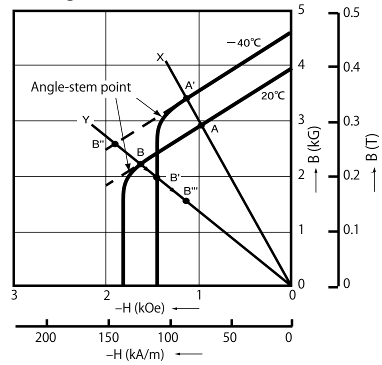
Principles

1. Operating Point

Right figure presents an example of moving state of operating point due to temperature variations. A-B shows demagnetization curve of Q6 material at 20°C. And A'-B' shows the curve of Q6 at 40°C. And 2 operating state are shown in operating line X-0 and Y-0. In X-0 operating state, operating point of magnet irreversibly changes along X-0 line holding constant temperature coefficient(0.19%/°C). However, in Y-0 operating state, where operating line is more slanted, the operating point will move from B to B' and that remanence value will be equivalent to the value of irreversible attenuation B''-B'. This difference will not be changed even when tem-perature returns to normal level. After exposed to irreversible demagnetization at low temperature, the operating point moves to B'''on Y-0 line.

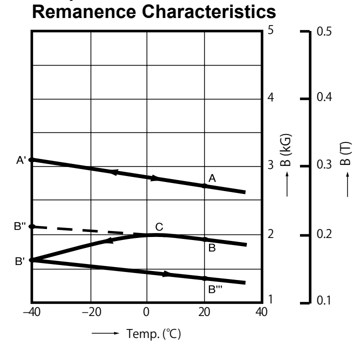
Temperature vs. Demagnetization Characteristics



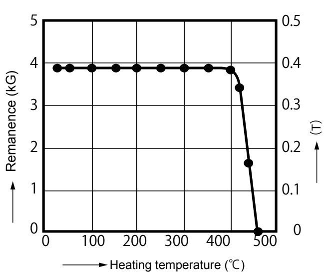
2. Remanence Curve at Operating Point (X-0, Y-0)

Right figure presents variations of remanence value on operating line X-0 and Y-0 shown in above figure on another scale. It shows the irreversible demagnetization starts at low temperature starts from point C.
This low-temperature demagnetization is affected by material or operating points (permeance coefficient). Therefore, when avoiding low-temperature demagnetization, material with large Hc such as Q2 should be used. Or permeance coefficient should be set high so that the operating point can be positioned above angle-stem point of demagnetization curve at minimum usage limit of the material in Quadrant II.

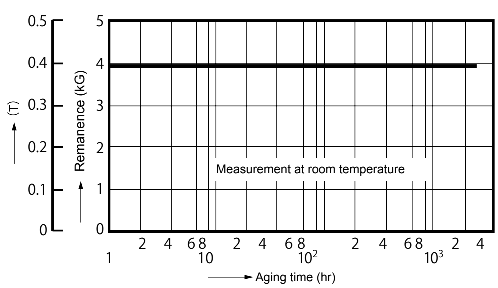
Temperature vs. Remanence Characteristics



High-temperature Heating vs. Remanence Characteristics



Remanence vs. Time (right)



High-temperature Heating vs. Remanence Characteristics (left)
Heating up to high-temperature causes few demagnetization although remanence will be irreversibly changed up to 400℃ (lower than Curie temperature). After going back to normal temperature, there is not much demagnetization.

Remanence vs. Time (right)
It is hardly changed due to the time consumed.

3. Magnetization and Degaussing

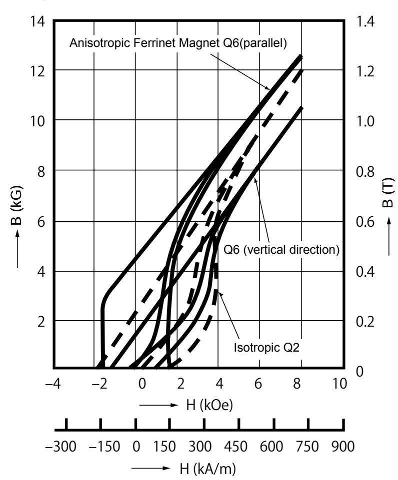
●Magnetization
As seen from hysteresis loop shown on right figure, Ferrite Magnet requires much larger magnetizing field than metal magnets. And to reach saturation, magnetic field of more than 15,000 Oe must be added. But practically, approximately 10,000 Oe is enough.

a) As shown in right figure, the hysteresis loop of isotropic Ferrinet Magnet, regardless of directions, will be almost identical. And magnetic strength will not be changed whether Ferrinet Magnet is installed before or after it is demagnetized. So it is very simple to handle.

b) As shown in right figure, the hysteresis loop of anisotropic Ferrinet Magnet will be completely different whether the direction of Ferrinet Magnet is parallel or perpendicular to the magnetic direction during molding process. In general, the larger the azimuth ratio [Br(//)/Br [⊥]], the better anisotropy anisotropic Ferrinet Magnet shows. The anisotropy is between 3.0 and 4.0.

●Degaussing
Degaussing of every materials requires reverse magnetic field commensurate Hc, however, for any materials, reverse magnetic field is to high degaussing cannot be done completely. Therefore, to conduct large amount of degaussing safely, the best method is heat-degaussing (heat materials above Curie temperature).

Hysteresis Loop



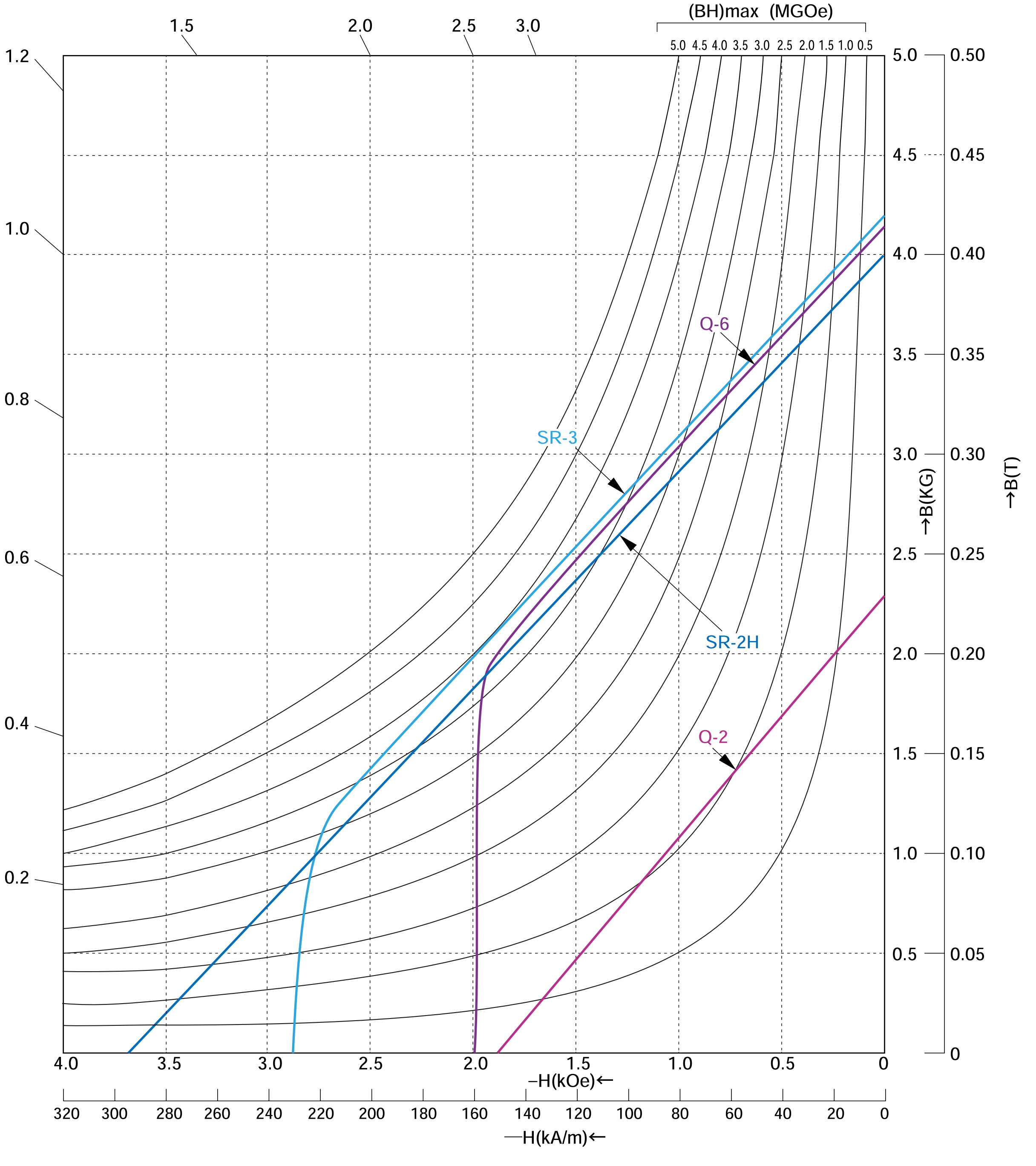
Demagnetization Curves and Magnetic Stability

1. Demagnetization Curves

Following 2 figures present demagnetization curves of various types of Ferrite Magnets. It clearly shows the difference in performance of each Ferrite Magnet. Permeance coefficient (p=Bd/Hd) during operation should be lower than that of cast magnets. The value should ideally be between 1.5 and 3. The shape of magnet will be generally flattened.

■Demagnetization Curves of Isotropic and Wet Anisotropic Ferrite Magnet

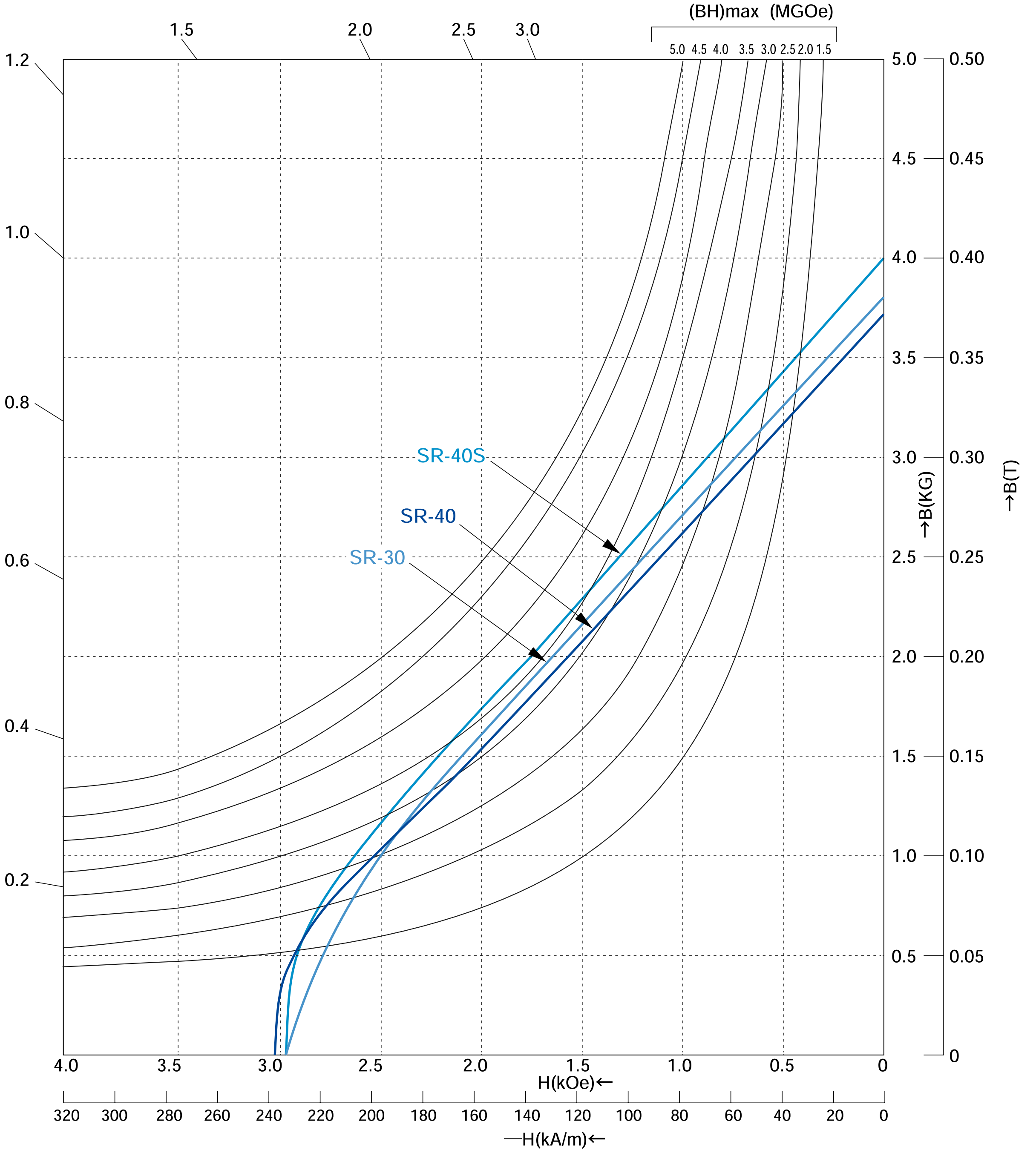
(Permeance Coefficient p=Bd/Hd)



Demagnetization Curves and Magnetic Stability

■Demagnetization Curves of Dry Anisotropic Ferrite Magnets

(Permeance Coefficient p=Bd/Hd)



Demagnetization Curves and Magnetic Stability

2. Magnetic Stability

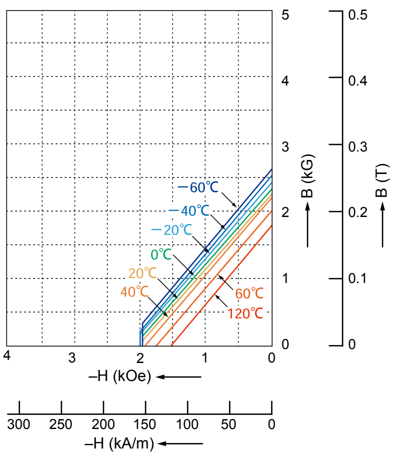
Magnetized materials tends to be demagnetized due to various external influences during operation. Therefore, it is necessary to perform various stabilizing processes when general magnets are used. However, Ferrite Magnet has high magnetic stability, and its performance is hardly lowered by external disordered magnetic field and machinery shocks, thanks to its great coercive force.

●Temperature Change

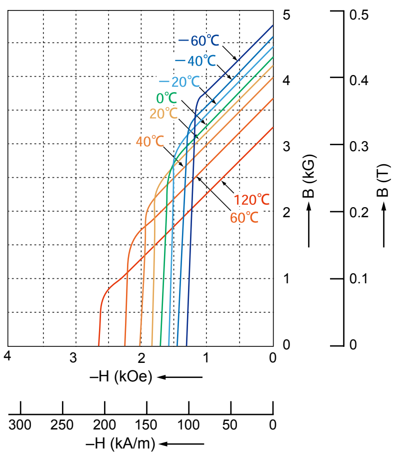
Following tables present temperature change in demagnetization curves of various Ferrite Magnets. Ferrite Magnet has large temperature coefficient of remanence (apparent remanent magnetic flux density) and tends to receive irreversible demagnetization. Therefore, you must be careful of deciding operating point of magnets.

3. Thermal Variations in Demagnetization Curves

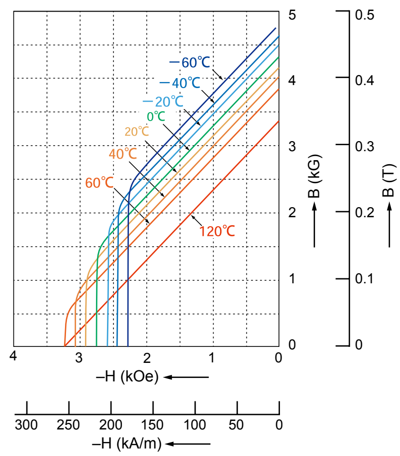
Q2



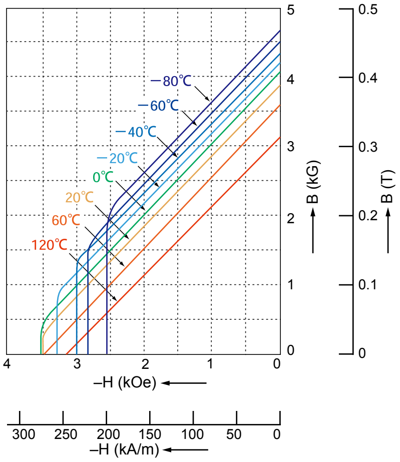
Q6



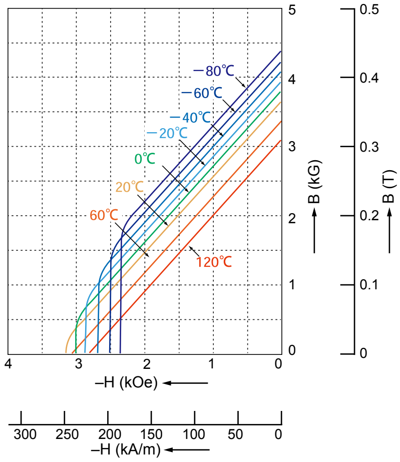
SR-3



SR-2H



SR-30



Glossary of Terms (SI Units)

1. Magnetic Properties

●Magnetic Fields

There exists magnetic fields on earth. This exists not only in Ferrite Magnets but also around electric conductors. Magnetic field is represented by H. The SI unit is represented by A/m (CGS unit is represented by Oe). For instance, earth magnetic field is approximately 24A/m. It is possible to create easily magnetic filed of 1.6MA/m by using electromagnets. However, it needs some device to create stronger magnetic fields.

●Magnetization

When placing magnetic materials in magnetic fields, that material will generate magnetic changes. This is called magnetization. Further, the rate of magnetization is called "intensity of magnetization". And its strength is represented by M. Its unit is T (for CGS units, it is represented by 4πI, and the unit is G).

●Saturation Magnitization

As increasing magnetic fields imposed upon magnetic material, that material will reach saturation. This degree of magnetization is calledsaturation magnitization. For instance, saturation magnitization Js of barium ferrite magnet is approximately 0.44T (4400G).

●Magnetizing

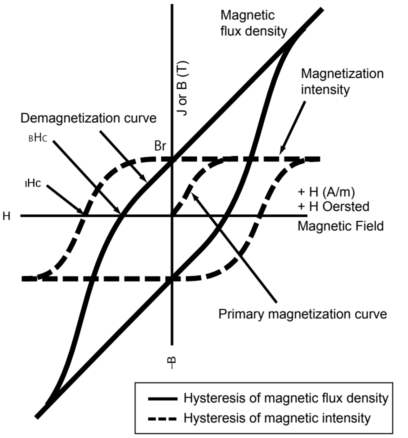
The operation to apply magnetic field enough for magnetic material to reach saturation is called magnetizing. And when remove magneticfield used for magnetizing from the material, it will keep the state of being magnetized. After going through this process, magnetic material will be Ferrite Magnet.

●Magnetic Flux Density (Magnetic Induction)

As stated above, magnetic material is magnetized by magnetizing. In this case, magnetic flux goes through the material. Magnetic flux per unit area is called magnetic flux density (magnetic induction) and it is represented by B. The unit is represented by gauss (G), equal to that of intensity of magnetization. This magnetic flux density is represented by $B = J + \mu 0H$. Briefly speaking, this value is equivalent to magnetic field given to the material plus intensity of magnetization. The intensity of magnetization in the air is nearly zero regardless of the intensity of the magnetic field (In another words, 4πI of the air is nearly zero.). Therefore, after taking the magnets used for magnetizing out of the magnetic field, the intensity of magnetization around the magnet will be equal to the magnetic field on site. Practically, the most important matter is the value of this magnetic flux density.

●Residual Magnetic Flux Density, Coercive Force, and Hysteresis Curve

This section explains the change in the intensity of magnetic field and the magnetic flux density when exerting magnetic field to the magnetic material gradually or conducting the reverse process by decreasing magnetic field. At first, as stated in the previous section, when gradually adding magnetic field to magnetic material, it will gradually gain magnetization and finally reaches saturation magnetization. This process is called primary magnetizing process. In the next stage, the magnetic flux density gained by decreasing magnetic fields and eliminating external magnetic field exerted upon the magnetic material is called residual magnetic flux density Br (residual magnetic induction). Further, by exerting magnetic field to the material without external magnetic field towards the reverse direction, the magnetizing and magnetic flux density will decrease. Then the magnetic flux will not go through the magnetic material. The intensity of magnetic field exerted upon the material on this stage is called coercive force H_{CB}. Further, when increasing magnetic field of reverse direction, the magnetic flux will flow toward reverse direction and then magnetization intensity will be eliminated. Magnetic field exerted upon the material on this stage is called H_{CJ}. In another word, there are two kinds of coercive force. One is magnetic field H_{CB} which decreases magnetic flux density B to zero. Another is magnetic field H_{CJ}, which decreases the intensity of magnetization intensity J to zero.



When increasing diamagnetic field beyond coercive force HCJ, the magnetization intensity will turn around to the opposite direction and correspond to the direction of diamagnetic field, and finally the mag-netization intensity will be saturated. The curve describing repetition of these processes is called Hysteresis Loop (Refer to above figure).

●Diamagnetic Field

Ferrite Magnet generates external magnetic field by its N and S pole. On the other hand, the magnetic field exists within the magnet generated by the same N and S pole. This is called diamagnetic field (demagnetization field). The size and direction is different from mag-netic flux density inside the magnet. Diamagnetization field tends to decrease its own magnetic intensity. And as near as N and S pole exists (the length of magnet is short; Length comparison = length/diameter), demagnetization field gets larger.

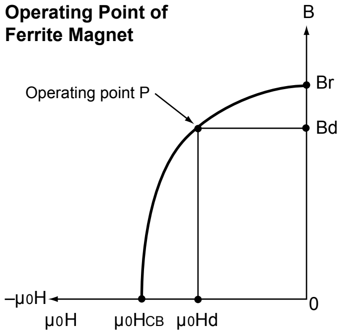
●Demagnetization Curve

As stated in the section of magnetic flux density, Ferrite Magnet uses its magnetic flux generated through magnetization process.Therefore, as much magnetic flux density remains in the Ferrite Magnets despite large diamagnetic field, it can be said that its feature is more prominent. As a result, the essential condition for superior Ferrite Magnet is that it has large residual magnetic flux density and coercive force BHC. Demagnetization curve is used in order to find out how magnetic flux density changes according to the intensity of diamagnetic field. This curve is identical to the second quadrant of hysteresis loop which explains the relationship between magnetic flux density and magnetic field. (Refer to above figure). The first step to evaluate the Ferrite Magnet is to see its hysteresis Loop.

Glossary of Terms (SI Units)

●Operating Point

When diamagnetic field exerted upon the Ferrite Magnet is equal to Hd, the magnet generates magnetic flux density (magnetic induction) which correspond to Bd on the demagnetization curve. In this way, the point represented by Hd and Bd is called the operating point of the Ferrite Magnet. (Refer to below figure). However, in practical use, this point changes according to the environmental conditions. For example, the operating point of magnet is positioned at P in right figure after being magnetized, it will move to area in which diamagnetic field decreases and magnetic flux density increases when attaching iron piece to the magnet.

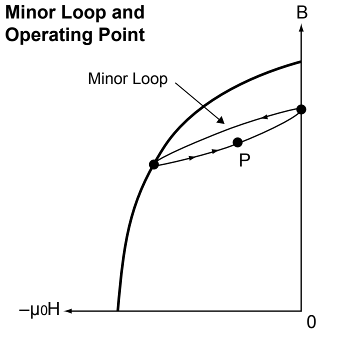


●Maximum Energy Product

As stated in the section of demagnetization curve, the criteria to judge the magnetic properties of Ferrite Magnet is to see demagnetization curve. In another words, if some diamagnetic field Hd exists, it is only necessary to find out how much the magnetic flux density Bd is. So, best way to judge magnetic properties of Ferrite Magnet is to use maximum product of Hd x Bd on operating point. Since Hd x Bd is proportional to energy per magnet volume which magnet enables to give off into outer space, that value is called maximum energy product. The unit of maximum energy product is J/m^3 for SI units, and GO_3 for CBS unit. Optimum method to design Ferrite Magnet is to make sure that the operating point is identical to the point of maximum energy product. The reason is that it is possible to minimize the volume of Ferrite Magnet required to gain necessary energy.

●Minor Loop

In the previous section, it is stated that operating point moves according to operational conditions of Ferrite Magnet. This does not mean the operating point moves exactly on demagnetization curve. But it moves on hysteresis Loop which are formed with the primary operating point as the datum point as shown in below figure. This small hysteresis Loop which starts from demagnetization curve is called minor loop. The operating point of Ferrite Magnet should generally be on minor loop. However, in case the operating point does not move such as that of magnet for speaker, it is naturally on demagnetization curve.



2. Thermal Variations of Magnetic Properties

●Irreversible Thermal change

Magnetic flux density of Ferrite Magnet decreases when it is exposed to high temperature even though the quality of material does not change. This rate of change in magnetic flux density gradually gets smaller proportional to the length of the time during which the magnet is exposed to high temperature. And it reaches saturation in relatively short period of time and stop to change. The rate of change at this stage corresponding to primary value of magnetic flux density is called irreversible thermal variations. The irreversible thermal variations, whether small or large, is found in any Ferrite Magnet. The degree of variation varies in a large scale depending upon retention temperature and position of operating point of magnet.

●Reversible thermal change (Temperature Coefficient)

So far, magnetic properties at room temperature is stated. Conditions of magnetic properties when magnet is exposed to low or high temperature is extremely important upon practical operation. In order to find thermal change of magnetic properties, demagnetization curve at each temperature is required. By simplifying this process, changes in operating point Bd per 1℃ is called rate of irreversible thermal change (temperature coefficient). This rate should be measured after irreversible thermal variations at every temperature is completed.In addition, regarding general magnets, rate of irreversible thermal variations will change according to the position of operating point of the magnet. However, when this rate is represented by one figure, the value should be based on the variations of Bd at the point of maximum energy product like reversible permeability.

MARUWA

Handling Precautions

1. Precautions for safety

a) Large magnets exert an extremely powerful suction force (and sometimes a repelling force) on other magnets or metal scraps and other magnetically attracted substances. This force is capable of causing you to suddenly lose your balance or suffer serious injury if your hand or other parts of your body become trapped in the magnetic field while carrying or installing the magnets. Please take sufficient care when handling these magnets and always use appropriate tools.

b) The sharp edges of magnets can cause injury to your fingers and hands especially. Please handle the magnets with care.

c) When attaching magnets using a hollow-core coil, please be aware that the magnet may suddenly spring away from the coil. For safety's sake, place the magnet in the center area of the coil and secure it.

d) Keep magnets out of the reach of children so as to avoid accidental swallowing. Should this occur, see a physician immediately.

e) People whose skin is allergic to metals should avoid working with magnets, as this may cause an adverse reaction (rough, red skin).

f) It is extremely dangerous to handle magnets near people who are wearing pacemakers or other electronic medical devices. Take special care when using magnets around medical equipment, as it may impair normal operations.

h) Magnets are generally susceptible to breakage. Please take care when handling any magnet, and be aware that magnet fragments can easily enter your eyes or cause other serious bodily injury.

2.Design Precautions

a) Some anisotropic Ferrite Magnets, depending on the material, suffer reduced magnetism at low temperature. Always check the performance of the magnet at the temperature at which it will be used.

b) Ferrite Magnets are often used for transmission; since the material cracks very easily, take measures to protect it from shock.

3.Handling Precautions

a) If magnetized Magnets are placed one on top of another, they can become difficult to pull apart or chip. Separate the magnets by using a spacer such as cardboard.

b) If a magnetized magnet is allowed to be attracted to a metal plate or if two magnetized magnets are allowed to attract or repel each other, their magnetism may decrease, so use caution.

c) If a magnetized magnet enters an AC or DC magnetic field, its magnetism may decrease.

d) A magnetized magnet will attract debris such as iron filings, so unpack it from the case in a dust-free environment.

e) A magnet can adhere to small magnetic bodies even if unmagnetized, so use caution in handling. In addition, when mounting a magnet in a precision motor, clean it after assembly before use.

f) Each magnet has its own characteristic Curie temperature, depending on the material. If a magnet is heated to near the Curie temperature, it will lose its magnetism. If it is absolutely necessary to heat a magnet in an assembly process, please consult with us.

g) If a magnet is held to, for example, a yoke by adhesion, select an appropriate adhesive and adhesion method so that mechanical distortion will not remain after adhesion. If the magnet is used while residual stress is still applied, the magnet may be cracked by even a slight shock.

h) Magnets are not very resistant to shock and are easily cracked and chipped, so use caution. Cracking and chipping may cause deterioration of the magnet's characteristics, as well as loss of rigidity.

4.Others

a) Please keep magnets away from magnetic tape, floppy disks, prepaid cards, CRTs, magnetic tickets, electronic watches and similar items. This can result in loss of recorded data or lead to malfunction due to magnetization.

b) Please keep magnets away from electronic devices such as measuring boards and control panels, as this may cause them to malfunction or result in an accident.

c) When cutting a magnet, please be aware that resulting magnetic dust can catch fire spontaneously due to the heat produced by friction during cutting. Keep magnets away from fire or flammable materials. As a precaution against fire, keep a dry chemical extinguisher, a supply of sand, and any other necessary equipment. Also, do NOT use an electric vacuum cleaner.