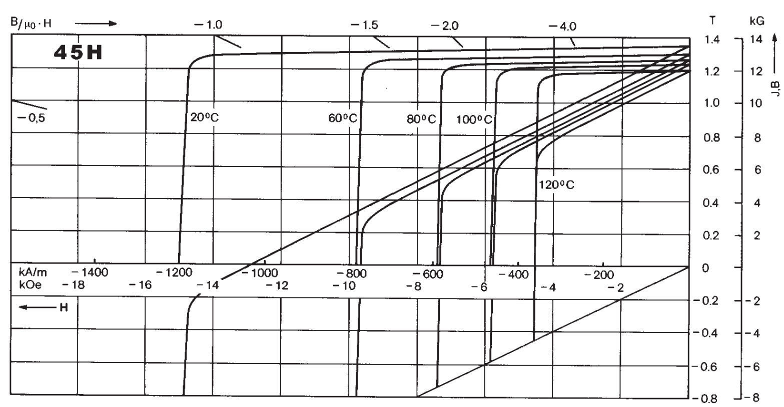


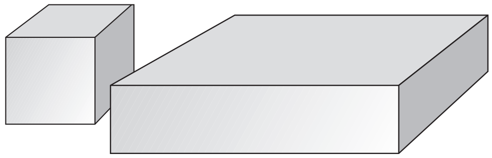
NdFeB 39H	TYPICAL	MINIUM
B_r (Gauss)	12,800	12,200
H_c (Oersteds)	12,300	11,400
H_{ci} (Oersteds)	21,000	19,000
BH_{max} (MGOe)	40	34.5

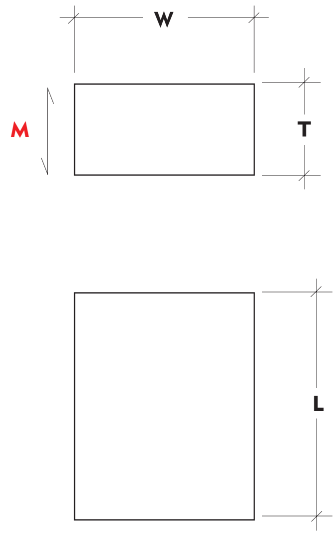


NdFeB 45H	TYPICAL	MINIUM
B_r (Gauss)	13,500	13,200
H_c (Oersteds)	12,900	12,100
H_{ci} (Oersteds)	15,000	14,000
BH_{max} (MGOe)	45	42









Die Pressed Blocks

PART NUMBER	L	W	T	CONDITION
27HNE686835	1.07	1.07	0.56	AS SINTERED
27HNE742432	2.72	1.93	0.55	AS SINTERED
28NE603505	0.940	0.560	0.080	FINISHED
28NE2812832	2.000	2.000	0.500	FINISHED
28UHN502538	1.97	0.79	2.09	AS SINTERED
30NE323232	0.500	0.500	0.500	FINISHED
30NE646432	1.000	1.000	0.500	FINISHED
30NE2812832	2.000	2.000	0.500	FINISHED
30NE2812864	2.000	2.000	1.000	FINISHED
30HNE286477	1.00	2.00	1.20	AS SINTERED
35NE111111	0.175	0.175	0.175	FINISHED
35NE301412	0.475	0.230	0.195	FINISHED
35NE501212	0.790	0.195	0.195	FINISHED
35NE602814	0.945	0.435	0.215	FINISHED
35NE603514	0.945	0.550	0.215	FINISHED
35NE642424	1.000	0.375	0.375	FINISHED
35NE646432	1.000	1.000	0.500	FINISHED
35NE209620	1.500	0.305	0.305	FINISHED
35NE281107	2.000	0.170	0.107	FINISHED
35NE2812832	2.000	2.000	0.500	FINISHED
39HNE646496	1.000	1.000	1.500	FINISHED
40NE2312334	1.92	1.92	2.10	AS SINTERED
45NE499693	2.34	1.50	1.47	AS SINTERED

Isostatically Pressed Blocks

PART NO.	L	W	T	CONDITION
28NE28128RL	2.00	2.00	7.00	AS SINTERED
32SHNE9854RL	4.09	2.32	11.00	AS SINTERED
35SHNE9854RL	4.09	2.32	11.00	AS SINTERED
39HNE10650RL	4.17	2.05	11.00	AS SINTERED
39HNE70287RL	4.45	1.14	11.00	AS SINTERED
39HNE8062RL	3.27	2.52	11.00	AS SINTERED
42HNE9854RL	4.09	2.32	11.00	AS SINTERED
45HNE9854RL	4.09	2.32	11.00	AS SINTERED
48HNE9854RL	4.09	2.32	11.00	AS SINTERED

First two digits in part number indicate grade of material.
As sintered blocks are generally used to fabricate custom magnets by cutting and grinding to specifications.
Special assemblies fabricated to order.
All materials are oriented through the "T" dimension.
Dimensions shown in inches. See page 1-2 for tolerance information.

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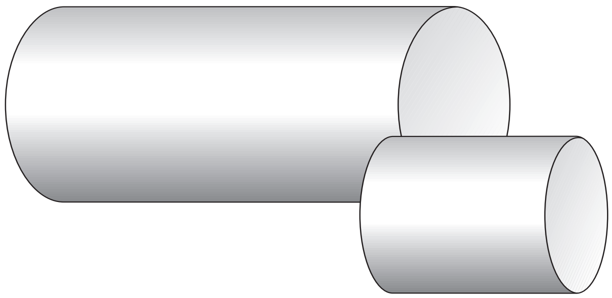
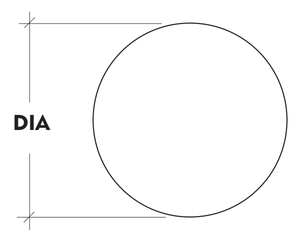
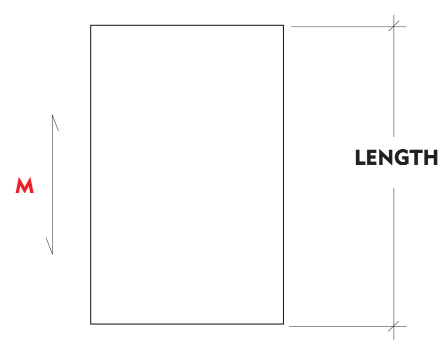
NEODYMIUM IRON BORON
RODS



PART NUMBER	DIA	LENGTH	CONDITION
35NERR16-2	0.250	2.000	FINISHED
35NERR24-2	0.375	2.000	FINISHED
39HNERR32	0.500	1.250	FINISHED
39HNERR40	0.630	1.250	FINISHED
39HNERR64	1.03	10.00	AS SINTERED
39HNERR103	1.61	10.00	AS SINTERED
35NERR128	2.00	6.00	AS SINTERED
39HNERR126	2.09	10.00	AS SINTERED
39HNERR166	2.60	10.00	AS SINTERED
35NERR192	3.00	6.00	AS SINTERED
39HNERR212	3.31	10.00	AS SINTERED
35NERR256	4.00	6.00	AS SINTERED
39HNERR265	4.14	10.00	AS SINTERED





First two digits in part number indicate grade of material.
As sintered rods are generally used to fabricate custom magnets by cutting and grinding to specifications.
All materials are oriented through the "Length" dimension.
Dimensions shown in inches.
See page 1-2 for tolerance information.

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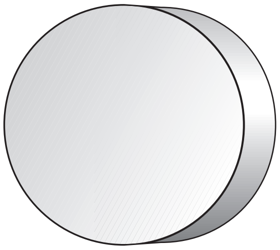
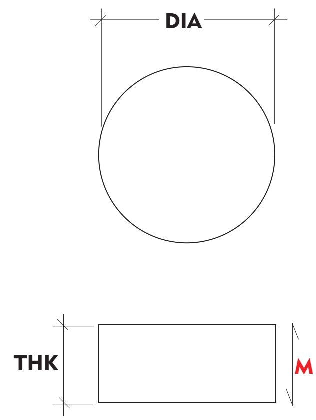


Discs

PART NO.	DIA	THK
35DNE0802	0.138	0.040
35DNE0905	0.138	0.077
35DNE1002	0.157	0.040
35DNE1005	0.157	0.077
28DNE1606	0.250	0.100
30DNE1606	0.250	0.100
28DNE1613	0.250	0.200
35DNE1616	0.250	0.250
35DNE1832	0.281	0.500
24DNE2016	0.312	0.250
24DNE2404	0.375	0.060
28DNE2404	0.375	0.060
24DNE2406	0.375	0.100
27DNE2412	0.375	0.187
27DNE2413	0.375	0.200
27DNE2416	0.375	0.250

Discs

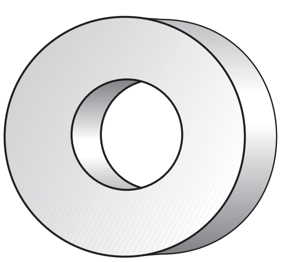
PART NO.	DIA	THK
27DNE3208	0.500	0.125
27DNE3213	0.500	0.200
27DNE3216	0.500	0.250
24DNE3224	0.500	0.375
27DNE3232	0.500	0.500
35DNE4824	0.750	0.375
35DNE4848	0.750	0.750
35DNE5624	0.875	0.375
27DNE5629	0.875	0.450
27DNE5664	0.875	1.000
28DNE6412	1.000	0.187
35DNE6416	1.000	0.250
28DNE6424	1.000	0.375
35DNE6424	1.000	0.375
24DNE6432	1.000	0.500
27DNE6432	1.000	0.500
27DNE6448	1.000	0.750
35DNE6448	1.000	0.750
35DNE12832	2.000	0.500

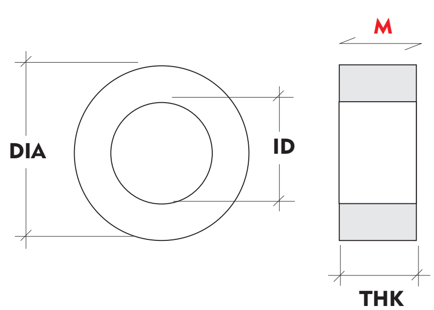


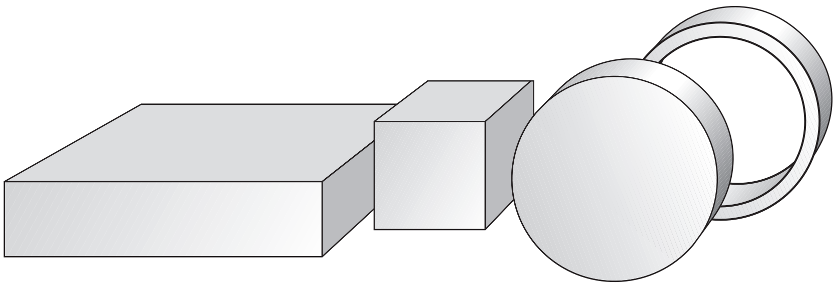
First two digits in part number indicate grade of material.
All parts shown have been finished by grinding the thickness dimensions.
Special assemblies fabricated to order.
All materials are oriented through the thickness.
Dimensions shown in inches. See page 1-2 for tolerance information.

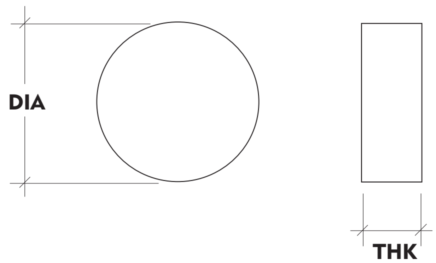
Ring

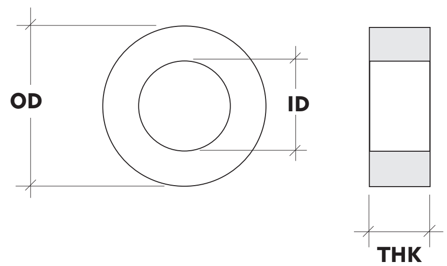
PART NO.	OD	ID	THK
24NEG240804	0.375	0.125	0.060

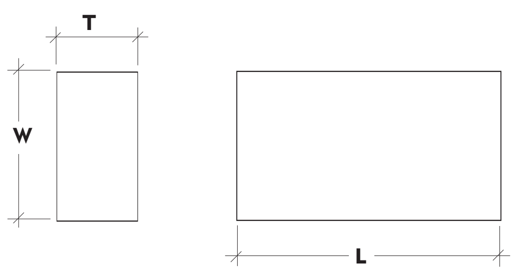












Standard material is grade B10N. Magnetic properties can be engineered to suit application: any energy product from 1 to 10 can be manufactured on special request.
Special assemblies fabricated to order.
These materials are isotropic and may be magnetized in any direction.
Multiple pole magnetization requires special magnetizing fixtures.
Dimensions shown in inches.
See page 1-2 for tolerance information.

Discs

GRADE B10N

PART NO.	DIA	THK
NB003C	0.080	0.197
NB003A	0.080	0.394
NB001C	0.118	0.138
NB001A	0.118	0.275
NB002A	0.157	0.275
NB002B	0.157	0.394
NB005E	0.197	0.080
NB005D	0.197	0.157
NB005B	0.197	0.197
NB008A	0.236	0.079
NB008B	0.236	0.157
NB012A	0.394	0.197
NB012C	0.394	0.252
NB012B	0.394	0.394
NB013B	0.492	0.394
NB015D	0.590	0.394
NB017B	0.787	0.303
NB017F	0.787	0.335
NB019B	0.984	0.394
NB019C	0.984	0.591

Rings

GRADE B10N

PART NO.	OD	ID	THK
NB048B	1.180	0.630	0.394
NB025A	1.370	0.827	0.394

Rectangles

GRADE B10N

PART NO.	L	W	T
NB022B	0.394	0.197	0.197
NB042A	1.969	0.394	0.472
NB042B	1.969	0.394	0.394
NB042C	1.969	0.394	0.197
NB042D	1.969	0.394	0.080
NB043A	1.181	1.181	0.197
NB043B	1.181	1.181	0.394
NB043I	1.181	1.181	0.080
NB043K	1.181	1.181	0.748
NB053A	0.807	0.303	0.150
NB053B	0.807	0.303	0.275
NB081G	1.970	1.970	1.000

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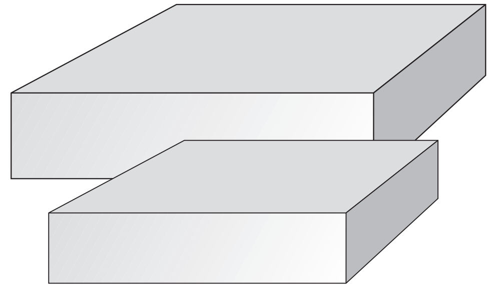
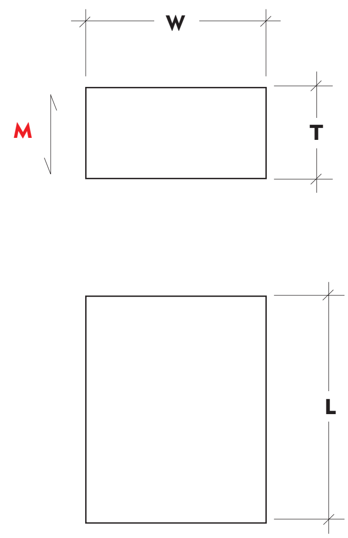
PART NO.	L	W	T	CONDITION
GRADE 18, TYPE 1:5				
RE100404	0.160	0.055	0.055	FINISHED
RE2812808	2.000	2.000	0.125	AS SINTERED
RE2812812	2.000	2.000	0.187	AS SINTERED
RE2812816	2.000	2.000	0.250	AS SINTERED
RE2812824	2.000	2.000	0.375	AS SINTERED
RE2812832	2.000	2.000	0.500	AS SINTERED
RE9854RL	4.09	2.32	11.0	AS SINTERED
GRADE 22, TYPE 1:5				
22RE2812732	1.98	1.98	0.50	AS SINTERED
GRADE 26, TYPE 2:17				
26RE468802	2.29	1.37	1.60	AS SINTERED
26RE5311108	2.40	1.80	1.70	AS SINTERED
26RE801203	1.250	0.190	0.056	FINISHED
26RE1236044	1.95	0.95	0.69	AS SINTERED
GRADES 27, 28 & 32, TYPE 2:17				
27HRE7558RL	2.95	2.28	11.00	AS SINTERED
27HRE151101RL	2.36	1.57	10.50	AS SINTERED
28RE5311108	2.40	1.80	1.70	AS SINTERED
32RE468802	2.29	1.37	1.60	AS SINTERED
BONDED SMCO GRADE B15				
B15S1283228	2.000	0.500	0.437	FINISHED





As sintered blocks are generally used to fabricate custom magnets by cutting and grinding to specifications.
Special assemblies fabricated to order.
All materials are oriented through the "T" dimension.
Dimensions shown in inches. See page 1-2 for tolerance information.

magnet SALES & MANUFACTURING INC.

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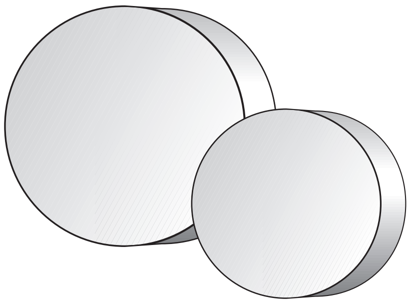
SAMARIUM COBALT
DISCS



GRADE 18, TYPE 1:5

PART NO.	DIA	THICKNESS
18DRE0606	0.100	0.100
18DRE0704	0.118	0.060
18DRE0707	0.118	0.118
18DRE0903	0.138	0.050
18DRE1004	0.156	0.060
18DRE1204	0.187	0.060
18DRE1303	0.200	0.046
18DRE1304	0.200	0.060
18DRE1604	0.250	0.060
18DRE1606	0.250	0.100
18DRE1608	0.250	0.125
18DRE1613	0.250	0.200

GRADE 18, TYPE 1:5

PART NO.	DIA	THICKNESS
18DRE1616	0.250	0.250
18DRE1618A	0.256	0.285
18DRE2008	0.312	0.125
18DRE2404	0.375	0.060
18DRE2408	0.375	0.125
18DRE3204	0.500	0.060
18DRE3208	0.500	0.125
18DRE3216	0.500	0.250
18DRE4008	0.625	0.125
18DRE4816	0.750	0.250
18DRE4824	0.750	0.375
18DRE12832	2.000	0.500

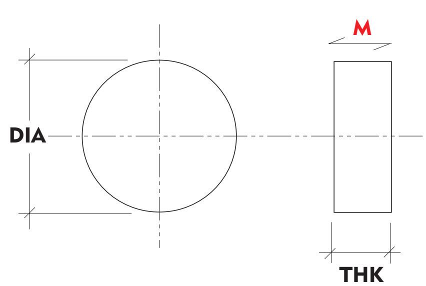
First two digits in part number indicate grade of material.
All parts shown have been finished by grinding the thickness dimension.
Special assemblies fabricated to order.
All materials are oriented through the thickness.
Dimensions shown in inches.
See page 1-2 for tolerance information.

GRADE 26, TYPE 2:17

PART NO.	DIA	THICKNESS
26DRE1604	0.250	0.060
26DRE1608	0.250	0.125
26DRE1616	0.250	0.250
26DRE2404	0.375	0.060
26DRE2408	0.375	0.125

GRADE 26, TYPE 2:17

PART NO.	DIA	THICKNESS
26BDRE2424	0.375	0.375
26DRE3208	0.500	0.125
26DRE3216	0.500	0.250
26DRE4816	0.750	0.250
26DRE4824	0.750	0.375



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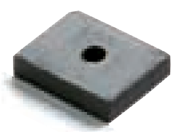
SECTION 2
CERAMIC MAGNETS

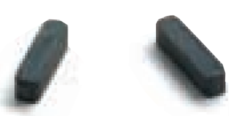


Ceramic magnets are sintered permanent magnets composed of Barium or Strontium Ferrite. This class of magnets, aside from good resistance to demagnetization, has the popular advantage of low cost.

Ceramic magnets are very hard and brittle, and require specialized machining techniques. Moreover, they should be machined in an unmagnetized state. We are equipped to machine these materials to specifications.

Anisotropic grades are oriented in the manufacturing direction, and must be magnetized in the direction of orientation. Isotropic grades are not oriented and can be magnetized in any direction, although some degree of greater magnetic strength will be found in the pressing dimension, usually the shortest dimension.

Due to their low cost, Ceramic magnets enjoy a very wide range of applications, from motors and loudspeakers to toys and crafts, and are the most widely used permanent magnets today.



TOLERANCES

1. Blocks

Tolerances on blocks are the greater of ± 3% or ± 0.045" on cross sectional dimensions, and ± 0.005" on the orientation direction.

2. Discs and Rings

Tolerances on diameters are the greater of ± 1.5% or ± 0.015", and the greater of ± 1% or ± 0.010" on lengths.

SHAPES, SIZES, AND GRADES AVAILABLE

In addition to the stock shapes, sizes, and grades listed in the catalog, others are available. Please inquire. Non standard shapes and sizes can be fabricated to blueprint specifications from raw stock.

ASSEMBLIES

We are able to manufacture metal and other components of finished sub assemblies using our CNC machining facilities.

Assemblies using metal or other components and magnets can be fabricated by adhering magnets with adhesives to suit a range of environments, by mechanically fastening magnets, or by a combination of these methods. Due to the relatively brittle nature of these magnet materials, press fits are not recommended.

SURFACE TREATMENTS

The corrosion resistance of Ceramic is considered "excellent", and no surface treatments are required. However, Ceramic magnets may have a thin film of fine magnet powder on the surface and for clean, non-contaminated applications, some form of coating may be required.

MACHINING

Ceramic is brittle, and prone to chipping and cracking. Special machining techniques must be used to machine this material. We are fully equipped to machine these materials to your blueprint specifications.

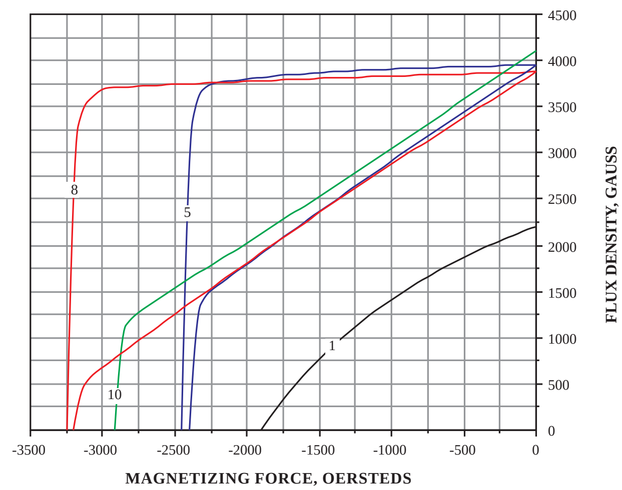
MAGNETIZING AND HANDLING

Ceramic magnets require magnetizing fields of about 10 KOe. They can be magnetized with multiple poles on one or both pole surfaces. No special handling precautions are required, except that large blocks of Ceramic magnets are powerful, and care should be taken to ensure that they do not snap towards each other.

TEMPERATURE EFFECTS

Up to about 840° F, changes in magnetization are largely reversible, while changes between 840° F and 1800° F are remagnetizable. For all Ceramic magnets, the degradation of magnetic properties is essentially linear with temperature. At 350° F, about 75% of room temperature magnetization is retained, and at 550° F, about 50% is retained.

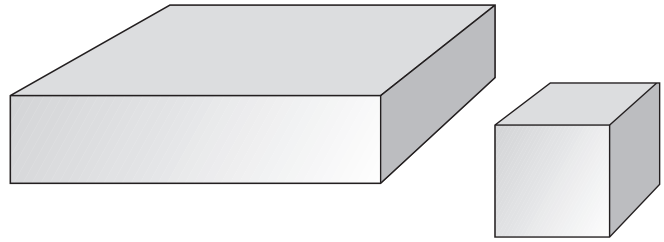
CERAMIC

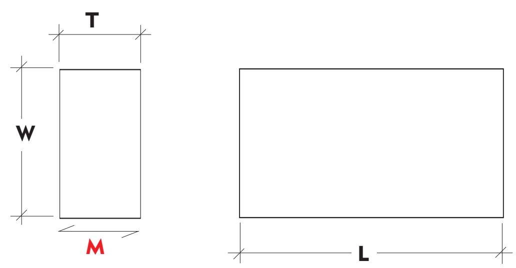


Ceramic Grade 8

PART NO.	L	W	T
F83208	3.00	2.00	0.125
F84410	4.00	4.00	0.157
F83212	3.00	2.00	0.185
F84416	4.00	4.00	0.250
F86416	6.00	4.00	0.250
F86424	6.00	4.00	0.375
F86232	6.00	2.00	0.500
F86432	6.00	4.00	0.500
F106432†	6.00	4.00	0.500
F810332	10.63	3.50	0.500
F86448	6.00	4.00	0.750
F810348	10.63	3.50	0.750
F86456	6.00	4.00	0.875
F86464	6.00	6.00	1.000

† Ceramic Grade 10 material





Ceramic Grade 5

PART NO.	L	W	T
55B2007512	1.94	0.74	0.125
55B756216¤	0.75	0.63	0.165
55B1007518*	1.00	0.75	0.177
55B872218	0.88	0.23	0.187
55B973120	0.98	0.31	0.200
55B1173523	1.18	0.36	0.235
21987	1.37	0.74	0.270
55B505037	0.50	0.50	0.375
21988	1.75	0.88	0.387
21989	1.88	0.88	0.387
21990**	1.88	0.88	0.387
55B1002539	1.00	0.25	0.390
55B2002539	2.00	0.25	0.390
55B1001350	1.00	0.13	0.500
55B1007550	1.00	0.75	0.500

¤ with .13 diameter centerhole

* with .19 diameter centerhole

** with 2 x .187 countersunk holes,
1.00” between centers

Custom sizes and shapes fabricated to specifications.
Special assemblies fabricated to order.
All materials are oriented through the “T” dimension.
Dimensions shown in inches. See page 2-2 for tolerance information.

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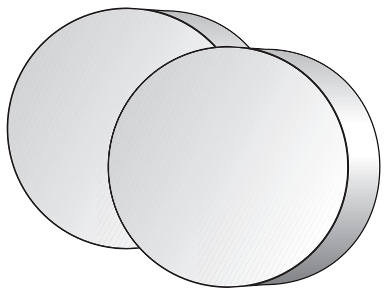


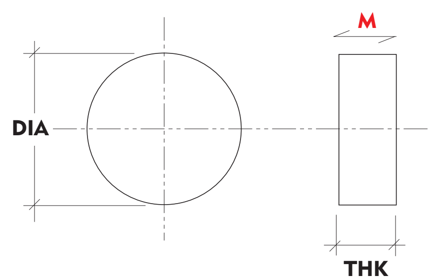
Ceramic Grade 5

PART NO.	DIA	THK
42B3112	0.31	0.13
42B3725	0.37	0.25
42B4915	0.49	0.15
42B5020	0.49	0.20
42B5023	0.50	0.23
42B5612-M1	0.56	0.13
42B7525-M1	0.71	0.20
42B7525-M5†	0.71	0.20
42B7528	0.71	0.25
42B7512	0.75	0.13
F50566	0.87	1.00
42B10015-M1	0.98	0.16
42B10015-M5†	0.98	0.16
42B10027	1.00	0.27

† Magnetized multiple poles on one surface

Ceramic Grade 8

PART NO.	DIA	THICKNESS
42C5075	0.50	0.750
42C3742	0.58	0.655
42C11225	1.13	0.250
42C7321	1.15	0.330



Custom sizes and shapes fabricated to specifications.
Special assemblies fabricated to order.
All materials are oriented through the thickness dimension.
Multiple pole magnetization available.
Dimensions shown in inches. See page 2-2 for tolerance information.

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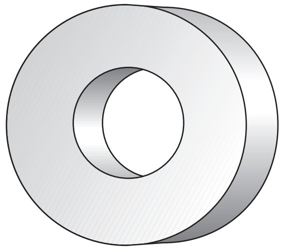

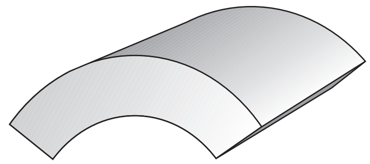

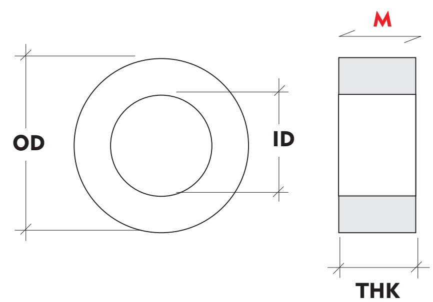

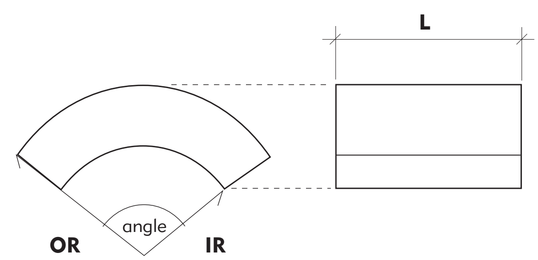

Ceramic Grade 5 Rings

PART NO.	OD	ID	THK
63B0552220	0.55	0.23	0.200
63B06929118	0.69	0.29	0.118
63B1150250	1.18	0.50	0.250
63B12526233	1.25	0.26	0.330
63B1253719	1.25	0.38	0.188
63B1554250	1.50	0.54	0.250
63B1787225	1.77	0.87	0.225
63B20866394	2.00	0.87	0.394
63B2016130	2.00	1.69	0.130
63B2180270	2.10	0.80	0.270
63B2198197	2.16	0.98	0.197
63B2312276	2.36	1.26	0.276
F639	2.36	0.95	0.276
63B23710028	2.37	1.00	0.275
63B23710037	2.38	1.00	0.375
63B2312352	2.39	1.26	0.352
63B2711325	2.79	1.19	0.325
63B3312425	3.37	1.28	0.425
63B43177425	4.33	1.77	0.425
63B8246750	8.35	4.66	0.750
63B8643866	8.66	4.33	0.866

Ceramic Grade 5 Arcs

PART NO.	OR	IR	L	ANGLE
C5A613868	0.96	0.72	1.06	120°

Custom sizes and shapes fabricated to specifications.
Ring magnets can be magnetized with multiple poles on one or both pole faces.
Special assemblies fabricated to order.
Ring magnets are oriented through the thickness dimension.
Arc magnets are oriented radially.
Dimensions shown in inches. See page 2-2 for tolerance information.

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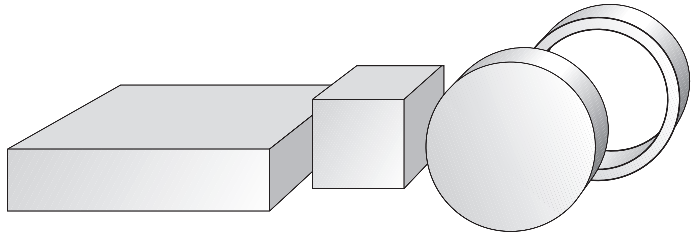
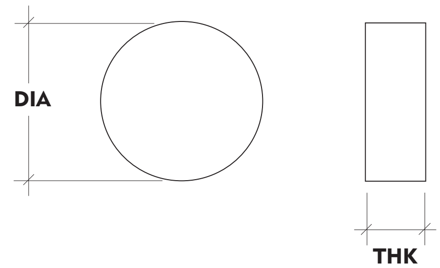


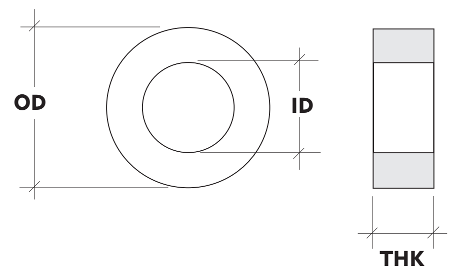
Discs

PART NO.	DIA	THK
42A4744	0.47	0.438
42A5015-M1	0.50	0.150
42A5018	0.50	0.187
42A6218	0.63	0.187
42A7525-M3†	0.75	0.250
42A10725	1.08	0.250
42A13028	1.30	0.280
42A15019-M5†	1.50	0.187



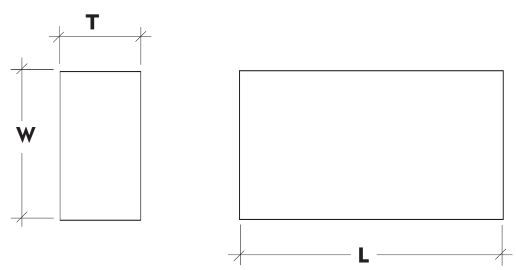
Rings

PART NO.	OD	ID	THK
63A180618	0.19	0.06	0.187
63A500925	0.50	0.09	0.250
63A501812	0.50	0.19	0.125
63A752725	0.75	0.26	0.250
63A1047925	1.04	0.80	0.250
F403	1.08	0.60	0.250
63A1082113	1.08	0.22	0.135
63A1123925	1.13	0.40	0.250
63A1095025	1.13	0.50	0.250
63A1132250	1.13	0.22	0.500
63A1181112	1.19	0.12	0.125
63A1770375	1.71	0.71	0.375



Rectangles

PART NO.	L	W	T
55A2007512B†	1.95	0.75	0.125
55A705915	0.71	0.60	0.157



† Magnetized multiple poles one surface

Custom sizes and shapes fabricated to specifications. Ceramic 1 materials are isotropic and may be magnetized in any direction. Multiple pole magnetization available.
Special assemblies fabricated to order.
Dimensions shown in inches. *See page 2-2 for tolerance information.*

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SECTION 3
ALNICO MAGNETS

Alnico materials, composed primarily of alloys of Aluminum, Nickel, and Cobalt are characterized by excellent temperature stabilities, high residual inductions, and relatively high energies. They are manufactured through either a casting or sintering process. Cast magnets may be manufactured in complex shapes, such as horseshoes, not possible with other magnet materials. Sintered Alnicos offer slightly lower magnetic properties but better mechanical characteristics than cast Alnicos.

Cast Alnico 5 is the most commonly used of all the cast Alnicos. This material is used extensively in rotating machinery, meters, instruments, sensing devices, and holding applications, to name a few.

Alnico is hard and brittle. Machining or drilling cannot therefore be accomplished by ordinary methods. Holes are usually cored in at the foundry, and magnets are cast close to final size and then finish machined to closer tolerances.

Alnico has a low coercive force, and is easily demagnetized if not handled with care. For optimum performance of Alnico 5, the magnetic length should be approximately 5 times the pole diameter or equivalent diameter. For example, a 0.250" diameter magnet should be about 1.250" long.

Because of its higher coercivity, Alnico 8 may be used in shorter le in disc shapes.

TOLERANCES

Tolerances on as cast dimensions are the greater of ± 1.5% or ± 0.015" on cross sectional dimensions, and ± 0.005" on finished dimensions. Tolerances on as sintered dimensions are the greater of ± 1.0% or ± 0.010" on cross sectional dimensions, and ± 0.005" on ground dimensions.

SHAPES, SIZES, AND GRADES AVAILABLE

In addition to the stock shapes, sizes, and grades listed in the catalog, others are available. Please inquire. Non standard shapes and sizes can be fabricated to blueprint specifications from raw stock.

ASSEMBLIES

We are able to manufacture metal and other components of finished sub assemblies using our CNC machining facilities.

Assemblies can be fabricated by adhering magnets with adhesives to suit a range of environments, by mechanically fastening magnets, or by a combination of these methods. Due to the relatively brittle nature of these magnet materials, press fits are not recommended.

SURFACE TREATMENTS

The corrosion resistance of Alnico is considered "excellent", and no surface treatments are required. However, Alnico magnets are easily plated for cosmetic reasons if required.

MACHINING

Alnico is hard and brittle, and prone to chipping and cracking. Special machining techniques must be used to machine this material. Holes must be made by EDM methods. We are fully equipped to machine these materials to your blueprint specifications.

MAGNETIZING AND HANDLING

Alnico magnets require magnetizing fields of about 3 KOe. Because of their relatively low coercivities, special care should be taken to assure that these magnets are not subjected to adverse repelling fields, since these could partially demagnetize the magnets. Magnetized magnets should be stored with "keepers" to reduce the possibility of partial demagnetization. If Alnicos are partially demagnetized, they may be easily remagnetized.

TEMPERATURE EFFECTS

Up to about 1,000° F, changes in magnetization are largely reversible and remagnetizable, while changes above this are largely structural and not fully reversible or remagnetizable. Approximately 90% of room temperature magnetization is retained at temperatures of up to 1,000° F.

MATERIAL CHARACTERISTICS

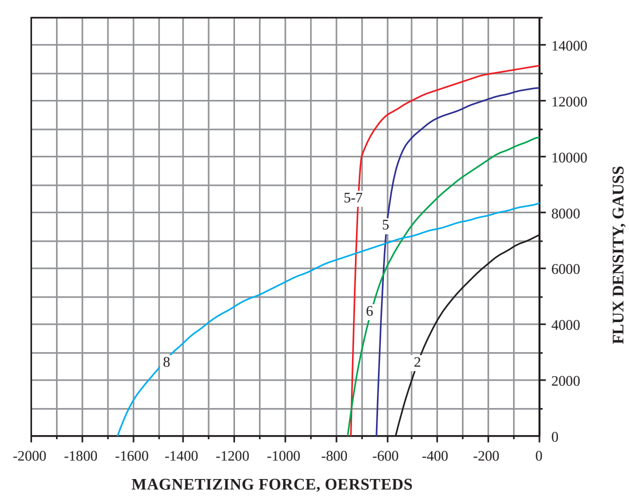
Cast Alnico materials commonly contain casting voids and hairline cracks within the material. These can be exposed by finish machining. The following is an extract from MMPA standards regarding such imperfections:

"These are materials used primarily for their magnetic capabilities as permanent magnets without regard to mechanical properties. These materials, prepared by good metallurgical practice, by their very nature will unavoidably contain a degree of physical imperfection. It is not generally recommended that these materials be used for structural or decorative purposes unless the physical requirements of the magnet are previously suitably specified."

HOLDING FORCE OR PULL DATA

All pull values shown in this catalog are approximate and offered only for comparison. They have been measured when pole surfaces are in contact with a 1/2" thick, ground, mild steel plate. Due to the nature of magnetism, it is very difficult to establish a definite holding force to fit all applications. We suggest that each customer make his own pull tables on an actual model.

ALNICO



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Centerless Ground Alnico 5 Rods

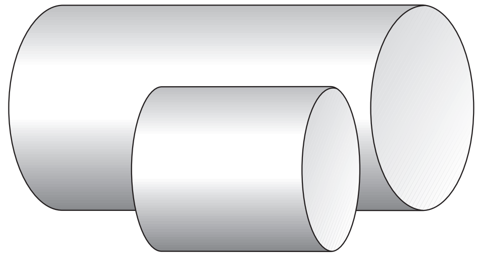
PART NO.	DIA	LENGTH
CG701	0.062	L
CG702	0.093	L
CG704	0.187	L
CG704-750	0.187	0.750
M7103	0.187	1.000
CG705	0.250	L
CG705-750	0.250	0.750
CG706	0.312	L
CG706-1000	0.312	1.000
CG706-1500	0.312	1.500
CG707	0.375	L
CG709	0.500	L

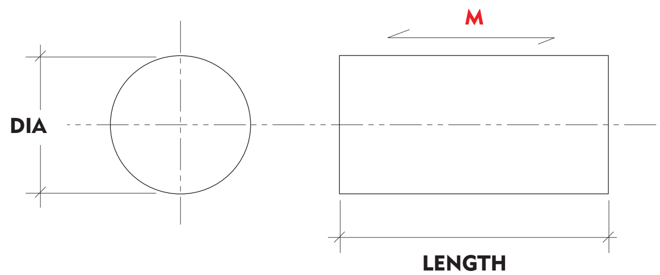
As Cast Alnico 5 Rods

PART NO.	DIA	LENGTH	
RR8	0.125	L	
RR10	0.150	L	
57RR12	0.184	1.600	Alnico 5-7
RR13	0.203	L	
RR16	0.250	L	
RR16-1000	0.250	1.000	
RR24	0.375	L	
RR24-1500	0.375	1.500	
RR32	0.500	L	
RR32-2500	0.500	2.500	
57RR33	0.520	2.330	Alnico 5-7
RR40	0.625	L	
RR48	0.750	L	
RR64	1.000	L	

As Cast Alnico 8 Rods

PART NO.	DIA	LENGTH
8RR6G	0.100	L
8RR8	0.125	L
8RR16	0.250	L
8RR16-920	0.250	0.920
8RR24	0.375	L
8RR32	0.500	L
8RR48	0.750	L
8RR64	1.000	L





Alnico rod magnets are generally stocked in lengths which vary from about 4" to 12". Any length "L" can be cut and ground to specified dimensions and tolerances. Non standard diameters can be ground from stock sizes. All materials are oriented through the "Length" dimension. Dimensions shown in inches. Tolerance of diameter of centerless ground rods is ± 0.001". See page 3-2 for other tolerance information.

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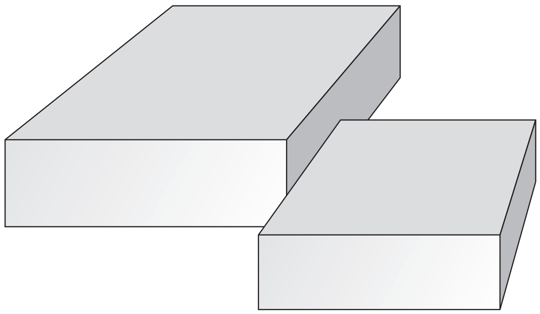

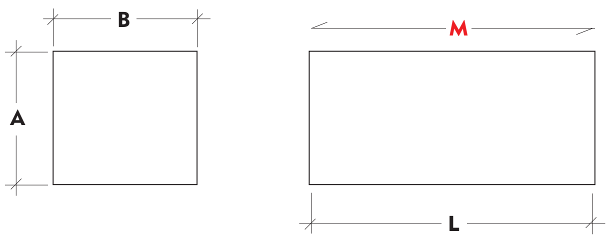

Cast Alnico 5 Bars

PART NO.	A	B	L
SB8	0.125	0.125	L
RB816	0.125	0.250	L
RB832	0.125	0.500	L
RB848	0.125	0.750	L
RB917	0.140	0.265	L
SB12	0.187	0.187	L
RB1348	0.203	0.765	L
SB16	0.250	0.250	L
SB16-1000	0.250	0.250	1.000
SB16-1250	0.250	0.250	1.250
RB1632	0.250	0.500	L
RB1648	0.250	0.750	L
RB1664	0.250	1.000	L
SB18	0.275	0.275	L
RB2210-450	0.350	0.156	0.450
SB32	0.500	0.500	L
RB3264	0.500	1.000	L
RB3296	0.500	1.500	L
SB48	0.750	0.750	L
SB64	1.000	1.000	L
SB128	2.000	2.000	L

Sintered Alnico 5 Bars

PART NO.	A	B	L
S5SB1672	0.240	0.240	1.125
S5SB432	0.062	0.062	0.500
S5SB448	0.062	0.062	0.750
S5SB838	0.125	0.125	0.600
S5SB848	0.125	0.125	0.750

Cast Alnico 8 Bars

PART NO.	A	B	L
8SB8	0.125	0.125	4.000
8RB824-820	0.125	0.375	0.820
8SB12	0.187	0.187	4.000
8SB16	0.250	0.250	4.000
8RB1632	0.250	0.500	4.000
8RB3248	0.500	0.750	4.000
8SB48	0.750	0.750	4.000
8RB4864	0.750	1.000	4.000

Sintered Alnico 8 Bars

PART NO.	A	B	L
S8RB816	0.125	0.250	0.500
S8SB0848	0.125	0.125	0.750

Alnico bar magnets are generally stocked in lengths which vary from about 4" to 12". Any length "L" can be cut and ground to specified dimensions and tolerances. Non standard cross sections can be ground from stock sizes.
All materials are oriented through the "Length" dimension.
Dimensions shown in inches.
See page 3-2 for other tolerance information.

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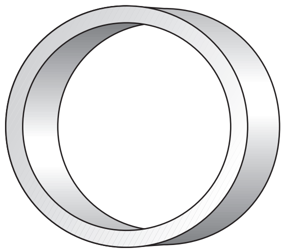
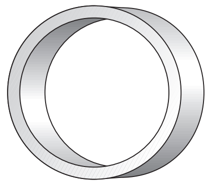




Cast Alnico 5 Rings

PART NO.	OD	ID	THK
ARG4816*	0.750	0.250	0.250
RG4909	0.780	0.375	0.150
RG6416	1.000	0.250	0.250
RG6417	1.000	0.250	0.500
RG6432	1.000	0.500	0.125
RG6440	1.000	0.625	0.500
RG6448	1.000	0.750	0.500
RG8016	1.250	0.250	1.259
RG8040	1.250	0.625	0.156
RG9624	1.500	0.375	0.750
RG9648	1.500	0.750	0.187
RG13096	2.030	1.500	0.250
RG26196	4.062	3.058	1.318
RG96128128	4.625	2.000	2.000
RG32160	5.000	2.500	2.950

Cast Alnico 6 Rings

PART NO.	OD	ID	THK
6RG3814*	0.600	0.221	0.135
6ARG6758*	1.050	0.375	0.906

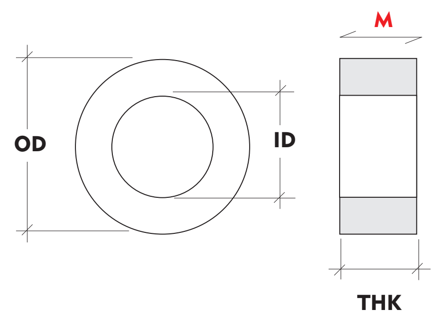
Cast Alnico 8 Rings

PART NO.	OD	ID	THK
8RG5632	0.875	0.505	0.187
8RG5830	0.910	0.475	0.270
8RG583318	0.910	0.520	0.275
8RG6731	1.040	0.480	0.270
8RG833611	1.300	0.570	0.170

Sintered Alnico 2 Rings

PART NO.	OD	ID	THK
S2RG3108G†	0.480	0.129	0.086
S2RG4016G†	0.625	0.245	0.250

* Oriented across diameter
† Isotropic



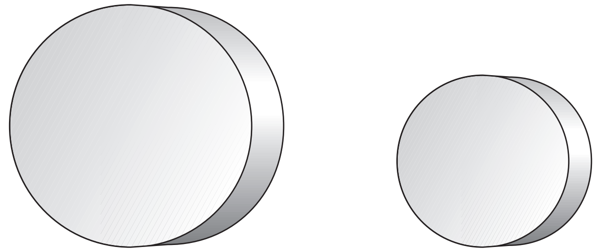
Non standard sizes can be ground from stock sizes.
All materials are oriented through the thickness dimension, unless otherwise specified. Sintered Alnico 2 materials are isotropic and may be magnetized in any direction.
Dimensions shown in inches.
See page 3-2 for other tolerance information.

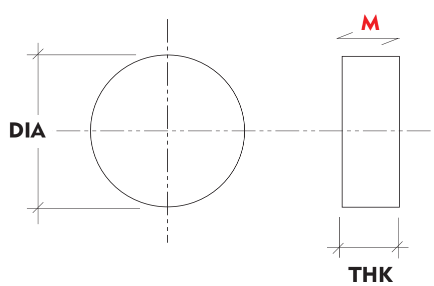
Cast Alnico 8 Discs

PART NO.	DIA	THK
C8D3213	0.500	0.200
C8D3232	0.500	0.500
C8D3822	0.600	0.345
C8D3935	0.610	0.550
C8D4538	0.700	0.600
C8D4815	0.750	0.240
C8D6416	1.000	0.250
C8D6424	1.000	0.375
C8D6432	1.000	0.500
C8D9632	1.500	0.500
C8D9718	1.515	0.275

Sintered Alnico 8 Discs

PART NO.	DIA	THK
S8D1213	0.187	0.200
S8D1606	0.250	0.100
S8D1608	0.250	0.125
S8D1616	0.250	0.250
S8D1629	0.250	0.450
S8D2407	0.375	0.106
S8D2408	0.375	0.125
S8D2409	0.375	0.144
S8D2413	0.375	0.200
S8D3208	0.500	0.125
S8D3210	0.500	0.150
S8D3215	0.500	0.240
S8D4010	0.625	0.150
S8D4806	0.750	0.100
S8D4810	0.750	0.160
S8D4816	0.750	0.250





Non standard sizes can be ground from stock sizes.
All materials are oriented through the thickness dimension.
Dimensions shown in inches.
See page 3-2 for tolerance information.

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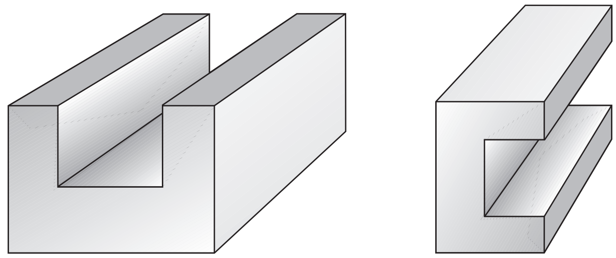
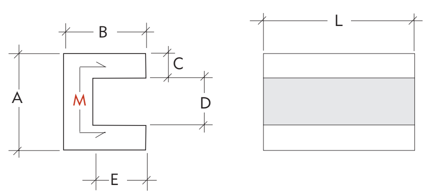


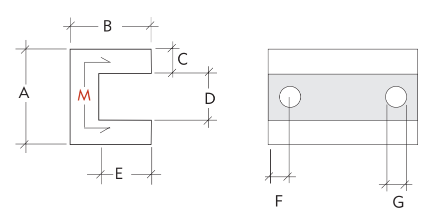
Alnico 5 Channels

TYPE	PART NO.	A	B	C	D	E	F	G	L	APPROX PULL
1	CH3220	0.50	0.31	0.16	0.19	0.13	-	-	6	10
1	CH3232	0.50	0.49	0.16	0.18	0.25	-	-	6	12
3	CH3728	0.58	0.45	0.25	0.17	0.19	0.63	0.16	4.75	22
1	CH4024	0.63	0.38	0.19	0.25	0.13	-	-	5	12
3	CH4435	0.69	0.55	0.19	0.31	0.30	2.00	0.22	9	32
1	CH4832	0.75	0.50	0.25	0.25	0.19	-	-	6	35
2	CH5648	0.88	0.75	0.25	0.38	0.44	-	-	6	40
1	CH6440	1.00	0.63	0.31	0.38	0.25	-	-	6	50
1	CH6448	1.00	0.75	0.31	0.38	0.38	-	-	6	55
1	CH8048	1.25	0.75	0.41	0.44	0.25	-	-	6	75
1	CH8064	1.25	1.00	0.41	0.44	0.50	-	-	6	80
4	CH8367	1.30	1.05	0.33	0.64	0.63	0.54	0.34	5.8	70
1	CH9656	1.50	0.88	0.50	0.50	0.31	-	-	6	85

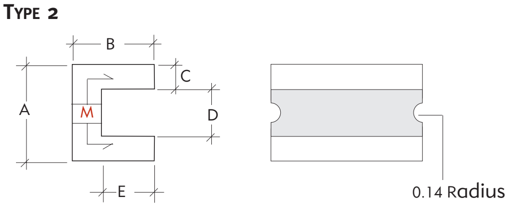
Type 1



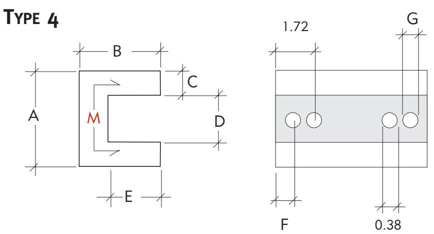
Type 3



Type 2



Type 4



Any lengths cut and ground to dimension and tolerance specifications.
All channels are oriented as a "U". Pole and back surfaces are ground, other surfaces are as cast.
Dimensions shown in inches. Pull figures shown in pounds.
See page 3-2 for tolerance information.

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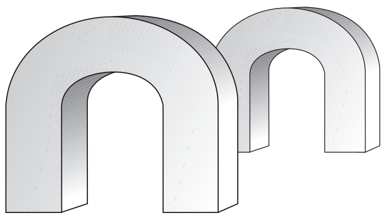


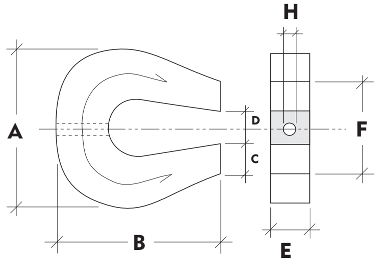
Alnico 5 Horseshoes

TYPE	PART NO.	A	B	C	D	E	F	H	APPROX PULL
3	HS3228	0.50	0.44	0.13	0.25	0.13	0.50	-	1
1	HS6659	1.02	0.92	0.30	0.24	0.34	0.84	0.13	5
2	HS8070	1.25	1.09	0.31	0.63	0.31	1.25	0.13	10
3	HS8078	1.25	1.22	0.19	0.38	0.25	0.75	-	6
3	HS8577	1.33	1.20	0.44	0.32	0.43	1.09	-	11
3	HS9680	1.50	1.25	0.44	0.38	0.44	1.25	-	15
3	HS11610	1.81	1.56	0.63	0.38	0.63	0.51	-	15
3	HS12120	1.88	1.88	0.63	0.63	0.68	1.88	-	33
3	HS12888	2.00	1.38	0.63	0.75	0.61	2.00	-	22
1	HS13924	2.15	1.93	0.62	0.51	0.70	1.76	0.16	25
3	HS15292	2.38	1.44	0.75	0.88	0.94	2.38	-	35

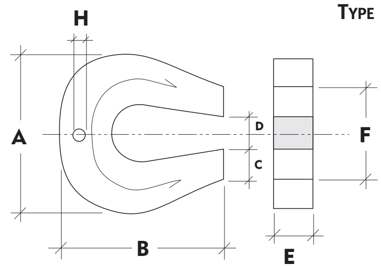
Alnico 5 Red Painted Horseshoes

TYPE	PART NO.	A	B	C	D	E	F	H	APPROX PULL
3	100-1	1.13	1.00	0.25	0.26	0.31	0.34	-	2
1	100-2	1.13	0.75	0.25	0.63	0.75	1.13	0.19	13
1	100-4	1.50	1.00	0.31	0.88	1.00	1.50	0.19	20
1	100-6	1.75	1.13	0.31	1.13	1.13	1.75	0.19	25
1	100-8	2.19	1.81	0.50	1.19	0.94	2.19	0.19	30
1	100-10	2.22	2.00	0.63	0.97	0.94	2.22	0.25	32
1	100-12	2.63	2.25	0.63	1.38	0.94	2.63	0.25	40
1	100-16	3.00	2.50	0.75	1.50	0.94	3.00	0.25	45
1	100-24	2.50	1.19	0.63	1.25	1.88	2.50	0.25	60

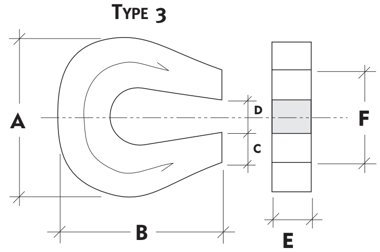
TYPE 1



TYPE 2



TYPE 3



All horseshoes are oriented as a “U”.
Pole surfaces are ground, other surfaces are as cast.
Dimensions shown in inches. Pull figures shown in pounds.
See page 3-2 for tolerance information.

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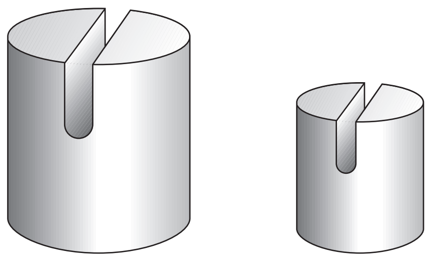


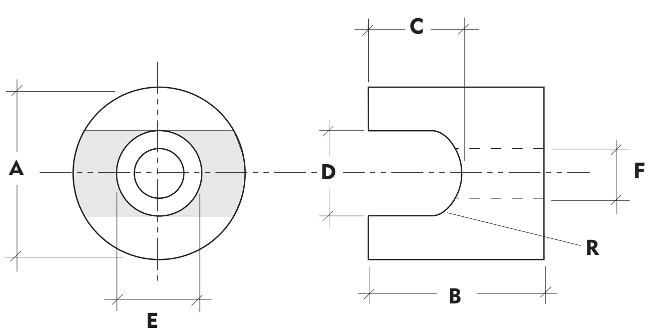
Alnico 5 Two Pole Round Horseshoes

PART NO.	A	B	C	D	E	F	R	PULL
HU2824	0.44	0.38	0.23	0.17	-	0.15	0.08	1
HU2828	0.44	0.44	0.22	0.16	0.26	0.14	0.08	2
HU4040	0.63	0.63	0.31	0.22	0.34	0.19	0.11	4
HU4444	0.69	0.69	0.34	0.25	0.34	0.19	0.13	5
HU5640	0.88	0.63	0.35	0.38	-	0.22	0.09	7
HU5656	0.88	0.88	0.44	0.31	0.41	0.25	0.16	7
HU5664	0.88	1.00	0.50	0.31	0.41	0.25	0.10	11
HU6464	1.00	1.00	0.50	0.35	0.41	0.25	0.18	12
HU7272	1.13	1.13	0.56	0.40	0.41	0.25	0.20	13
HU8048	1.25	0.75	0.44	0.50	0.50	0.19	0.20	18
HU8080	1.25	1.25	0.63	0.44	0.41	0.25	0.22	20
HU8088	1.25	1.38	0.69	0.33	0.53	0.31	0.22	23
HU9624	1.50	0.38	0.09	0.25	0.38	0.19	0.10	8
HU9611	1.50	1.75	0.88	0.41	0.63	0.38	0.25	35
HU12876	2.00	1.19	0.69	1.00	0.63	0.63	0.20	30

Alnico 5 Two Pole Red Painted Round Horseshoes

PART NO.	A	B	C	D	E	F	R	PULL
200-1	0.50	0.38	0.18	0.17	0.19	0.16	0.03	1
200-2	0.75	0.50	0.24	0.21	0.22	0.19	0.02	4
200-3	1.00	0.63	0.31	0.23	0.22	0.19	0.02	6
200-4	1.25	0.75	0.31	0.49	0.38	0.19	0.06	10
200-5	1.50	0.88	0.45	0.38	0.63	0.25	0.06	15

*All round horseshoes are oriented as a “U”.
Pole and back surfaces are ground,
other surfaces are as cast.
Dimensions shown in inches.
Pull figures shown in pounds.
See page 3-2 for tolerance information.*



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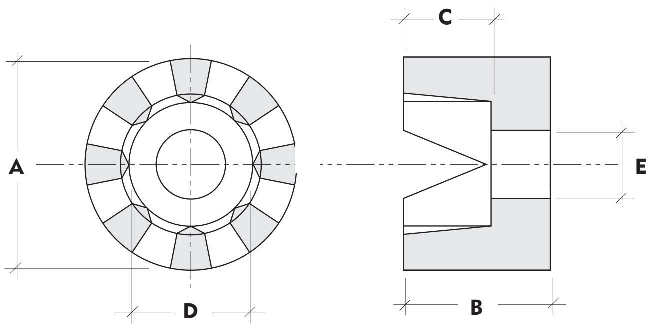
MULTIPLE POLE ROUND HORSESHOES & SEPARATORS

Alnico 5 Multiple Pole Round Horseshoes

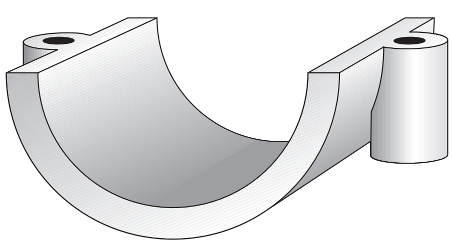
PART NO.	A	B	C	D	E	APPROX PULL	NO OF POLES
HR6448	1.00	0.75	0.50	0.50	0.25	11	4
HR7948	1.25	0.75	0.50	0.63	0.25	22	6
HR8248	1.28	0.75	0.50	0.59	0.45	25	6
HR9656	1.50	0.88	0.56	0.75	0.38	30	6
HR11680	1.81	1.25	0.88	0.63	0.31	50	6
HR18481	2.88	1.27	1.14	1.80	1.44	75	6
HR12872	2.00	1.13	0.76	1.00	0.51	55	8
HR12880	2.00	1.25	0.88	1.00	0.50	60	8

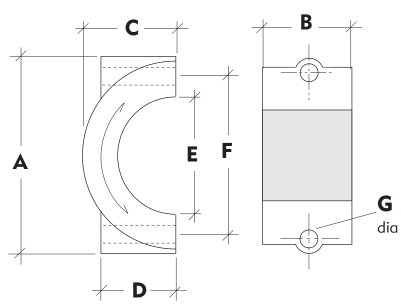


Oriented with 4, 6, or 8 poles as shown. Pole and back surfaces are ground, other surfaces are as cast.
Dimensions shown in inches.
Pull figures shown in pounds.
See page 3-2 for tolerance information.

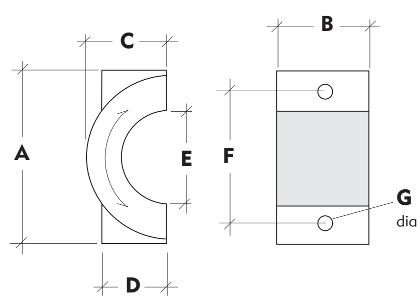
Alnico 5 Separators

TYPE	PART NO.	A	B	C	D	E	F	G	APPROX PULL
1	SE20008	3.13	1.25	1.40	1.40	1.38	2.25	0.25	31
2	SE22415B	3.50	2.38	1.69	1.31	2.13	2.81	0.38	90
1	SE24015	3.75	2.38	1.63	1.63	1.75	2.75	0.31	100





Type 1



Type 2

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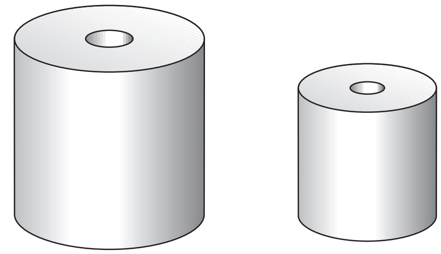
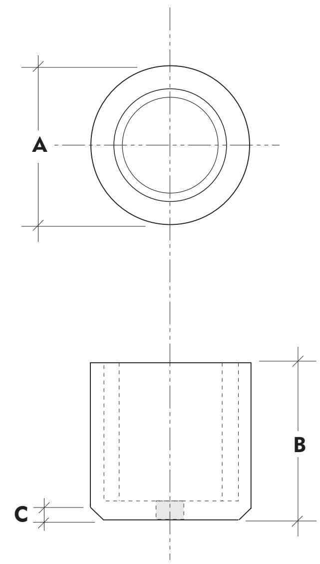
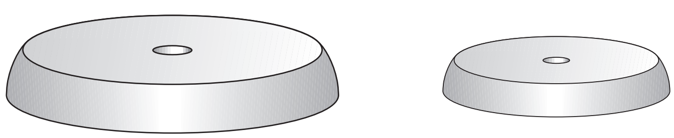
Pot Magnets, red painted

PART NO.	A	B	C	TAPPED HOLE	APPROX PULL
300-1	0.69	0.63	0.13	1/4-20	5
300-2	0.81	0.75	0.16	1/4-20	9
300-3	1.06	1.00	0.16	1/4-20	12
300-4	1.38	1.19	0.19	1/4-20	20



Alnico assemblies, with two poles on one surface, used primarily in holding applications. A tapped hole is provided on the non-magnetic surface for easy attachment.
Dimensions shown in inches.
Pull figures shown in pounds.
See page 3-2 for tolerance information.

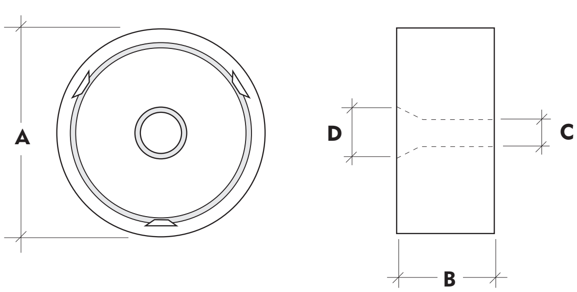




Shallow Pot Magnets, red painted

PART NO.	A	B	C	D	APPROX PULL
400-1	0.75	0.31	0.15	0.22	4
400-2	1.13	0.34	0.19	0.30	6
400-3	1.50	0.41	0.19	0.30	9

Shallow pot magnets, similar to the pot magnets shown above, but with lower height. Provided with a through hole, counter bored on the magnetic side, for attachment.
Dimensions shown in inches. Pull figures shown in pounds.
See page 3-2 for tolerance information.



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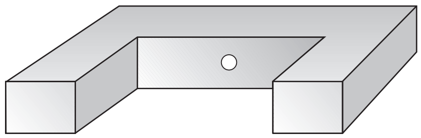
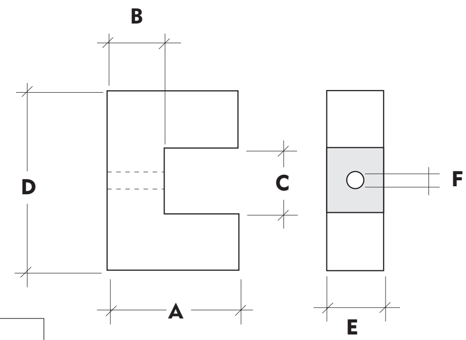
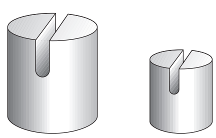




Sintered Alnico 2 Channels

PART NO.	A	B	C	D	E	F	CONDITION
S2CH2520	0.32	0.16	0.13	0.39	0.19	-	Unground
S2CH2826G	0.38	0.17	0.16	0.44	0.19	-	Ground
S2CH2448G	0.38	0.19	0.27	0.75	0.28	0.14	Ground
S2CH5726G	0.38	0.20	0.25	0.89	0.38	0.12	Ground
S2CH5726	0.41	0.20	0.25	0.89	0.38	0.12	Unground



Sintered Alnico 2 materials are isotropic and may be magnetized in any direction.
Dimensions shown in inches.
See page 3-2 for tolerance information.

Sintered Alnico 2 Round Horseshoes

PART NO.	A	B	C	D	E	F	CONDITION
S2HU1613	0.25	0.12	0.11	0.21	0.13	0.17	Unground
S2HU1627	0.25	0.10	0.06	0.16	0.08	0.11	Unground
S2HU2011	0.31	0.10	0.05	0.19	0.09	0.15	Unground
S2HU2012	0.31	0.09	0.08	0.20	0.08	0.16	Unground
S2HU2613	0.40	0.14	0.10	0.21	-	0.12	Unground
S2HU2912G	0.46	0.10	0.09	0.19	0.10	0.20	Ground
S2HU3216	0.51	0.16	0.11	0.25	0.16	0.31	Unground
S2HU3217	0.51	0.19	0.11	0.30	0.10	0.19	Unground
S2HU3228G	0.51	0.19	0.13	0.44	0.10	0.19	Ground

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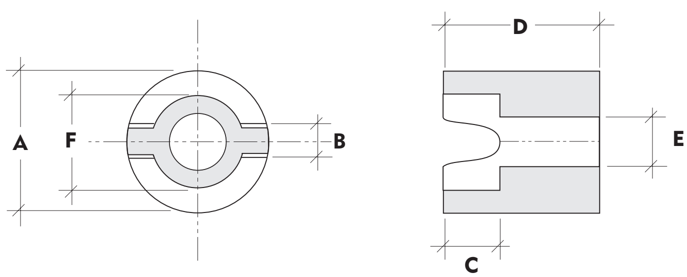
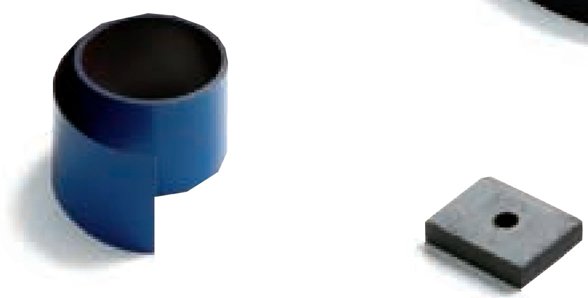
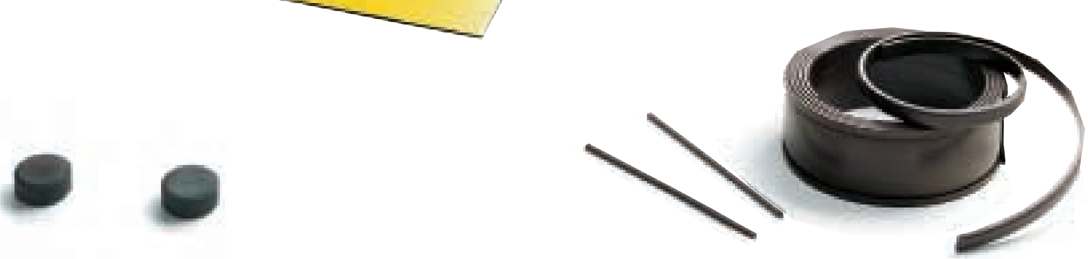


Flexible materials offer the product designer a uniquely desirable combination of properties at lower cost than other magnet materials. The flexibility and machinability of these materials permit design innovations and automated manufacturing techniques not possible with rigid or brittle materials.



Flexible materials can be bent, twisted, coiled, punched, and otherwise machined into almost any shape without loss of magnetic energy.

Higher energy flexible materials may sometimes replace Ceramic 1 materials, if close tolerances are not required, and if operating temperatures are below about 250° F. Standard grades of flexible materials have energy products from 0.6 MGOe to 1.6 MGOe.



TOLERANCES

Tolerances on widths are the greater of ± 1.5% or ± 0.015” of the width, and ± 0.005” in the orientation direction.

For cut pieces, tolerances are the greater of ± 1.5% or ± 0.015” of the cut dimension.

SHAPES, SIZES, AND GRADES AVAILABLE

In addition to the stock shapes, sizes, and grades listed in the catalog, others are available. Please inquire. Non standard shapes and sizes can be fabricated to blueprint specifications from raw stock. Non standard profiles of the 0.6 MGOe material can be extruded by fabricating special dies.

ASSEMBLIES

Assemblies using metal or other components and magnets can be fabricated by adhering magnets with adhesives to suit a range of environments, by mechanically fastening magnets, or by a combination of these methods. We are able to laminate a variety of standard pressure sensitive adhesives to magnetic strip. Standard adhesives are type “A”, for general purpose indoor use, and type “T”, for general purpose outdoor use. Type “T” adhesives are formulated for greater resistance to UV effects.

SURFACE TREATMENTS

No surface treatments are required to protect against corrosion. We are able to laminate a variety of decorative facings to magnetic strip.

MACHINING

Flexible materials are relatively easy to fabricate: they may be cut, scored, punched, slit, or die cut to shape. We are equipped to fabricate these materials to specification.

MAGNETIZING AND HANDLING

Low energy flexible magnets are magnetized with multiple poles on one surface to give greater holding force. Higher energy flexible magnets are magnetized either multiple pole, or single pole on one surface, as indicated in the catalog. No special handling precautions have to be taken with flexible magnets since they are relatively weak magnetically, and are not brittle.

TEMPERATURE EFFECTS

Magnetic properties of flexible magnets degrade linearly with temperature in the same way as Ceramic magnets. However, the limiting factor for flexible magnets are the binder materials used to render them flexible: these begin to flow at temperatures of about 250° F.

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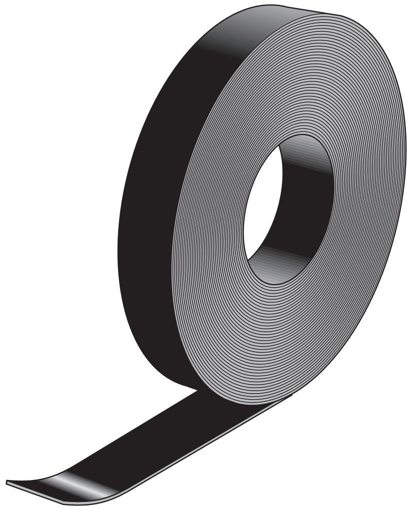

PART NO.	THK	WIDTH	GRADE	MAGNETIZATION
M30002	0.030	2.000	HF1	8 Poles per Inch
M60002	0.030	6.000	HF1	8 Poles per Inch
HF0432	0.060	0.500	HF1	Conventional
HF04322PES	0.060	0.500	HF1	4 Poles per Inch
HF0448-M7	0.060	0.750	HF1	4 Poles per Inch
HF0464-M7	0.060	1.000	HF1	4 Poles per Inch
HF0496	0.060	1.500	HF1	4 Poles per Inch
HF0416	0.062	0.250	HF1	Conventional
M40004	0.062	4.000	HF1	4 Poles per Inch
2M42504	0.065	4.250	HF2	4 Poles per Inch
2M55004	0.065	5.500	HF2	4 Poles per Inch
2M65004	0.065	6.500	HF2	4 Poles per Inch
HF0516	0.093	0.250	HF1	Conventional
HF06032	0.093	0.500	HF1	4 Poles per Inch
HF0832	0.125	0.500	HF1	Conventional
HF0848	0.125	0.750	HF1	Conventional
HF08482PES	0.125	0.750	HF1	2 Poles each surface
HF0864	0.125	1.000	HF1	2 Poles per Inch
M30008	0.125	3.000	HF1	4 Poles per Inch
HF1248	0.187	0.750	HF1	Conventional
M30012	0.187	3.000	HF1	4 Poles per Inch
2M050016-M1	0.250	0.500	HF2	Conventional
HF16322PES	0.250	0.500	HF1	2 Poles each surface
HF1640	0.250	0.625	HF1	2 Poles each surface
M10016	0.250	1.000	HF1	2 Poles each surface
M10016-M1	0.250	1.000	HF1	Conventional
M30016	0.250	3.000	HF1	4 Poles per Inch
M90016	0.250	9.000	HF1	Conventional
HF2448	0.375	0.750	HF1	Conventional
M30024	0.375	3.000	HF1	4 Poles per Inch

Note: Poles run parallel to length

High energy flexible materials have found increasing use in technical applications such as low cost speakers, micro-motors, and security devices, in addition to applications such as latch magnets, tool holder, toys, games, and others. These materials are anisotropic (have a preferred direction of magnetization), and magnetic properties are equal to or exceed those of the Ceramic 1 types, depending on the grade.

All sizes available in HF1, HF2, or HF3 grades. Any size custom fabricated to specifications. Can be manufactured with special binders to withstand harsh environments. When ordering, please state magnetization pattern required, or consult our sales staff for assistance in selecting proper pattern. Dimensions shown in inches.

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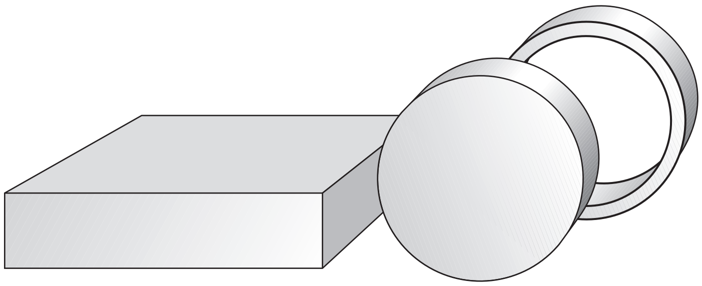
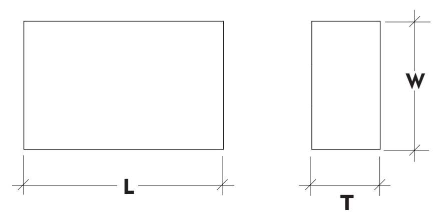
FLEXIBLE
HIGH FORCE PUNCHED PARTS



Rectangles

PART NO.	L	W	T	COMMENT
21F	1.00	0.75	0.093	3/16 Dia Center Hole
22F	1.00	0.75	0.187	3/16 Dia Center Hole
55F1501029	1.50	1.06	0.290	
24F	2.00	0.75	0.250	
55F6001313	6.00	0.13	0.130	

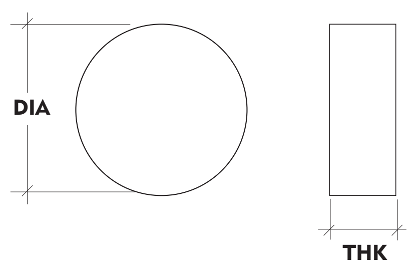


Discs

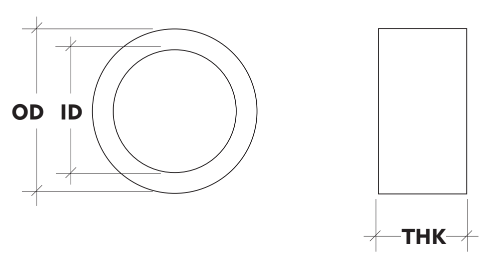
PART NO.	DIA	THK
42F12125	1.13	0.13

Rings

PART NO.	OD	ID	THK
63F1217125	1.13	0.18	0.125
63F1410187	1.49	1.06	0.187



All sizes available in HF1, HF2, or HF3 grades.
Any size custom fabricated to specifications.
Can be manufactured with special binders to withstand harsh environments.
Dimensions shown in inches.



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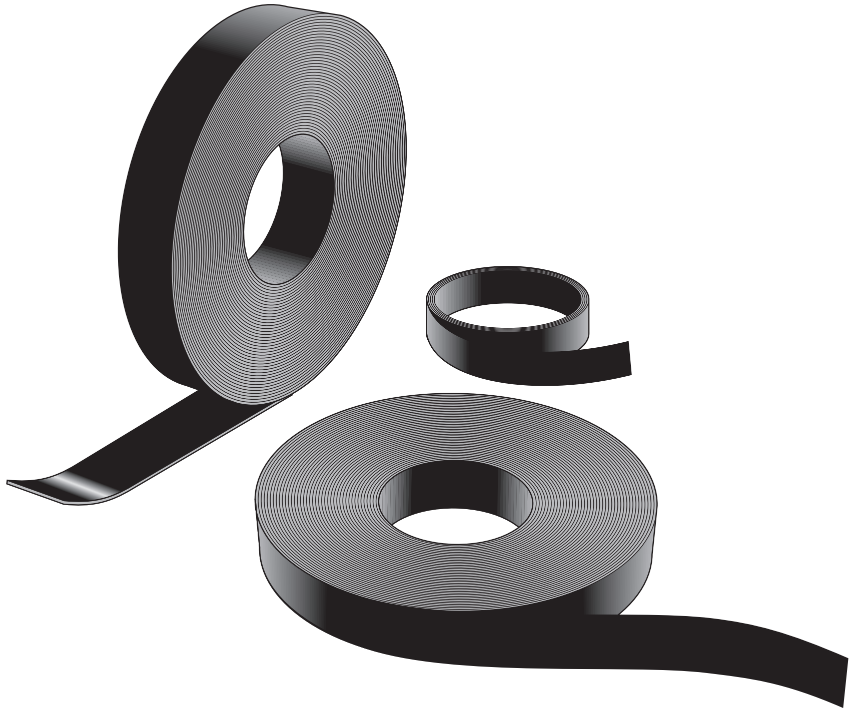
PART NO.	THK	WIDTH
0643	0.030	2.000
10003	0.045	1.000
01604	0.060	0.250
02404	0.060	0.375
0632	0.060	0.500
0630	0.060	0.750
0639	0.060	1.000
09604	0.060	1.500
0642	0.060	2.000
0648	0.060	3.000
0633	0.093	0.250
03206	0.093	0.500
0640	0.093	1.000
0644	0.093	2.000
0635	0.125	0.375
03208	0.125	0.500
04808	0.125	0.750
0645	0.125	1.000
20008	0.125	2.000
0634	0.171	0.312
0637	0.180	0.438
10012	0.187	1.000
0638	0.250	0.594



We supply flexible magnetic strip:

In convenient roll sizes. *Rolls are about 12" diameter for ease of handling. For material which is 0.060" thick, this is a 100 foot long roll. Longer roll sizes are available.*

With or without pressure sensitive adhesive backing. *Rubber based adhesives (Type A) for general purpose indoor applications, and acrylic based adhesives (Type T) for general purpose outdoor applications, are standard. Type T adhesives perform better with plastics and other "hard to adhere" materials. Other non standard adhesives are available to meet your requirements. We recommend that adhesives be tested on your product prior to ordering production quantities. To order strip with adhesive, add the letter "A" or "T" to the part number, depending on which type of adhesive is required.*

Cut to length. *We can cut strip to any specified length. Tolerances on cut dimensions are the greater of +0.030" or +2% of the cut length.*

Scored to length. *Instead of cutting all the way through, material can be scored to length. This allows greater ease in removing adhesive liner paper, and storage of material in roll form.*

Special non standard sizes, and custom extruded shapes. *Call to discuss special non standard shapes and sizes.*

These strip materials are magnetized with multiple poles on one surface. Dimensions shown in inches.

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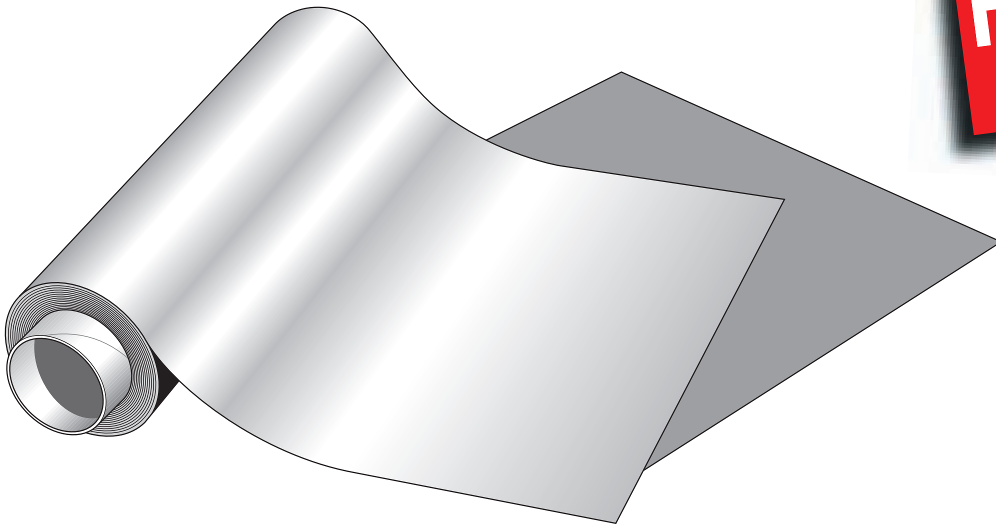

PART NO.	THK	FINISH
8100	0.010	Plain
8103	0.010	Matte white
8120	0.015	Plain
8121-I	0.015	Indoor adhesive
8123	0.015	Matte white
8220	0.020	Plain
8221	0.020	Outdoor adhesive
8221-I	0.020	Indoor adhesive
8222	0.020	Gloss white
8223	0.020	Matte white
8223-C	0.020	Colored
8320	0.030	Plain
8321	0.030	Outdoor adhesive
8321-I	0.030	Indoor adhesive
8322	0.030	Gloss white
8322-SM	0.030	Gloss white, Safemag
8323	0.030	Matte white
8323-SM	0.030	Matte white, Safemag
8323-C	0.030	Colored
8420	0.045	Plain
8423	0.045	Matte white
8620	0.060	Plain
8621	0.060	Outdoor adhesive
8623	0.060	Matte white

We supply flexible magnetic sheet:

In convenient roll sizes. *24" wide by 50 feet or 100 feet long are standard - smaller orders are gladly accommodated.*

With or without pressure sensitive adhesive backing. *Rubber based adhesives for general purpose indoor applications, and acrylic based adhesives for general purpose outdoor applications, are standard. Acrylic based adhesives perform better with plastics and other "hard to adhere" materials. We recommend that adhesives be tested on your product prior to ordering production quantities.*

Cut to length. *We can cut sheet to any specified length. Tolerances on cut dimensions are the greater of ± 0.030" or ± 2% of the cut length.*

Slit to width. *We can slit standard 24" wide sheet to your specified width. Slitting tolerances are the greater of ± 0.060" or ± 3% of the slit dimension.*

In eleven colors. *Red, yellow, orange, blue, green, brown, black, silver, gold, and white vinyl laminates, and chrome mylar laminates are standard. Non standard colors available on request.*

With a protective backcoating. *Safemag sheeting is backcoated to provide a safe barrier between the magnetic surface and the surface to which it is applied. This backcoating reduces the risk of paint damage when magnetic sheet is applied to painted surfaces.*

These sheet materials are magnetized with multiple poles on one surface.
Dimensions shown in inches.

SECTION 5
MAGNET MEASUREMENT

This section is devoted to some useful tools for measuring and learning about permanent magnets. Gaussmeters are be used to measure flux densities, and assist in the design and understanding of, as well as the inspection of, magnetic devices. The magnetometers shown here are useful for comparing one magnet to another, and the viewing devices shown help to visualize the field patterns created by magnets. The magnetizer shown is capable of magnetizing Alnico magnets, and small sections of Ceramic magnets. It cannot be used to magnetize Rare Earth magnets. Two books we have found to be useful in understanding the physics and applications of permanent magnets are also included.

Model 410 Gaussmeter

The model 410 is a hand held gaussmeter designed for accurate magnetic field measurements from 0.1 Gauss to 20 Kilogauss. Most operating functions can be selected via the front panel keypad with one or two keystrokes. The 410 displays in gauss or Tesla, AC or DC magnetic field values with a 100mG resolution on the 200 G range.

Operating Functions

Max. Hold - *The largest field magnitude measured since the last reset is displayed.*

Filter - *When the field being measured is noisy, the filter function will average readings to produce a more stable display.*

Alarm - *An audible alarm is sounded and the display indicator flashes when the measured field is higher than the keypad entered alarm point.*

Zero Probe - *Used to eliminate probe offsets and small external fields.*

Relative Reading - *When activated, measurements are referenced to the keypad entered reading.*

Autoranging - *Automatically selects the appropriate range.*

Memory Hold - *On power down, the 410 stores in non volatile memory, the complete configuration of the instrument, including the calibration number and probe offset, making it unnecessary in most cases to go through a set up procedure on power up.*

Specifications

Display: LCD, 3-1/2 digits.
Resolution: 100mG (200 G range)
DC Accuracy: 2% of reading +0.1% full scale at 25 degrees Centigrade.
AC Accuracy: +5% of reading.
Frequency Response: 20Hz to 10Khz.
Ranges: +200 G, +2 KG, +20 KG.
Operating Temperature Range: 0 to 50 degrees Centigrade.
Instrument Temperature Coefficient: 0.05% of reading per degree Centigrade.
Instrument and Probe Temperature Coefficient: 0.1% of reading per degree Centigrade.
Weight: 1 lb.
Size: 7.6” x 3.9” x 1.7”
Power: 4 “AA” batteries (included). Battery life greater than 160 hours.

Ordering Information

Gaussmeter **Part Number 410-SC** *(includes batteries, soft case, and extension cable for use with probes).*

*Two standard probes are available: an axial probe (***Part Number MSA-410***), which measures fields parallel to the axis of the probe, and a transverse probe (***Part Number MST-410***), which measures fields perpendicular to the axis of the probe.*

A specially designed hard case with foam padding is also available. **Part Number HC-410**

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Micropower Gaussmeter, Model GM-1

Features:
Low cost for both probes and instrument.
Simple operation.
Included 9V battery will typically last 100 hours.
Large easy to read liquid crystal display.
Accurate to +0.25% of reading, +1 digit.
20 Gauss to 20 Kilogauss ranges with standard probes, can be extended using special probes.
Analog jack included - can be used to graph output.
Size: 5.75" x 3.6" x 1.6"
Weight: 10 ozs.

*Standard transverse probe (***Part Number PT-70***) is encased in brass sleeve.*
*Standard axial probe (***Part Number PA-70***) is encased in plastic tube.*

Ordering Information
A standard soft case is included with the GM-1 Gaussmeter, with a pocket that will accommodate two standard probes.

TRANSVERSE PROBES

PART NO.	SENSING AREA	SENSITIVITY COEFFICIENT**	SENSING AREA LINEARITY	LOCATION*
PT-70	0.080 x 0.180"	-0.20%	1.5% to 10 KG	0.075"
PT-72	0.050 x 0.075"	-0.07%	1% to 20 Gauss	0.100"
PT-75	0.062 x 0.120"	-0.08%	1% to 10 KG	0.085"

AXIAL PROBES - SENSING AREA IS 0.025" FROM PROBE SURFACE

PART NO.	SENSING AREA	SENSITIVITY COEFFICIENT**	*LINEARITY
PA-70	0.080 x 0.180"	-0.20%	1.5% to 10 KG
PA-72	0.050 x 0.075"	-0.07%	1% to 20 Gauss
PA-74-10	0.020" Dia	-0.04%	0.25% to 10 KG
PA-74-30	0.020" Dia	-0.04%	1% to 30 KG

* from end of probe
** per degree Centigrade

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Pocket Magnetometers

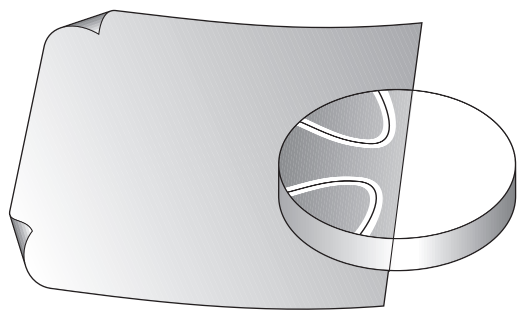
Pocket magnetometers allow you to check magnets fast and inexpensively. They are useful in inspection, engineering, laboratory and tool room.

Check for residual magnetism, polarity (a positive deflection indicates a North pole), and relative strength. Use as a "go, no-go" test for magnets and magnetic devices. Particularly useful when large numbers of magnets must be tested.

Models available:

#100 - *with a -100 to +100 scale.*
#50 - *with a -50 to +50 scale.*

Size: 2-1/2" diameter x 1-1/4 high. Weighs 3 ozs.



Magneview Paper

This unique film allows you to see the magnetization pattern on your magnets. Poles are seen as dark areas bounded by light lines.

Use to reveal inconsistent magnetization, check for magnetization patters.

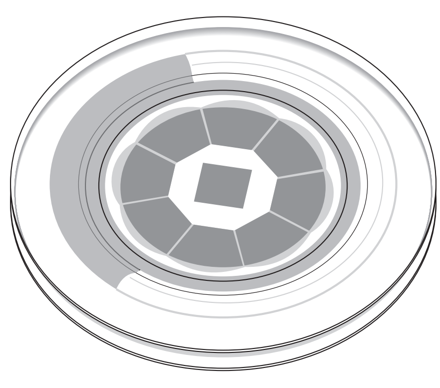
Color: Green
Thickness: 0.006"

PART NO.	SIZE
MR1-G	4" X 4"
MR1-G09	9" X 9"
MR1-G12	12" X 12"
MR1-G1836	18" X 36"

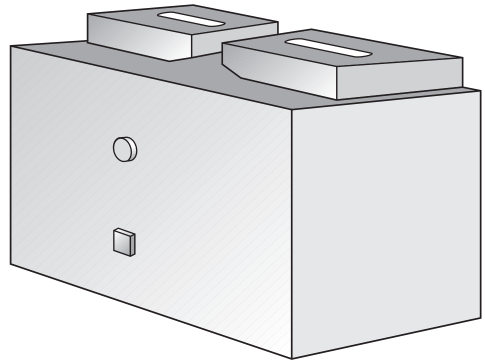
Magnetic Viewer

The B-1022 Magnetic Viewer provides a fast, clean way to view magnetization patterns, more sensitively than the Magneview Paper. You can view recorded signals for head alignment, track placement, and pulse definition on magnetic tape not possible with the Magneview Paper, as well as patterns created by permanent magnets. Resolution is 200 digital B.P.I.

Part Number B-1022



Model M-24000 Magnetizer



Ready for immediate operation. Includes magnetizing coils, adjustable pole shoes, rectifier, fuse and switch. An optional foot switch is recommended for production or continuous operation.

The M-24000 develops up to 24,000 Ampere Turns of magnetizing force.

Following are the values (in Ampere Turns per Inch) recommended for different types of magnetic materials.

CHROMIUM OR TUNGSTEN STEELS	600
COBALT STEELS	2,400
ALNICO 1,2 OR 3	4,000
ALNICO 4,5, OR 6	6,000
ALNICO 8	10,000
CERAMIC	20,000

Alnico 5 magnets up to 4" long by 1" square can be saturated by this magnetizer. Ceramic magnets up to 1" long by 1" square can be saturated by this magnetizer. Note that Rare Earth materials cannot be magnetized by this magnetizer, since very high magnetizing fields are required.

To Use: *Connect o any standard 120 volt single phase outlet. Adjust pole shoes to fit magnet length (supplied with thumb screws for rapid adjustment without tools). Place magnet between pole shoes and depress switch. Full capacity magnetization develops in less than one second. Holding the switch down longer or repeating the cycle does not increase the magnetization.*

Specifications

Operates on 110 to 120 V AC single phase, 50 to 60 Hz.
Draws a maximum of 8 amps, fused for 10 amps.
Develops 24,000 Ampere Turns.
Pole shoes are tapered on one side to 1" x 1/2", other end 1" x 2". Adjustable for lengths up to 4-1/2".
Double pole switch with momentary action activates magnetizer. Spring action opens switch when operator's hand is removed.
Size: 10-1/8" x 7-3/8" x 5-1/8".
Weight: 43 lbs. Shipping weight approximately 55 lbs.
Optional foot switch.

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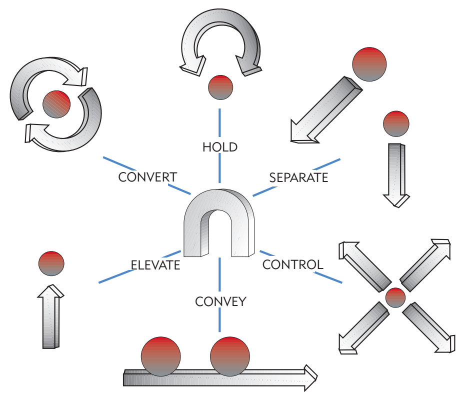
Permanent Magnet Design and Application Handbook
by Lester Moskowitz
Catalog Number: BOOK



This 385 page volume, revised in 1986, is the result of a lifetime of study of the permanent magnet - history of magnetism, its development, comparison of different magnet materials, sources of magnet supply, applications of permanent magnets in every conceivable use from toys to medical devices. Useful for the practicing engineer, for inventors, and scientists, teachers, and students.

Chapter headings include: Basic manufacturing Processes, Fundamentals of Magnetism, General Design Considerations, Leakage and Fringing, Circuit Effects, Exact Design Methods, Measurement and Testing, Magnetization, Demagnetization, Stabilization, and Calibration, and others.

The text is straightforward and easily understood by anyone with a general technical background, but no specific background in magnets, metallurgy, or electricity.

The author, Lester Moskowitz, served as President of the Society of Magnetic Engineers, as Dean of Technology at Spring Garden College in Philadelphia, and as executive director of the Permanent Magnet Users Association.

Permanent Magnet Materials and their Application,
by Dr. Peter Campbell
Catalog Number BOOK-3

This 203 page book, first published in 1994, has been written as a comprehensive review of magnet technology, intended for scientists and engineers involved in all stages of the manufacture, design, and use of permanent magnets. The core of the book is a detailed treatment of the methods that are used to design permanent magnets, including assessments of the changes they experience in practical operating conditions. Modern analytical techniques are described, including the finite element method. Familiarity with mathematical methods is necessary for a thorough understanding of this book.

Chapter headings include: Fundamentals of Magnetism, Permanent Magnet Processes, Thermal Stability, Magnetic Circuit Design, Magnetic Field Analysis, Magnetizing and Testing, and Applications. Applications studied include DC Motors, Stepper Motors, Synchronous Motors, Moving Coil Actuators, Holding Force Actuators, Magnetic Suspensions, Sensors, and Steady Fields.

Dr. Campbell is President and founder of Princeton Electro Technologies, a consulting firm specializing in magnetics. He is internationally recognized through his publications and presentations in permanent magnet applications and design. He has been a Professor of Electrical Engineering at both the University of Southern California, Los Angeles, and at the University of Cambridge, England, where he was a Fellow of Downing College.

Standard Specifications for Permanent Magnet Materials,
published by the Magnetic Materials Producers Association.
Catalog Number BOOK-2

Originally published in 1964 and revised periodically, these standards are intended to serve as a guide to governmental and industrial purchasers of permanent magnets so that they may be assured of uniform quality materials manufactured to commercial standards.

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