MAGNET APPLICATIONS®

A Bunting® Magnetics Company

magnetapplications.com

TOTAL MAGNETIC SOLUTIONS™

About Magnet Applications, Inc.

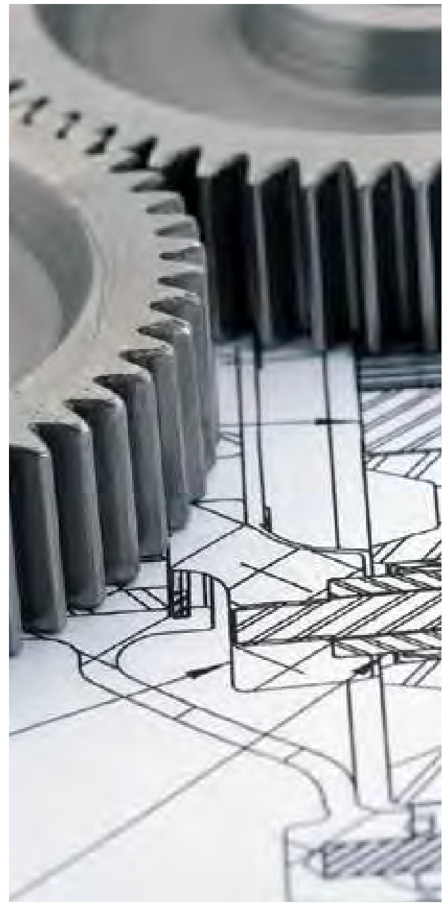
Magnet Applications has been supplying industries throughout the world for over 50 years.

We undertakes a wide range of design contracts and our expertise covers the complete range of permanent magnet materials, including; alnico, ferrite, samarium cobalt, neodymium iron boron, and production routes, which includes; sintering, extrusion, calendering, compression bonding and injection molding.

Our ability to build magnetizing fixtures, manufacture magnets, and supply machined components from our in house facilities offers a rapid prototype service.

We're capable of running both ferrite and rare earth compounds. Our single part production rates range from a few hundred pieces per month to more than 2 million pieces per month.

We provide Total Magnetic Solutions™.



With a history dating back more than a half century, it's not surprising that Magnet Applications' operations span the globe. With manufacturing facilities in North America and Europe, as well as additional sales and distribution points around the world, we can offer an unsurpassed corporate strength and commitment to providing total magnetic solutions to our customers.

We measure and certify the quality of our processes and products as stringently as you do. All of our plants are ISO 9001:2008 certified, ensuring that we are as deeply concerned with satisfying your customer as you are.

Magnetic needs vary widely from application to application. As a provider of Total Magnetic Solutions™, we offer the capability of meeting any requirement. Whether you are using our Just-In-Time shipping capabilities, or working with our engineers to develop an entirely new permanent magnet design.

Part of our Total Magnetic Solutions philosophy is helping our customers develop their new applications to the fullest extent. While every new application brings with it new problems to solve, our engineers offer some of the industry's most extensive experience in magnetics. By making us a part of your design and manufacturing team, we can help your design meet its full potential, while also increasing the cost-effectiveness of the manufacturing process.

Selection Guide

ITAR COMPLIANT

Magnet Applications, Inc. is registered with the U.S. Department of State, Directorate of Defense Trade Controls (DDTC) and is in compliance with the International Traffic in Arms Regulations (ITAR)

Magnet Applications

A Bunting® Magnetics Company

Magnet Glossary

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

Coercive Force, Hc : 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, Tc : The temperature at which the parallel alignment of elementary magnetic moments completely disappears, and the material is no longer able to hold magnetization.

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.

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 X axis, Y axis).

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, Hci : 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 Hci 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 re-magnetization. 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.

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.

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

Maximum Energy Product, BHmax : 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".

Residual Induction, Br : 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.

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.

Permeance Coefficient, Pc : Ratio of the magnetic induction, Bd, to its self demagnetizing force, Hd. Pc = Bd/Hd. 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, Bd.Hd = Lm/Lg, where Lm is the length of the magnet and Lg is the length of an air gap that the magnet is subjected to. Pc 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 the lines of flux.

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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 automobiles, to instrumentation, production equipment, and research. Their contributions are 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, loud speakers, 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 insight into permanent magnets.

MODERN MAGNET MATERIALS

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

- Sintered Neodymium Iron Boron
- Samarium Cobalt
- Bonded Neodymium Iron Boron
- Alnico
- Ferrite / Ceramic
- Flexible

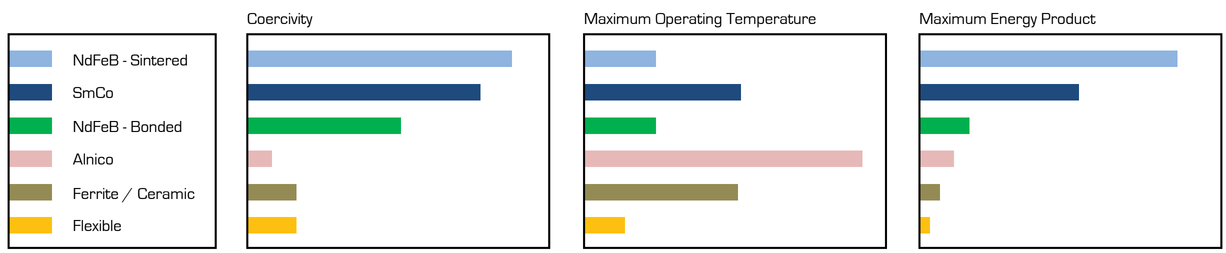
Neodymium Iron Boron and Samarium Cobalt are known as Rare Earth magnets because they are both composed of materials from the Rare Earth group of elements. Neodymium Iron Boron (general composition of $Nd_2Fe_{14}B$ often abbreviated to NdFeB) is the most recent commercial addition to the family of modern magnet materials. There are two classes of NdFeB magnet materials, bonded and sintered. Of the 2 general classes of Rare Earth materials, NdFeB magnets cover the largest range of magnetic strengths and exhibit the highest properties (at room temperature) of all magnet materials. Samarium Cobalt is manufactured in two compositions: Sm_1Co_5 and Sm_2Co_{17} (often referred as the SmCo 1:5 or SmCo 2:17). SmCo 2:17 types, with higher Hci values, offer greater inherent stability than the 1:5 types. Ferrite also known as Ceramic magnets (general composition $BaFe_2O_3$ or $SrFe_2O_3$) have been commercialized since the 1950s and continue to be extensively used due to their lower cost. A special form of Ceramic or NdFeB magnet referred to as "flexible" material is made by bonding Ceramic or NdFeB powder in a flexible binder. Alnico magnets (general composition Al-Ni-Co) were commercialized in the 1930s and are still 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 overview of considerations in selecting the proper material, grade, shape, and size of magnets for a specific application. *Refer to IEC-60404-8 – "Specifications for individual materials – Magnetically Hard Materials"

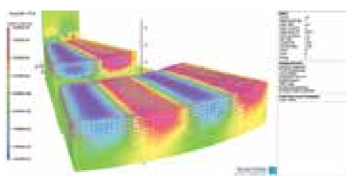
UNITS OF MEASURE

Two systems of units of measure are common: the CGS (centimeter, gram, second), SI (meter, kilogram, second) systems. This brochure uses the CGS system for magnetic units unless otherwise specified.

Comparison Charts of Magnetic Materials

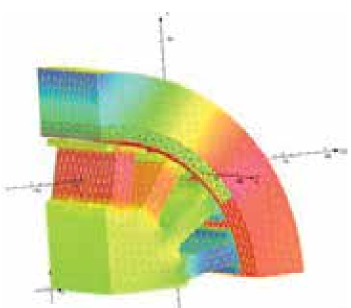


DESIGN CONSIDERATIONS



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.

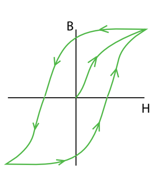
FINITE ELEMENT ANALYSIS



Magnetic Design has become a critical feature of Magnet Applications growth and we seek to work with our customers to realize their ideas. 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 magnetic 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.

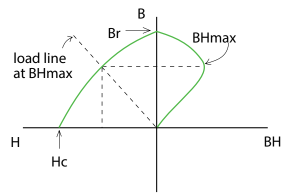
Magnet Applications uses a suite of 2D and 3D transient FEA modeling packages backed-up with in house design software and many years experience, not just in magnetics but also in general engineering expertise. This allows us to undertake a wide range of design contracts and across many industries including automotive, defense, and across many applications including sensors, Brushless DC (BLDC) motors. The length of design contract ranges from a few hours to many days and we pride ourselves on the cost effectiveness of this service.

THE BH CURVE



Hysteresis Loop

The basis of magnet design is the BH 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.



The Demagnetization Curve

The second quadrant of the BH 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 BH curve are the points at which it intersects the BH axes (at Br – the residual induction – and Hc – the coercive force – respectively), and the point at which the product of BH are at a maximum (BH max – the maximum energy product). Br 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. Hc represents the point at which the magnet becomes demagnetized under influence of an externally applied magnetic field. BH max represents the point at which the product of BH, 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 BH curve with temperature.

Measurement of BH curves requires specialist equipment. The most common types are DC Hyteresis graphs (Permeameter) where the magnet is driven around its BH loop in a DC electromagnet with sensing coils to the measure the BH of the magnet. Magnet Applications has a temperature controlled permeameter which can BH curves at temperatures from ambient up to 150°C. We use this data to qualify our materials and to supply accurate material data for our design software.

PERMANENT MAGNET STABILITY

The ability of a permanent magnet to support an external magnetic field results from small magnetic domains "locked" into 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 (Hc) 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.

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 varies 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 are 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.

TEMPERATURE

Temperature effects fall into three categories:

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

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 (Tc). Tc is expressed as % per degree C. These figures vary for specific grades of each material as a whole. It is because the temperature coefficients of Br and Hc are significantly different that the demagnetized curve develops a "knee" at elevated temperatures.

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.

Irreversible and unrecoverable losses

Metallurgical changes occur in magnets exposed to very high temperatures and are not recoverable by remagnetization. The table below shows examples of critical temperatures for the various materials where:

- Tcurie is the Curie Temperature at which the elementary magnetic moments are randomized and the material is demagnetized.
- Tmax is the maximum practical operating tempera tures in air, for general classes of major materials. Different grades of each material exhibit values differing from the values shown below.

Critical Temperatures for Various Materials °C

Material	T_C	T_{max}
NdFeB	310	150
SmCo	750	300
NdFeB Bonded	N/A	150
Alnico	860	540
Ceramic	460	300
Flexible NdFeB * *	N/A	100

* * Due to the bonding agents used, flexible magnets may not operate at temperatures above 100°C

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 orientations. A magnet thus stabilized will exhibit constant flux when exposed to equivalent or lesser temperatures.

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.

ADVERSE FIELDS

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

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 be easily 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.

PHYSICAL CHARACTERISTICS AND MACHINING OF 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 from small chips that may occur during machining and handling of these magnets, especially on sharp edges. Magnets may be tumbled to break the edges, this is done to avoid "feathering' of sharp edges due to the brittle nature of materials. Tumbling can achieve edge breaks of 0.003" to 0.010". Although sintered NdFeB is relatively tough as compared to Samarium Cobalt and Ceramic, it is still brittle and care must be taken in handling. Bonded NdFeB is not as brittle as the sintered materials but it is softer and must be handled with care as well. 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 cost, 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 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 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.

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.

NdFeB magnets, both sintered and bonded, 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 NdFeB magnets, however, the material must be properly prepared and the plating process properly controlled for successful plating.

Aluminum Chromate or Cadmium Chromate vacuum deposition (PVD) is a successful process that can provide a coating thickness as low as 0.0003". Teflon, Parylene, various epoxies and other organic coatings are relatively inexpensive and are also successful as NdFeB coatings. 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.

The effectiveness of coatings on customer's parts can be tested in Magnet Applications Temperature and Humidity Controlled Environmental Chamber. For further information please contact our sales team.

ASSEMBLY CONSIDERATIONS

The following points should be considered when designing magnet assemblies.

Affixing magnets to housings

Magnets can be successfully affixed to housings using adhesives. Cyanoacrylate adhesives which are rated to temperatures up to 180° C with 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 a vacuum. Potential outgassing of the adhesives should be considered.

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. It is recommended 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.

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.

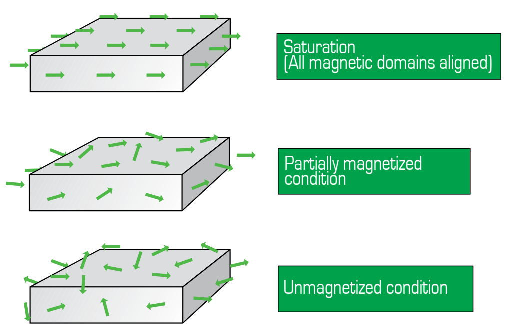
Welding

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) 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.

MAGNETIZATION

Permanent magnet materials are believed to be composed of small regions or "domains" each of which exhibit a net magnetic moment. An un-magnetized magnet will possess domains which are randomly oriented with respect to each other, providing a net magnetic moment of zero. Thus, a magnet when de-magnetized is only de-magnetized from the observer's point of view. Magnetization is achieved by exposing the magnet to a very high magnetic field, the strength of which depends on the type of magnet material. The magnetic field aligns the domains to give a net, externally observable field.

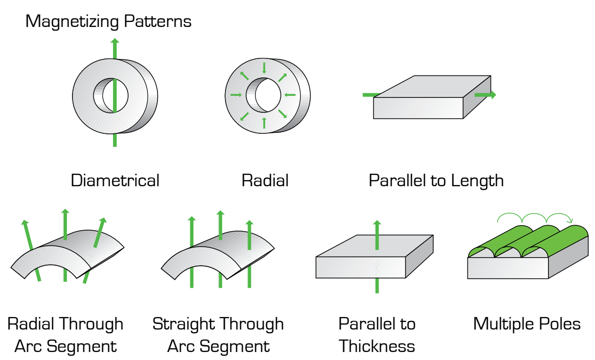
Magnetization



It is important when magnetizing a magnet to always magnetize the magnet to saturation, even if it will subsequently be slightly de-magnetized for calibration or stabilization purposes. Saturating the magnet and then de-magnetizing 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, leading to a less stable magnet.

In general, permanent magnets are supplied with a simple 2 pole magnetization pattern, a North pole on one face and a South pole on the opposite face. However by appropriate configuration of the magnetizing coils it is possible to construct a fixture that will magnetize a magnet with many pole-pairs, and for some materials, pole patterns on a single surface of the magnet. This is called multi-pole magnetization.



Anisotropic magnets, typically sintered magnets such as sintered NdFeB or ceramic magnets, have a preferred direction of magnetization which gives them higher magnetic properties than isotropic magnets of the same material. These magnet materials must be magnetized parallel to the preferred direction to achieve these optimum magnetic properties. Consequently, these materials are not generally suitable for multi-pole magnetization and such assemblies have to be constructed from individual pre-magnetized segments. However, isotropic magnets have no preferred direction and can therefore be magnetized in any direction making them ideally suitable for multi-pole magnetization in a single operation. This is one of the key advantages of Bremag® bonded magnets. Bremag® is a trademark of Magnet Applications, Inc. bonded materials.

Magnetizing Fixtures/Tooling

Magnetization is a key step in the manufacture of any permanent magnet component and is usually the last stage in the manufacturing process. While simple 2 pole magnets can be magnetized in one of our standard solenoid magnetizing coils, multi-pole magnets need their own custom made fixtures. Magnet Applications designs and manufactures all its own magnetizing fixtures either for use in house or to be used on customers own equipment. Due to the high energies required to generate the magnetizing fields, particularly for rare-earth magnets, production magnetizing fixtures are designed with water cooling and significant safety interlocks to protect the operators and also to ensure the fixtures can never be operated with the wrong settings resulting in only partially magnetized components. Production fixtures are built for the life of a project.

Prototype Magnetizing Fixtures/Tooling

For development projects, prototype fixtures can be built quickly after design. These allow for a small quantity of magnets to be magnetized and built into a prototype build program. Prototypes usually do not have the built in cooling or interlock features and can only be guaranteed for small volumes.

Magnetizing Systems

For customers who wish to bring the magnetization process in house, Magnet Applications can supply turnkey magnetizing systems for integration into a production line. This can range from magnetizing fixtures to run on customers own magnetizing equipment or full systems which include both the capacitor discharge magnetizing unit and fixtures.

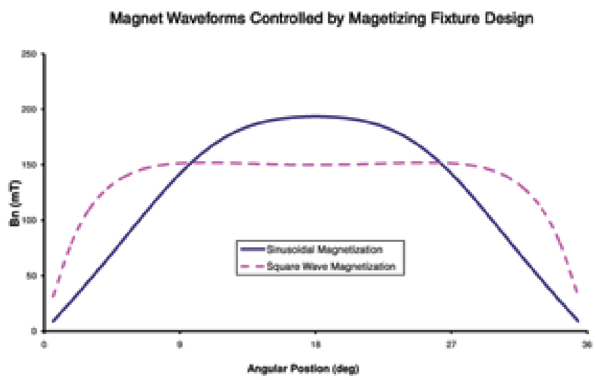
Magnet Applications manufactures its own capacitor discharge units which are all PLC controlled and therefore can be integrated into customer's own production lines. The units employ all the same interlock and safety features for production including magnetization fixture temperature control. Through appropriate consultation with customers, Magnet Applications will manage the process to ensure the magnetizing system meets the production requirements in the most efficient way.

Post Assembly Magnetization

From a production point of view, the most desirable approach is to build a multi-pole magnet assembly with un-magnetized magnets and then magnetize the assembled device as the final step in the manufacturing process. This avoids all the production issues associated with handling and locating very strong magnets. This process is called post assembly magnetization. Multi-pole magnetizing fixtures can be built to post-assembly magnetize customers own assemblies or those assembled by Magnet Applications. It is not always possible to achieve 100% saturation throughout the magnet volume but the effect of this can be simulated by Magnet Applications using our specialized FEA software so that customer's can assess if the practical and cost advantages of post assembly out way the disadvantages of a slight drop in performance.

Magnetization Waveforms

The software utilized by Magnet Applications can take full account of the true magnet properties achieved during magnetization and predict the surface or air-gap flux density waveforms of multi-pole magnets with the actual magnetizing fixture that will be used in production. This technique is not restricted to isotropic magnets. It can also be applied to permanent magnet assemblies. This is an invaluable capability when it comes to moving from development to production phases within a project.



In addition it allows us to design magnets with specialized flux density wave forms to meet specific customer requirements, whether it be for encoders, general switching magnets or rotor magnets for permanent magnet motors. On radially magnetized parts or assemblies it is possible to skew the poles to help reduce cogging torque and for isotropic magnet ring magnets, square waves, trapezoidal or sinusoidal waveforms can all be be achieved, sometimes to within a few percent total harmonic distortion. Increasingly there is a demand for very complex multi-pole, multi-track systems that require a very careful choice of materials to ensure requirements are met.

Halbach Magnetization

Halbach arrays or cylinders are a particular type of permanent magnet assembly which produces a field on one face of the assembly while cancelling out the field on the other side. In the case of a cylinder, the field will be concentrated into the center of the cylinder with zero field on the outside. In other words, completely self shielding. A true Halbach can only be achieved with a sinusoidally varying field distribution within the assembly. Close approximations to Halbach arrays can be achieved with arrays of magnet blocks but single isotropic ring magnets which can be multi-pole magnetized with continuously varying fields are ideal for this technology. Through careful design of the magnetizing fixture, close approximations to Halbach arrays can also be achieved without having to use complex multiple segment magnet assemblies which are both difficult to assemble and expensive.

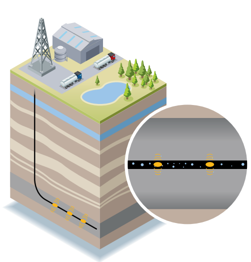
Magnetic Assemblies

Magnet Applications is a one-stop shop specializing in magnetic sub-assemblies. With our metal machining, magnet fabrication and final assembly capabilities, we utilize the latest technologies in fool proof devices and lean technologies applied to assembly processes such as, bonding, fastening, potting and not limited to welded, sleeved, and encapsulated magnet assemblies. Our final processes (post assembly) include final grind, balancing and field mapping allowing Magnet Applications to deliver a quality driven and precision magnet assembly. Magnet Applications has a "design for manufactureability" engineering team ready to discuss your project. We can reduce cost drivers, and develop a repeatable manufacturing process to deliver a quality product.

MOTORS / GENERATORS

Our most common assemblies include hub, rotor or back-plate machining and assembly, including potting, final grind and balancing for Internal Permanent Magnet (IPM), Surface Permanent Magnet (SPM) and Linear motor designs. We are the premier supplier of bonded magnets into the Brushless DC Motor (BLDC) market.

OIL AND GAS



We are industry experts in high temperature samarium magnet assemblies typically including stainless steel encapsulation and welding for pressure and vibration downhole applications. We offer a wide variety of material grades which have a high strength-to-weight ratio and will not lose attractive force over time, unless otherwise damaged.

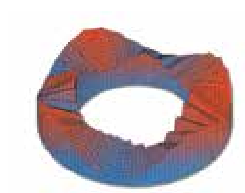
AUTOMOTIVE

Our injection mold, insert mold, and overmold capabilities allow us to produce magnetic sub- assemblies in high volume to automotive production and quality standards. Our ISO 9001 certification is critical to the success of our automotive customers. Magnet Applications can offer full level 3 PAPP documentation for all of your requirements.

MEDICAL

Our clean assembly area includes component assembly with an option for glove box clean air assembly and end-of-line pass/ fail test. Magnet Applications can offer a wide selection of materials and assemblies that meet your quality and precision while being competitively priced.

ENGINEERING



Our team of engineers are ready to discuss your torque, force and flux requirements. For specialized applications, we can provide supplemental 2D & 3D magnetics models and flux requirements.

Magnetic Materials

Magnet Applications engineers are ready to assist you with the important task of magnet material selection. The design considerations include temperature, vibration, cost, energy product, oxidization, electrical conductivity amongst other specific considerations in your circuit. The following is a brief description of magnet materials and we suggest you contact our sales engineers for further assistance.

Neodymium Iron Boron (NdFeB) falls within the Rare Earth category of magnets. Neodymium offers the highest Br and Hci values and exhibits the strongest magnet materials commercially available (currently up to 52 MGoe). Neodymium magnets are susceptible to oxidization due to the high concentration of iron particles. Dependent on the Permeance Coefficient, Neodymium magnets can be designed into environments up to up to 200 deg C.

Samarium Cobalt (SmCo) magnets fall into the Rare Earth category and are also considered extremely strong (currently up to 32 MGOe). Samarium magnets are less susceptible to oxidization, however they are more brittle than Neodymium. Samarium magnets are typically designed into high temperature environments (up to 300 deg C). Samarium magnets are typically more expensive than neodymium.

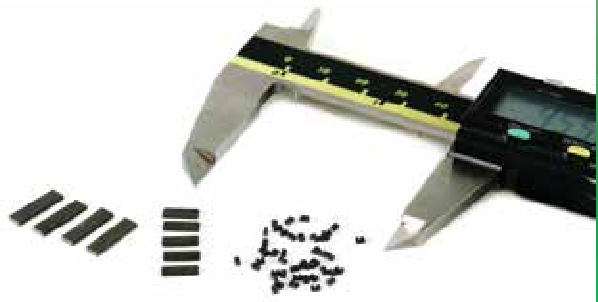
Bonded Neodymium is a resin bonded magnet that is increasingly popular as a mid level rare earth in cost and relative performance. The magnet has a high concentration of resin which is used to bond the particles during the compression or injection mold process. The magnets exhibit up to 11 MGOe magnet strength and can be used with or without a coating. Typical applications are utilized in encoders or BLDC motor applications that require multiple poles in a single piece magnet ring. The material structure is isotropic and thus can be magnetized in a wide variety of patterns. Temperature limitations are up to 150 deg C. A significant and popular aspect is that the material can be manufactured dysprosium free making the material very attractive from a cost basis.

The material also exhibits low electrical conductivity making it suitable for applications to reduce eddy current losses. Magnet Applications is the premier magnet manufacturing facility left in North America for the manufacture of bonded materials.

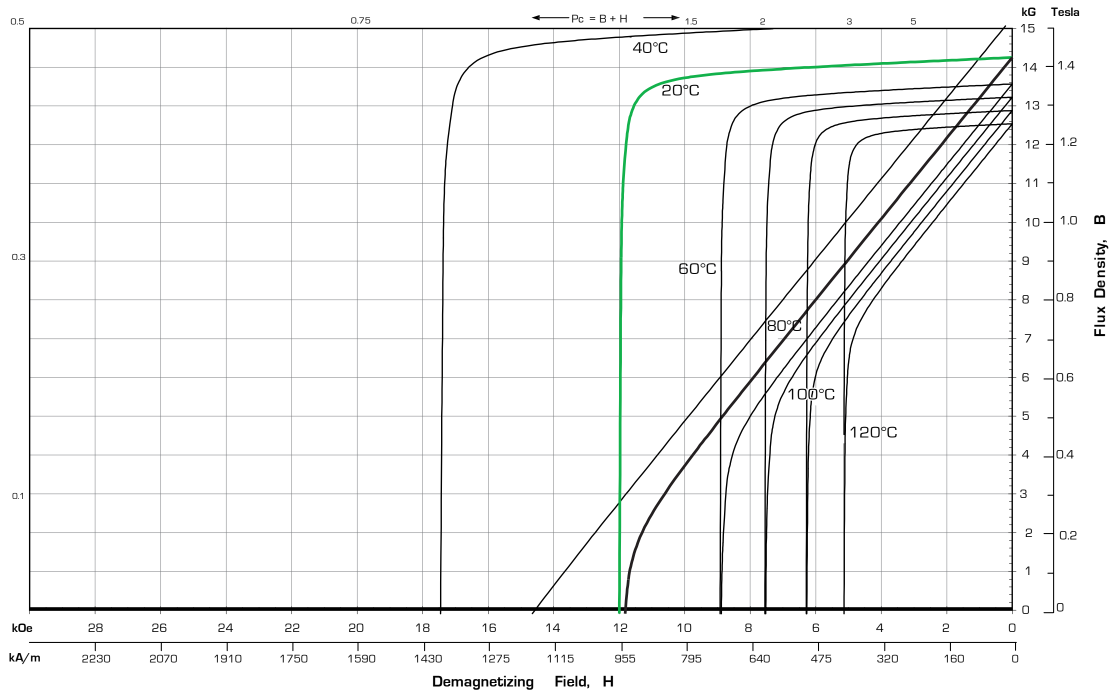
Ceramic magnets (also commonly referred to as Ferrite magnets) are produced from Barium or Strontium ferrite powders. Ceramic magnets are an excellent choice for low cost and low Br requirements up to 4.2 MGOe. They offer excellent resistance to corrosion, are great electrical insulators and can operate in environments up to 300° C.

Alnico magnets (the oldest manufactured material in the industry) derived from iron are made of aluminum, nickel and cobalt. Referred to as Alnico. These magnets are in production due to their ability to handle temperatures up to 540° C. Alnico magnets can be produced up to 5.5 MGOe, however can be easily demagnetized due to its low HCi values and should be considered carefully in your application. Alnico magnets are good electrical conductors and are resistant to oxidization.

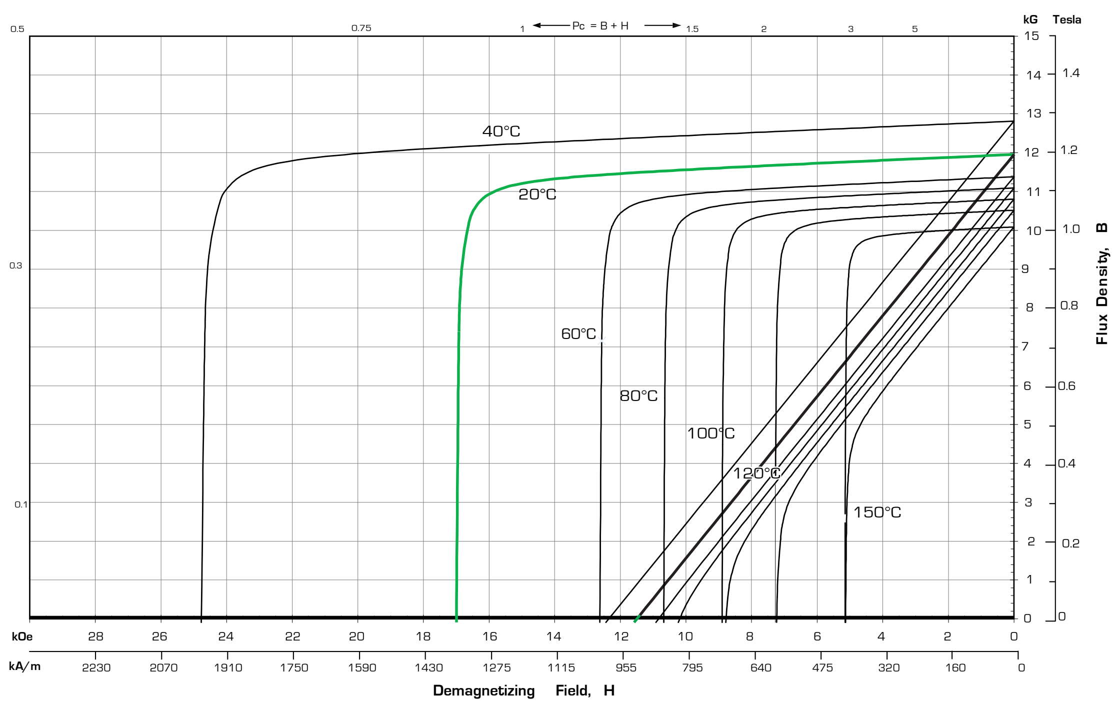
Flexible magnets are produced from a slurry compound of magnet powders and a resin binder that is typically calendared to develop into a flexible rubberized material. Flexible magnets exhibit the lowest magnetic properties (up to 1.4 MGOe) but can be magnetized multiple pole to develop strong magnetic fields. The material can be cut, slit, scored, stamped and coiled for unique applications. Relative cost is low compared to the other magnet materials.



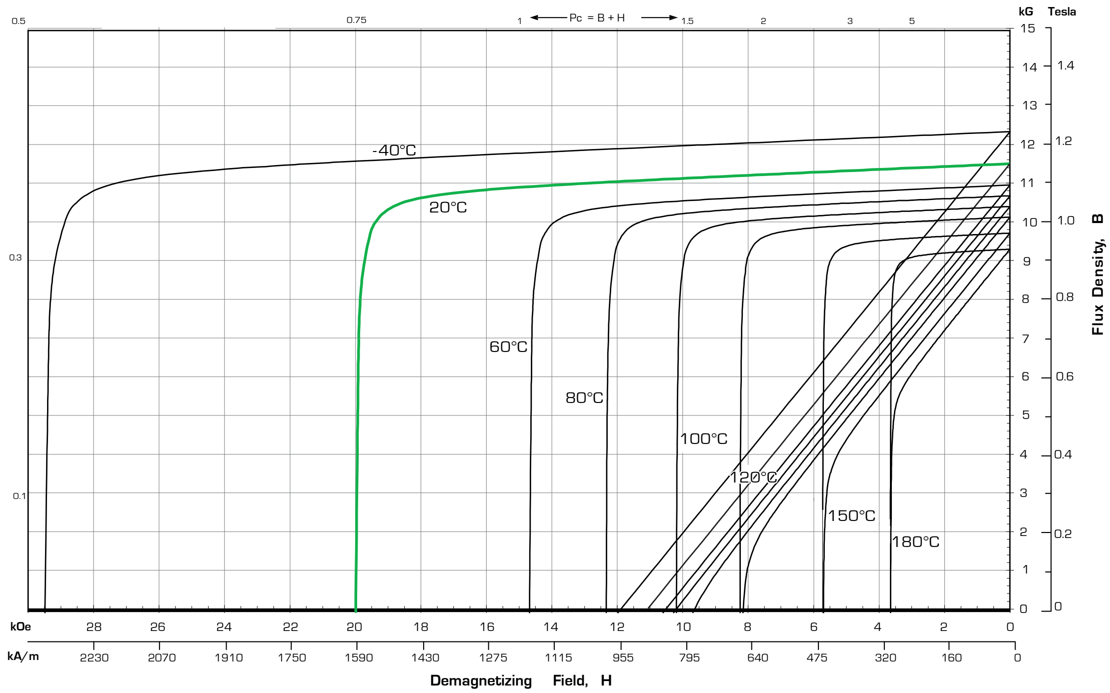
Sintered Neodymium N50



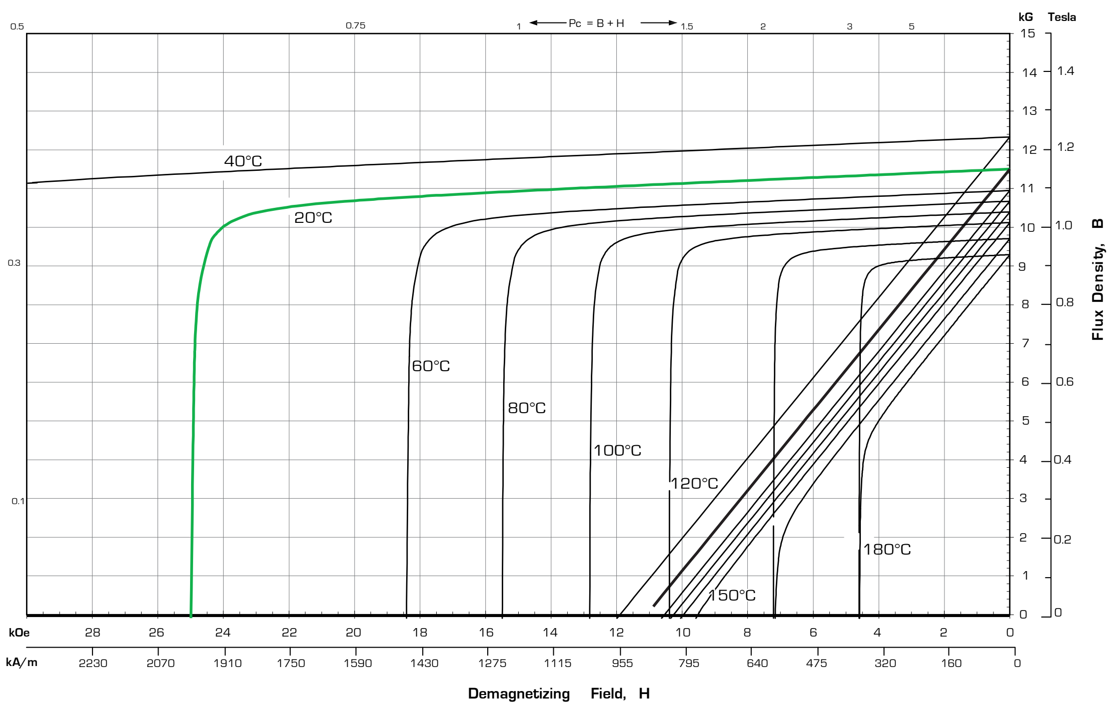
Sintered Neodymium N35H



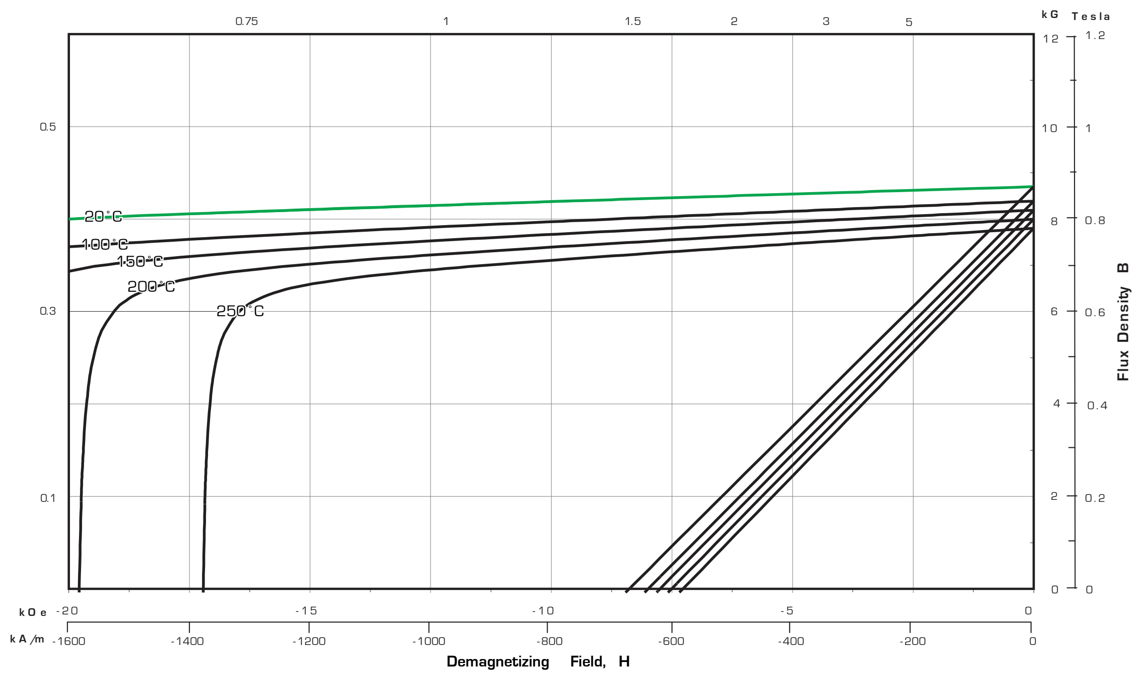
Sintered Neodymium N33SH



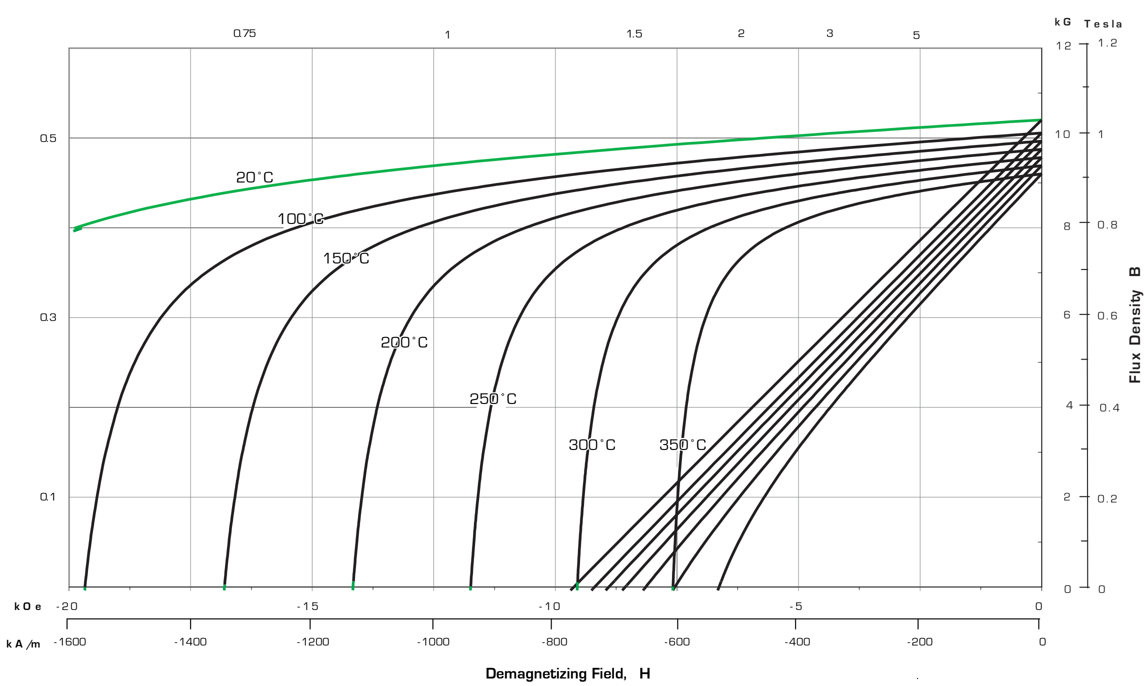
Sintered Neodymium N33UH



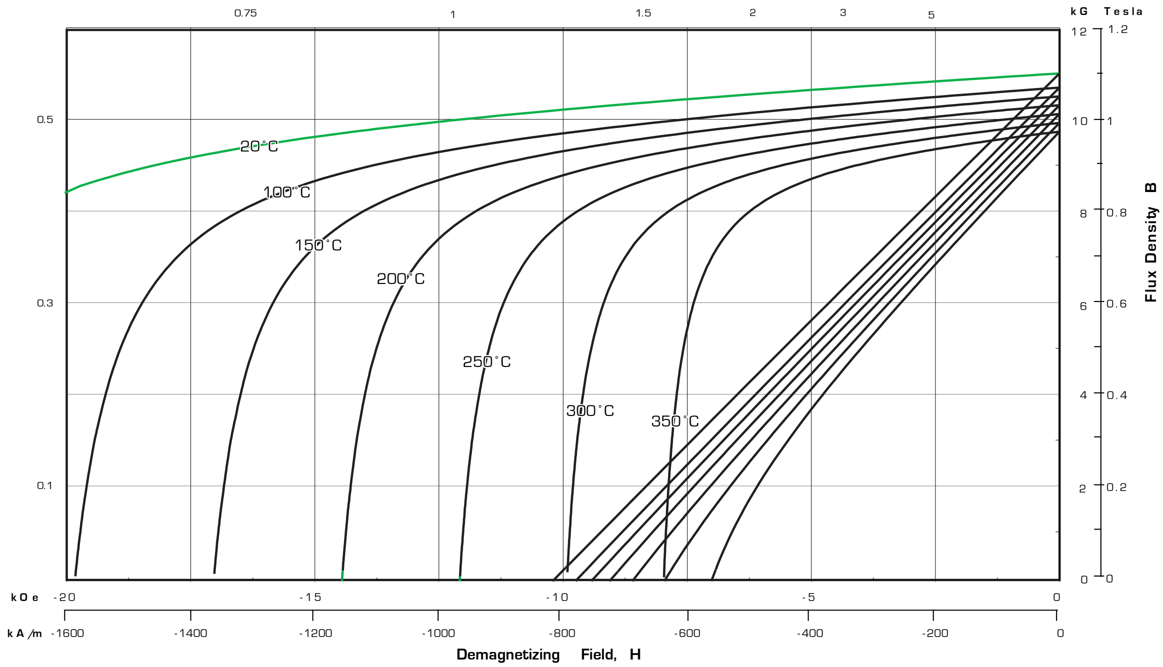
Samarium Cobalt S18



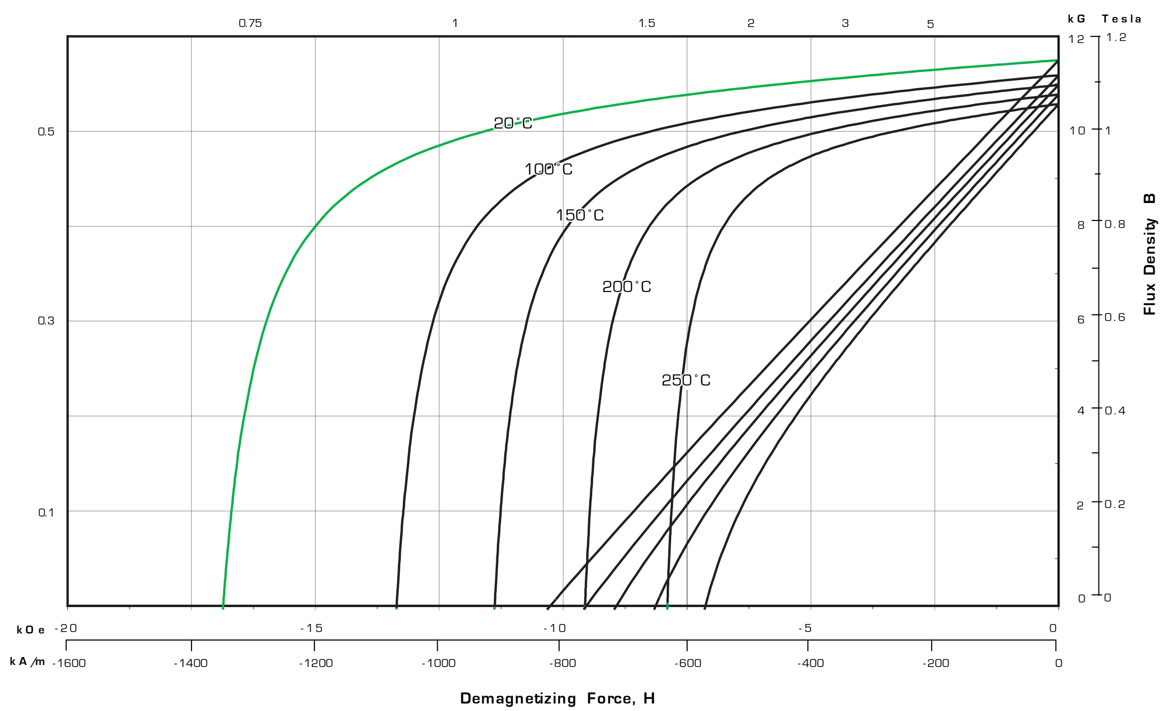
Samarium Cobalt S26



Samarium Cobalt S28

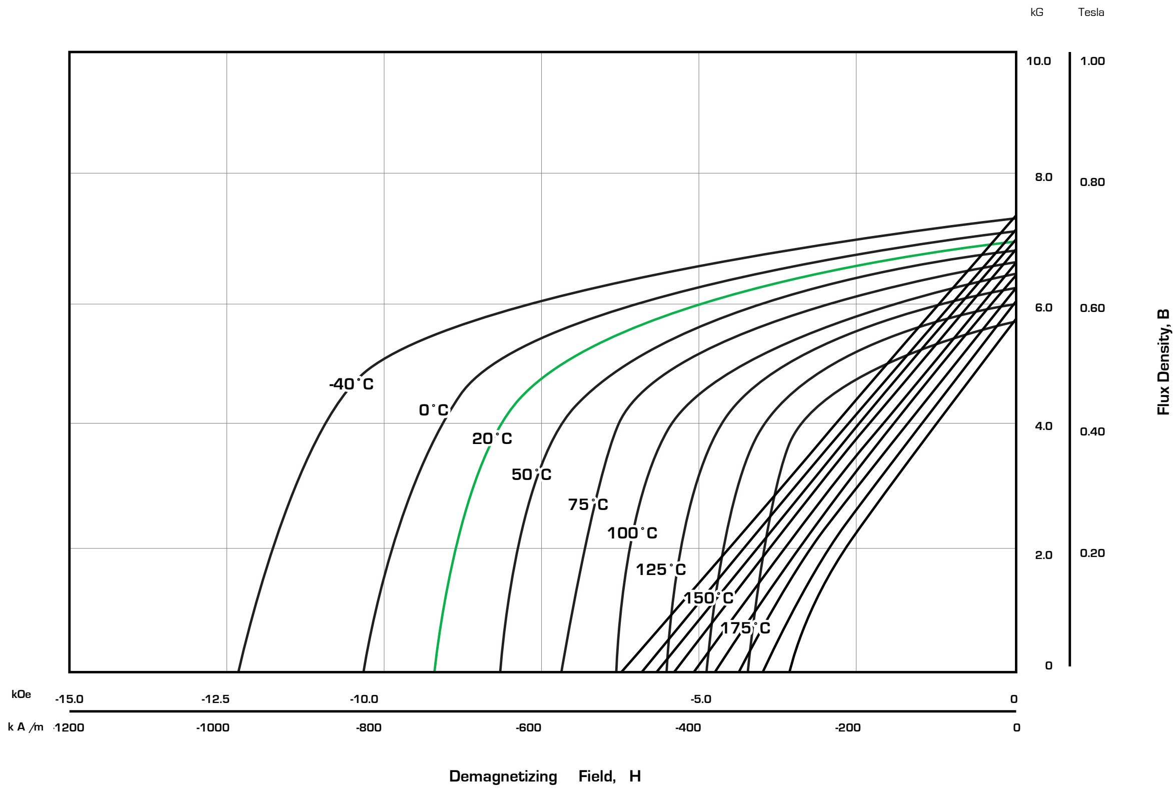


Samarium Cobalt S32

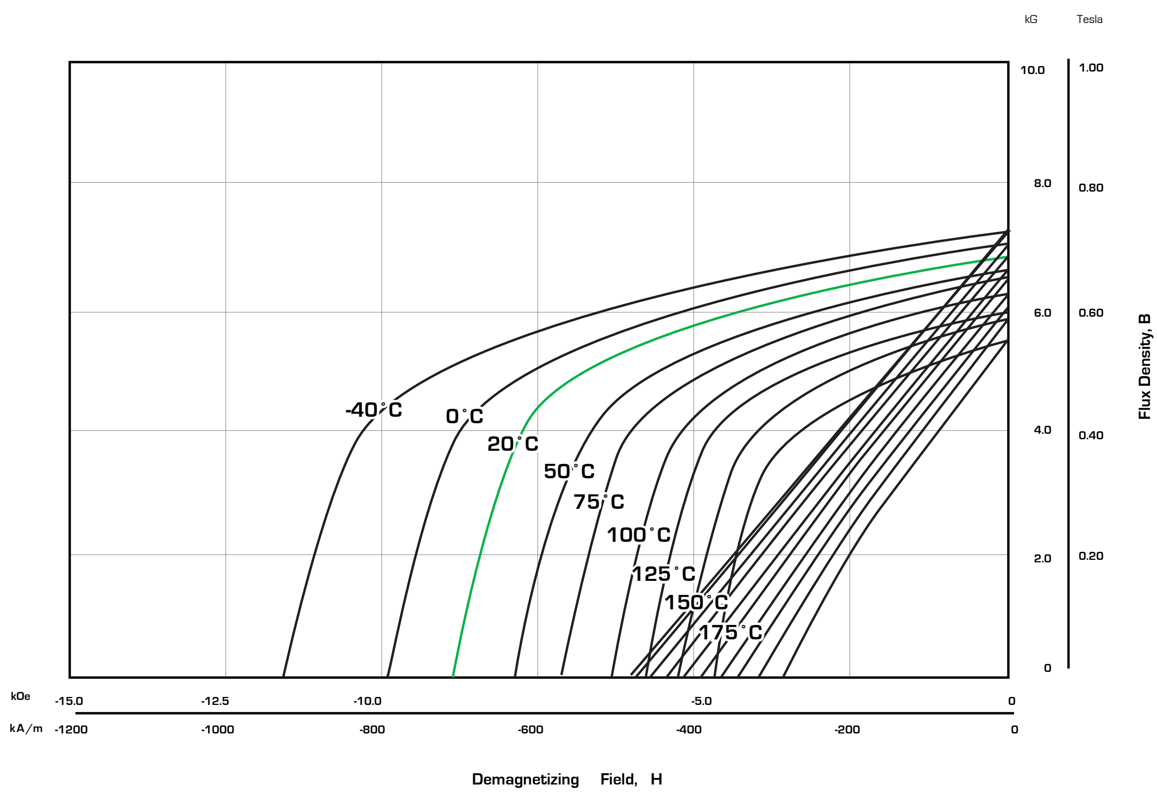


A Bunting® Magnetics Company

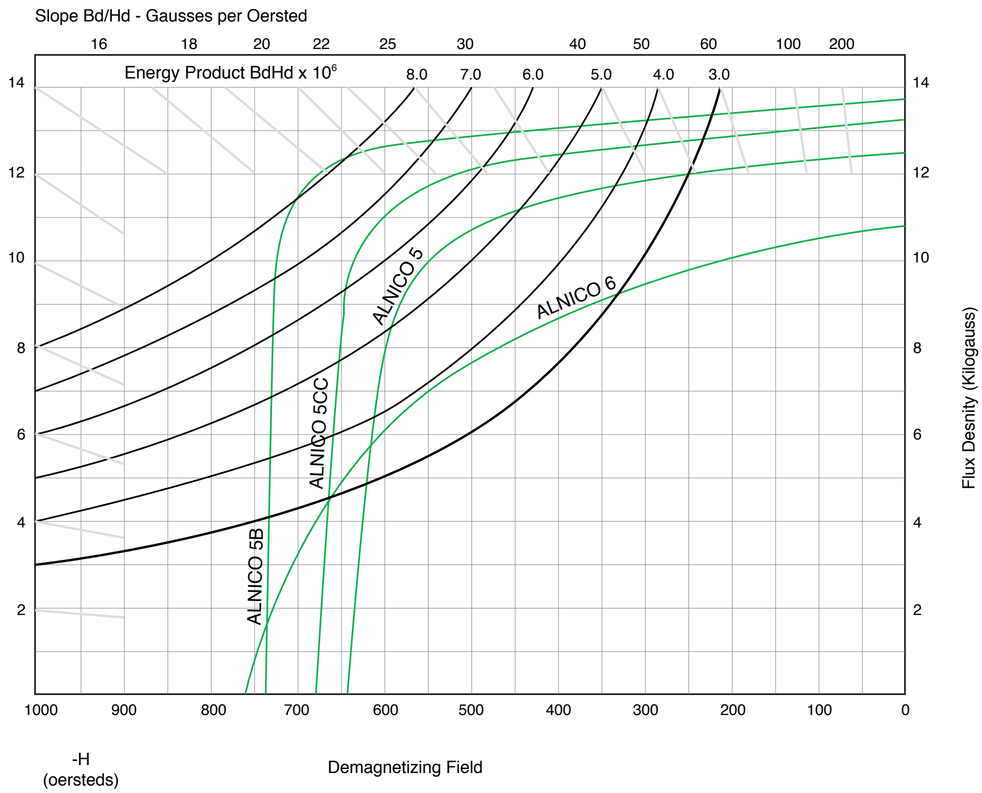
Bonded Neodymium B10



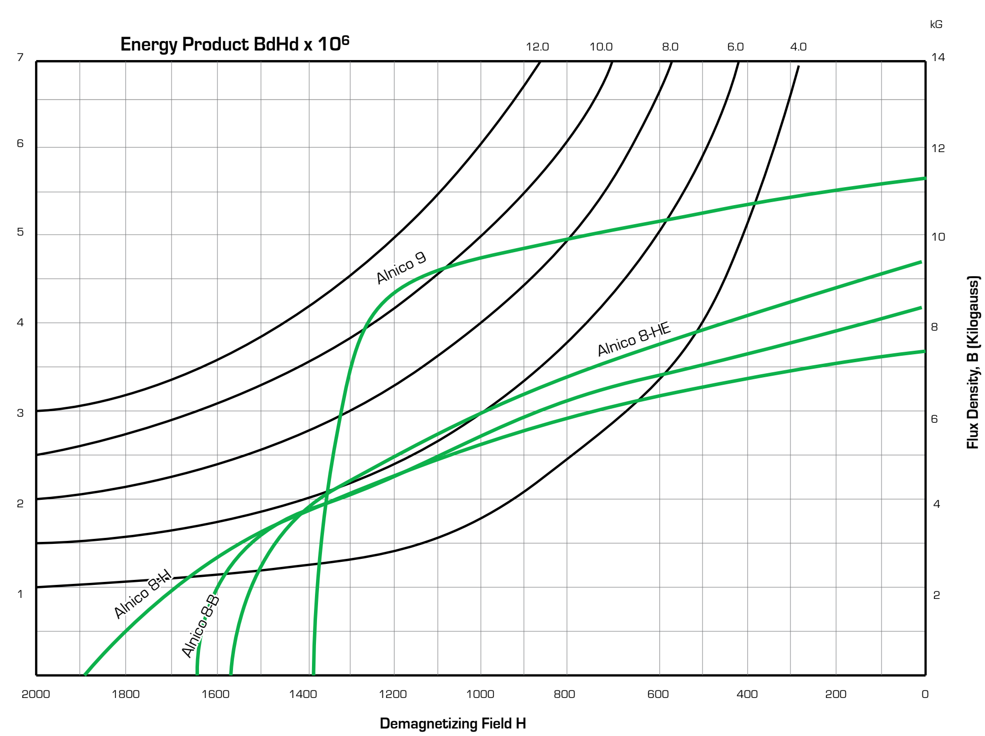
Bonded Neodymium B11



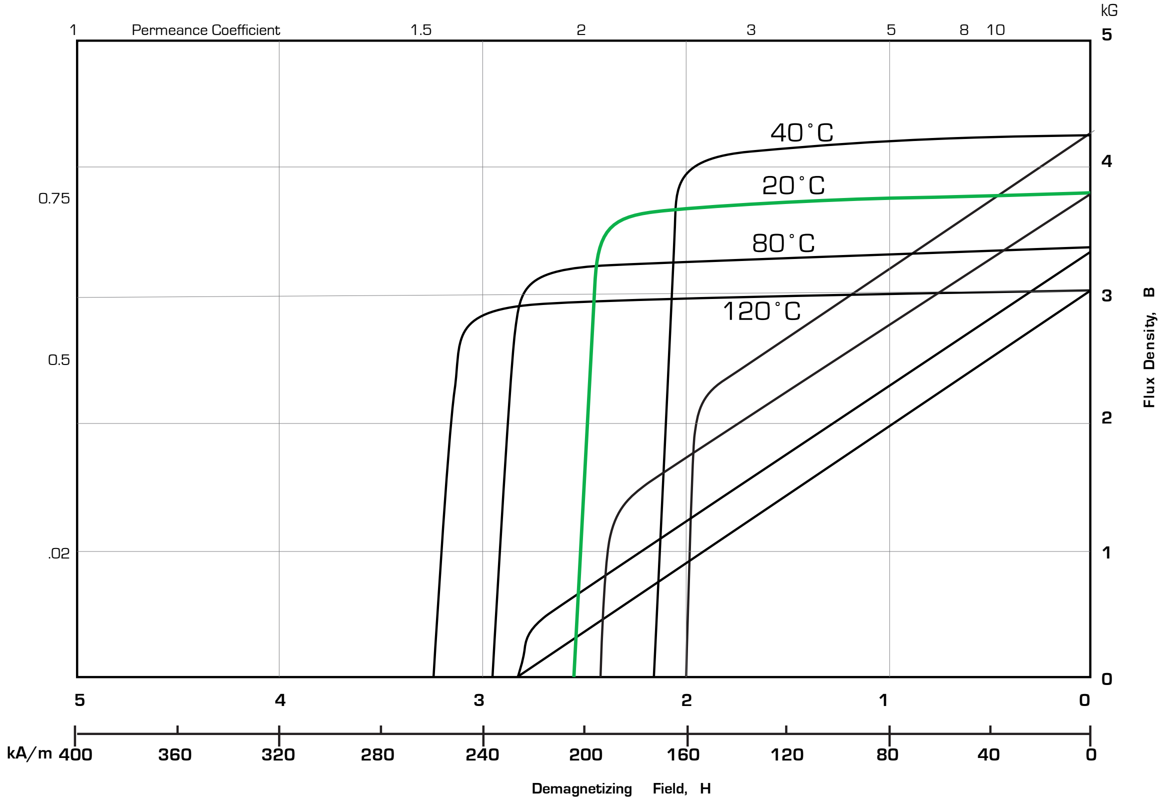
Alnico 5 & 6



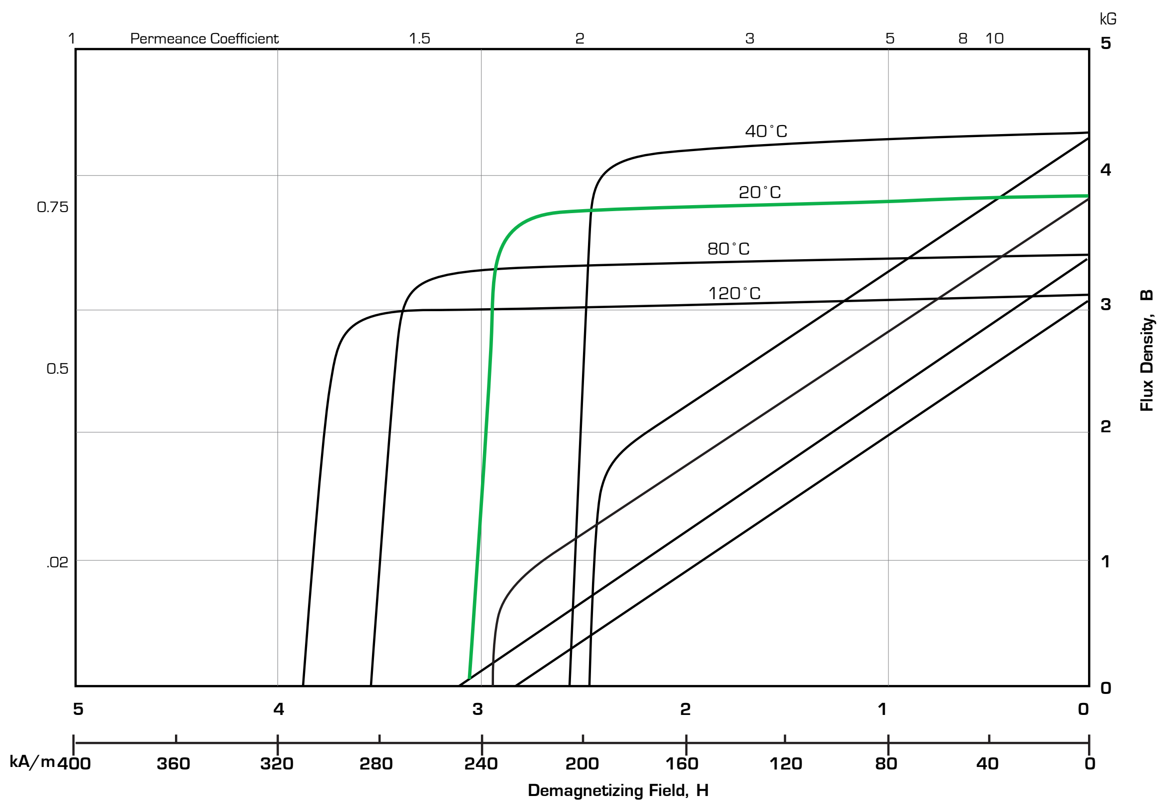
Alnico 8 & 9



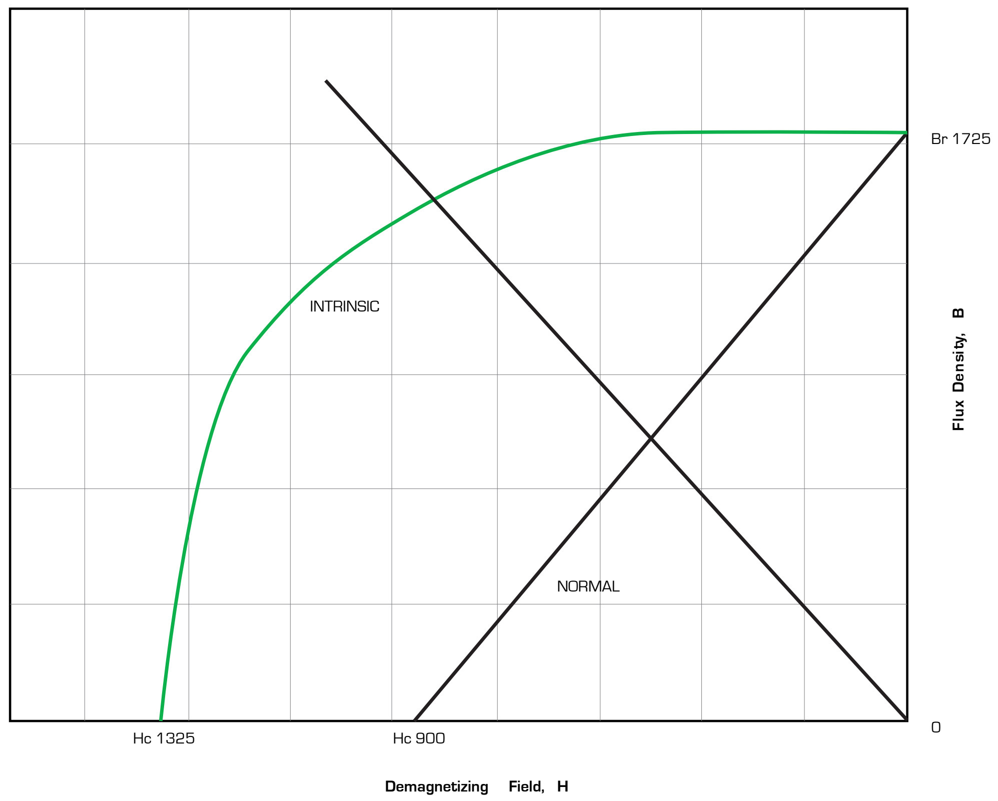
Ceramic 5



Ceramic 8



Flexible Magnet



Magnet Material Characteristic

Grade	Br		Hc		Hci		BHmax		Max Oper
	G	mT	Oe	kA/m	Oe	kA/m	MGOe	kA/m	Temp (C)
NdFeB, Sintered									
52M	14300	1430	12500	995	13000	1035	52	410	100
50	14200	1420	10000	796	11000	875	50	398	80
48	14000	1400	10500	835	11000	875	48	382	80
45	13500	1350	11000	875	12000	955	45	358	80
45H	13500	1350	12500	994	17000	1352	45	358	120
42M	13000	1300	12000	955	14000	1114	42	334	100
40SH	12600	1260	11800	939	20000	1591	40	318	150
38M	12300	1230	11300	899	14000	1114	38	302	100
35	11900	1190	10900	867	12000	955	35	278	80
35H	11900	1190	10900	867	17000	1352	35	278	120
33	11500	1150	10500	835	12000	955	33	262	80
33SH	11500	1150	10600	843	20000	1591	33	262	150
33UH	11500	1150	10700	851	25000	1989	33	262	180
30EH	11100	1110	10200	811	30000	2387	30	239	200
SmCo, Sintered									
32	11500	1150	8000	636	10000	796	32	254	300
28	10900	1090	9000	716	12000	955	28	223	300
26H	10600	1060	9200	732	18000	1432	26	207	300
26	10600	1060	8500	676	12000	955	26	207	300
20	9200	920	8600	684	18000	1432	20	159	280
18	8800	880	8400	668	18000	1432	18	143	280
NdFeB, Bonded									
B11N	7200	720	5500	440	9000	716	11	85	130
B10N	6800	680	5800	461	9100	724	10	80	150
B8N	6000	600	5000	398	9100	724	8	64	150
B6N	5500	550	4700	374	9100	724	6	48	150
NdFeB, Injection									
45/60 P2	5500	550	4700	374	9000	716	6	48	150
38/60 P1	5000	500	4000	318	9000	716	5	40	150
30/60 P1	4500	450	3900	310	9000	716	4	32	150
Alnico, Cast									
5 - 7	13500	1350	740	59	740	59	7.5	60	525
8	8200	820	1650	131	1700	135	5.3	42	550
Alnico, Sintered									
8	7400	740	1500	119	1600	127	4	32	550
5	10900	1090	620	49	630	50	3.9	31	525
Ferrite, Sintered									
8	3900	390	3200	255	3250	259	3.5	28	250
5	3800	380	2400	191	2500	199	3.4	27	250
1	2200	220	1900	151	3250	259	1.1	8	250
Ferrite, Injection									
16/21 P1	2870	287	2250	179	2600	207	2	16	150
14/21 P1	2780	278	2250	179	2700	215	1.8	14	150
12/22 P1	2600	260	2200	175	2830	225	1.5	12	150
3/17 P1	1300	130	1080	86	2170	173	0.4	3	150

Other material grades available upon request.

About Bunting®

Magnet Applications is a Bunting Magnetics Company.

As the industry-leading manufacturer of magnetic technology products, Bunting Magnetics Co. has developed precision magnetic products for the worldwide printing, automotive, plastics, food, electronics, pharmaceutical and recycling industries for more than 50 years.

Our family-owned group of companies manufactures products which serve global markets and include a broad range of magnetic materials and components, magnetic separation systems, material handling equipment, metal detection equipment, magnetic cylinders and flexible dies for the printing industry, bonded magnets, and assemblies.

Walter F. Bunting - Founder

Bob Bunting - President, CEO

BUNTING® Magnetics Co.

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