The principles of creating a magnetic mounting system: the physics every conservator needs to know

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ABSTRACT

How to fasten or secure an artefact to a mount has long been a focus in museums. We have stitched, glued and adhered items for decades, always attempting to keep the mounting as reversible as possible.

Magnets have gained great popularity recently since they offer a way to make an ideally reversible fastener. They have great potential as a new tool. Are magnets the truly reversible tool unlikely to damage an artefact?

New neodymium magnets can be part of our future, but we need a fuller understanding of how they work. Using magnets is not ‘magic’. Conservators can benefit greatly by understanding some of the science behind how a *magnetic system* functions. Three key factors working in concert must be considered: the strength of the magnet itself; the receiving ferromagnetic material; and the displacement over which the magnetic field acts, ‘the gap’. In this presentation, each of these components is explained in detail, to set the stage for improved mount designs. In addition, an overview of relevant physical phenomena of materials is introduced.

1. INTRODUCTION

Art conservators have been using magnets for many years, but it has been done in a very limited way (Dignard 1992; Spicer 2010). Perhaps the delay in using magnets occurred because systems had not been adequately described in the literature or because physics is not a required field of study for conservators in many countries. Perhaps it is a practice is still considered too novel to be widely embraced. Conservators need to understand how a *magnetic system* functions. Each part of the magnet system works in tandem to achieve the best combination for the artefact.

2. PERMANENT MAGNETS

Table 1: Types of permanent magnets

3. CREATING A MAGNETIC SYSTEM

When using and selecting magnets of any type, three key components are in play.

1. The strength of the magnet itself. Magnetic strength is measured and described in units of *gauss*.

2. The receiving component. This is the material that is magnetized in this system.

3. The magnetic field distance. This space between the magnet and the receiving ferromagnetic material is known as ‘the gap’.

Each component is important in determining how the magnet behaves and is able to perform the task (Feynman 1964; Livingston 1996; The Magnet Story 1998). Balancing these three parts correctly determines a successful system. No one method can be generally prescribed. Instead, each component is adjusted for any particular situation, further complicated by the wide variety of needs and requirements of each artefact.

The developed system must be sufficiently strong to support the artefact, but not so strong that damage results. Each variable can be slightly altered to reach the desired outcome. Each component is described below and is compared with known alternatives (Spicer 2013a, 2013c, 2016).

3.1 STRENGTH OF THE MAGNET

Magnets are purchased with a set polar direction. The most common magnet has north and south faces located on the largest surfaces of the magnet. These magnets are axially oriented, so the flat surfaces of these magnets have the strongest pull force present. This is because all of the magnetic fields are coming or going from this centre spot. The polar direction can also be oriented side-to-side, making diaxially-oriented magnets (Figures 1a-c).

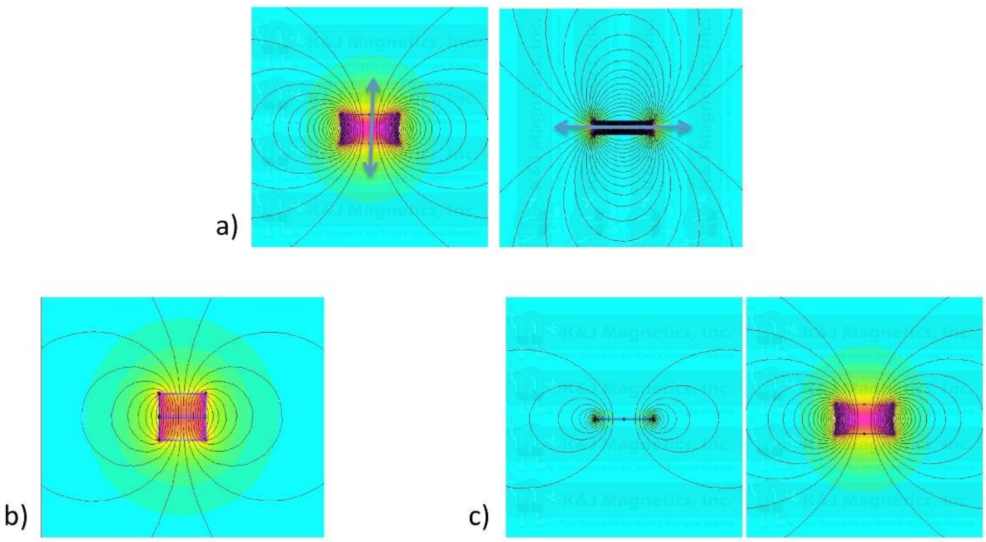

Fig. 1. a) The diagram of axially and diaxially oriented magnet. b) Two similar sized disc, axially oriented magnets creating a polar radiation loop. c) Two disc magnets of different thickness but of the same diameter. The magnetic field of the thinner magnet is much more compact at the outer edges when compared to the thicker magnets (K&J Magnets).

The pull force of a magnet, the amount of force necessary to pull the magnet straight from the surface of a steel plate, is measured in *gauss* both from its centre and from its outer surface.

The grade of a Neodymium magnet greatly alters its properties, such as strength, brittleness, and its Curie temperature (the temperature when all magnetism is lost). The grade of a Neodymium magnet can be thought of as the properties of the magnetic material itself and how the behaviour is affected. Neodymium rare earth magnet grades are represented with both letters and numbers. Grades commonly used by conservators are grades N35, N42 or N52. Note that a few suppliers use alternative naming conventions. The number represents the strength of a magnet, and generally speaking, the higher the number, the stronger the magnet. An example is N52, which compared to a N42 of the same size is about 20% stronger, and has a higher pull force of its surface field. The higher the number, the more brittle the magnet becomes. Breakage potential increases as the magnet becomes thinner. For example, a very thin N52 magnet will easily break and should be supported if frequently handled. The numbers used by most suppliers correspond to the Maximum Energy Product (MGOe) designation. Therefore, the N42 is 40-42MGOe and the N52 is 49.5-52MGOe.

The letter represents both their manufacturing method, as well as their formulations. Sintered magnets are represented as N, M, H grades and bonded magnets as BDM grade. Bonded magnets should be considered if the potential of high humidity conditions exist. Additional alloys in mixture with Neodymium, like Terbium and Dysprosium, are added to maintain a magnet's magnetic properties at higher temperatures (Brown 2004; Jones 2011); other letters represents these.

3.2 RECEIVING COMPONENT (THE MAGNETIZED MATERIAL)

Metals are divided into groups; *ferromagnetic* ones are very attractive, *paramagnetic* are weakly attractive, and *diamagnetic* ones oppose magnetic fields. The system will not function fully if the receiving component is not properly considered, as the full strength of a magnet is achieved only with sufficient ferromagnetic material.

Ferromagnetic metals that are most attractive to magnets include nickel, cobalt, and iron. Within the structure of these materials are small regions or domains that are aligned by permanent magnets, as shown in this illustration (Figure 2). The amount of alignment within the domains or saturation enables the strength of the magnet to be optimized. This is how the receiving substrate becomes a temporary or "soft" magnet. For a given sized magnet, there is a corresponding thickness at which the steel is saturated. If one uses a thicker steel plate, there is no real increase in the pull force (Figure 3). However, attaching a magnet to thinner steel sheets results in diminished pull strength, and the magnet will behave as if it were a lower strength magnet. This occurs because the ferromagnetic material will not become magnetically saturated. This means that the receiving material cannot hold all the magnet's flux (the amount of magnetic field passing through a given surface) and fails to utilize 100% of the magnets pull force that would occur with a thicker plate. In such cases, some of the magnetic field extends behind the steel. If another ferromagnetic material is placed behind it, this too is attracted and becomes a soft magnet. In this way, the force field travels through several neighbouring layers of ferromagnetic materials, increasing the magnetic force as needed. However, if the ferromagnetic material is thicker than the magnetic field's strength supports, then the reverse side of the metal shows no attraction.

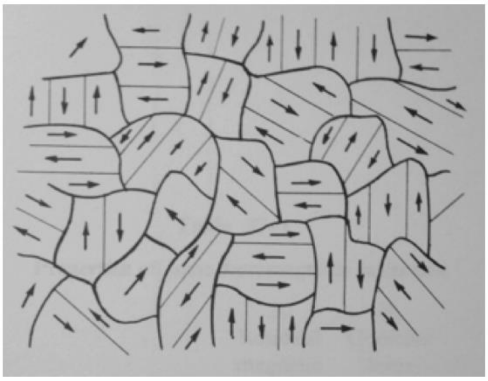

Fig. 2. Domain regions within a ferromagnetic material (Feynman *et al.* 1964).

When using rare earth magnets, the lowest and most minimum thickness of steel plate to use is 24-gauge in the US or 0.61 mm (Figure 3). A 22-gauge (or 0.76 mm) or thicker would be more optimal. (Note: in the US, the lower the gauge number, the thicker the steel). The ferromagnetic metal is an important, but often overlooked component of a magnetic system (Halbow and Taira 2011; Hovey 2012). It is only through control of all the variables: the magnet, the ferromagnetic material, and the layers between, that a system can be reproduced and adapted to any situation.

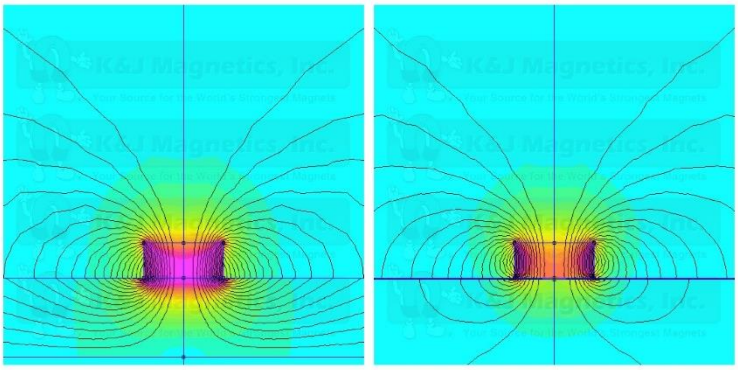

Fig. 3. The same size disc magnet on two different thickness of steel plate. The thicker steel, the magnetic field remains within the plate making it a strong "soft" magnet, where as the much thinner steel, the magnetic field extends beyond the plate, making it a weak "soft" magnet (K&J Magnets).

3.3 THE MAGNETIC FIELD DISTANCE OR THE GAP

The magnetic field strength diminishes with distance to an extent depending on the magnet strength. The *gap* is the sum of the artefact and all the layers used as padding and/or magnet barriers (such as Mylar or Melinex). The amount of usable gap distance is determined by the strength, size, and shape of the magnet used in the system. As the grade increases, the usable gap distance increases; conversely, as the space between the magnet and the receiving metal increases, the magnetic to ferromagnetic metal attraction becomes less powerful (Feynman *et al*. 1964; Livingston 1996; Spicer 2010, 2015) (Figure 4).

Magnetic pull force calculations are based on the distance between the parallel surfaces of the magnet and the ferromagnetic material. An effective gap or field distance is directly related to the grade, shape and size of the selected magnet. Figure 4 shows three variations in optimum conditions of field distance using popular sizes and grades. The variations illustrated show a commonly used magnet, compared to a comparable lower grade magnet, and with a magnet of the same grade and shape but half the thickness. The change in thickness has a greater effect on the field distance than does the grade. Each situation shows a decrease in pull force.

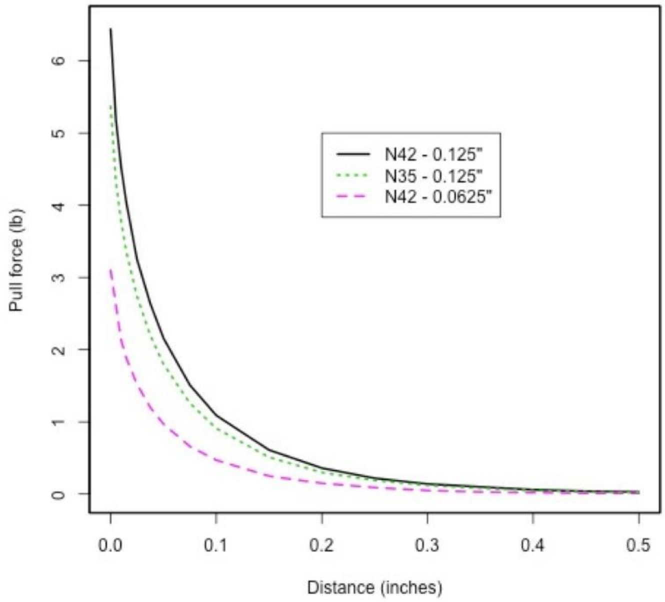

Fig. 4. The pounds of force vs. distance in inches of three different disc-shaped Neodymium magnets. (J&K Magnetics). The added layers provided added gap distance to that of the upper magnets used. 1. N42, ½ dia. 1/8 thick, (6.44 lbs of force or 2,952 gauss when in direct contact)-A commonly used size and grade; 2. N35 , ½ dia. 1/8 thick, (5.37 lbs of force or 2,706 gauss when in direct contact)-Lower grade value; 3. N42, ½ dia. 1/16, (3.1 lbs of force or 1,601 gauss when in direct contact)-Half the thickness.

The metal and magnet must be as close to parallel as possible for the system to be the most effective. When mounting artefacts, once gap materials are added, it is not only the gap distance at play, but also the types and characteristics of gap materials. Changing gap materials effects important differences in pull force performance.

3.4 The difference between pull and shear forces

To begin the discussion of the expanded meaning of *gauss*, we must distinguish pull and shear force. The difference between pull and shear forces with magnetic behaviour is very different and important to understand.

Most listings for *gauss* on websites or in the literature describing a specific magnet are based on pull force, the amount of force required to remove a magnet from a sheet of steel positioned horizontally. The magnet can either be pulled up from the sheet or down from the sheet. Each has equal pull force. This type of force can even be calculated given field distance alone or with 'gap' materials.

When a magnet is attached to a steel sheet forming a vertical surface, gravity enters the situation, and the friction coefficient is important. This depends on the surface of the two materials, i.e. smooth, rough, dirty or greased. Each of these surface characteristics has a very different effect on the amount of pull force there is between the magnet and the steel. Unfortunately for mounting artefacts onto walls, we cannot avoid this issue. This becomes critical when selecting materials for mount coverings, and gap layers. It is good to keep in mind that it is possible that a given magnet selected may only provide 10 – 25% of any listed pull force when held in the shear direction.

4. Types of Magnetic Systems

4.1 Point Fastener

In conservation, the majority of magnet solutions involve individually placed magnets as point fasteners, the simplest method for using magnets (Spicer 2016a, b). A magnet used as a point fastener is selected for its pull force and its interaction with the surrounding ferromagnetic material. The conservator can select a size and grade of magnet for ease of handling; adjust the gap between, and design the magnet to blend with the artefact. Magnets can then be added or subtracted based on what is deemed necessary for support. Typically, the artefact is large enough that there is no connection with surrounding magnets, and the polar direction of individual magnets is not of concern. When point fasteners are employed, many magnets are used, each magnet working independently of other magnets surrounding.

4.2 LARGE AREA PRESSURE

Continuous large area support consists of using several magnets in conjunction with each other to provide overall pressure or support. Necessary pressure can be achieved by several means including: adjusting the polar orientation of the magnets; using magnets with ancillary materials; magnets embedded within stiff materials; an attached webbing sleeve; as well as combinations of these. These methods require another level of design consideration when compared to point fasteners. Large area pressure methods also have the benefit of protecting the magnet because the layering material surrounding each magnet reduces possible coercivity from shock due to striking together suddenly (see appendix).

4.3 Two-part and Three-part Magnetic Systems

Three combinations of magnet and ferromagnetic material are possible and each has different results (Figure 5) (Spicer 2016b).

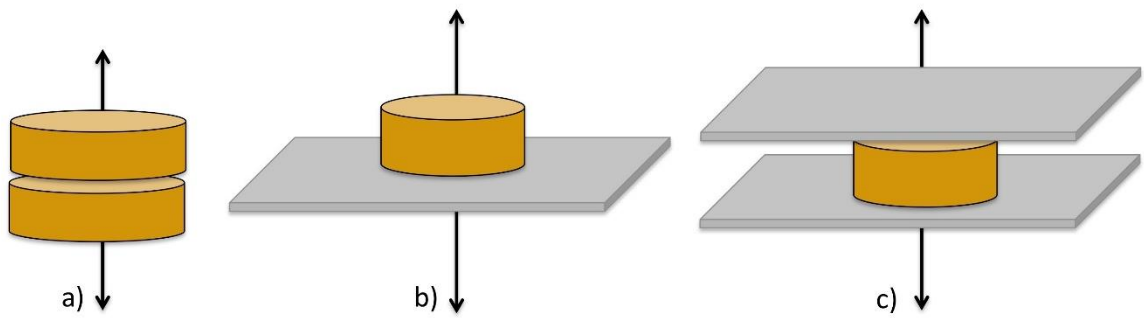

Fig. 5. Three combinations of using magnets and ferromagnetic materials; a) magnet-to-magnet; b) magnet-to-ferromagnetic material; c) ferromagnetic material-to-magnet-to-ferromagnetic materials, a three-part system.

4.3.1. Magnet-to-Magnet

Positioning an axially oriented disc magnet on a second similar magnet greatly increases the pull force of the system. When the magnets are positioned N-S to N-S, the two link together to create a polar radiation loop, preventing the two magnets from slipping from one another (Figure 1b). They are ideally suited as a point fastener. Use of steel is not necessary; Plexiglas or mat board can also be used (Ritschel and Douglas 2011).

4.3.2. Magnet-to-Ferromagnetic Material

The more commonly used magnetic system uses a magnet with a ferromagnetic material (fig. 5b). Steel can take many forms, many which are readily and economically available. This is critical for the optimal performance of the magnet. A full steel sheet gives the most flexibility of magnet placement, as it is a large board on which one can easily increase the necessary number of magnets needed for the best support. When a magnet is used with any type of ferromagnetic material, there is no radiation loop that is created. Therefore, the strength of the system is related to the alignment of domains within the steel and amount of saturation.

Both the magnet-to-magnet and the magnet-to-ferromagnetic types of systems create the same pull force when in direct contact. However, as gap layers are introduced between the two types, the magnet-to-magnet provides slightly more pull force at the same field distance.

4.3.3. Ferromagnetic Material-to-Magnet-to-Ferromagnetic Material

With the use of a third component, the pull force can be increased when another ferromagnetic material or magnet is added, thereby creating a three-part point fastener system (Figure 5c). As when a group of magnets are stacked together, their strength increases, this same effect can be used in creating a magnetic system. The pull force of any magnet can be increased 10 to 15% with the addition of another magnet or ferromagnetic material, creating a system of three elements that create both hard and soft magnets[1]. Here both ferromagnetic materials layers become "soft"

[1] Paul, M. 2014. Magnetic behavior [email] (Personal Communication, 3 January 2014). K&J Magnetics.

magnets (i.e. they are temporarily magnetized by the magnet). There is a jump in the calculated pull force when a magnet is placed between two steel plates.

5. The materials within the magnetic system

As more layers are placed between elements, and the thickness of material increased, the pull force decreases. Besides the distance affecting the force field, surface quality and area of the materials are also at play. The physical properties (topography of the materials, friction, static electricity and cohesion) all contribute to a small degree (Table 2).

It is possible that the various phenomenon that occur when materials are in contact actually assists, and are an additional force that aids the magnetic system.

5.1 Electron Exchange

Static charge has long been an issue in conservation, especially for fragile and friable materials (Margariti and Loukopoulou 2016). This concern has been part of the protocol for framed pastels, charcoals and friable silks. However, there has been little detailed research into its full role in the conservation field (Commoner 1998).

All bodies are composed of both positive and negative charges equally (Sello and Stevens 1984). The basis of electrostatic charging is a surface phenomenon where the disruption of the condition of equilibrium is seen in the neutral atom (Commoner 1998). Electrons have a negative charge. When energy is applied to a material system, such as by friction or pressure, a small number of electrons can jump from one material to the other. The material whose atoms gain electrons will become negatively charged with static electricity, while the material that loses electrons will become positively charged. When two materials are in contact, a flow of electrons moves from one to the other; whether it is the same material or between two different types (Figure 6).

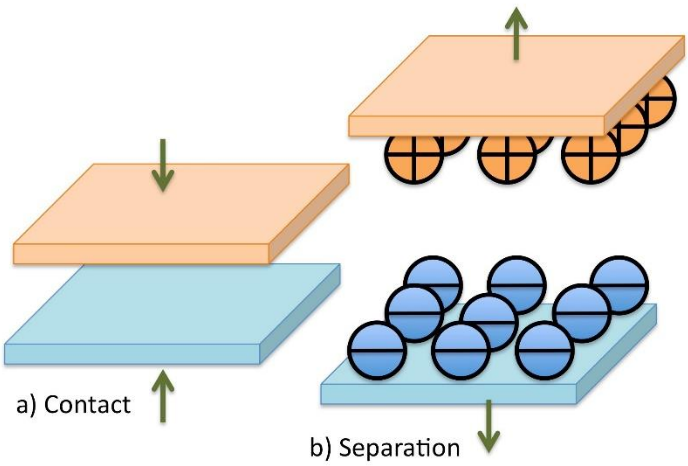

Figure 6: Schematic of electron exchange when two different materials are in contact and are then separated. The extent of this exchange is based on the materials placement on the Tribo-electric series (Table 3).

Static charge occurs when materials are in contact even without apparent rubbing, though more static is created with rubbing or other friction types. These electrical charges occur when bonds between electrons are broken (Carlton 1962). This electrical sharing greatly increases as contact increases.

5.2 Triboelectric Series

Materials that can gain or lose electrons are called triboelectric materials. The order of propensity to gain or lose electrons is called the triboelectric series (Sello and Stevens 1984). The series is based on the conductivity of the individual material. The level of charge is linked to a material's placement in this series. (See Table 3) It is the distance of the two materials from one another in the series that increases the charge effect rather than its specific location. Therefore, if two materials in contact are neighbours on the scale, like cotton and steel, there is less exchange. However, if they are far apart, no matter where on the scale, exchange occurs. Table 3, compiled from many sources, shows the ranking of commonly used materials for mounting artefacts.

As stated above, cotton and polyester materials are the two types of materials that are frequently used for mounting. Cotton is neutral and positioned close to steel, limiting the impact of the triboelectric phenomena. Materials made of polyester and steel are widely separated in the series, explaining why polyester Ultra-suede and Mylar have the potential to add to the holding power of a magnetic system.

5.3 Resiliency

Factors related to compression are the specific material's thickness, its manufacturing method, and loft. Each material's manufacturing and structure play a part in how it responds to compression. Textiles are such an example. It is not just the material or fibre composition, it is how the fibres are turned into threads and then woven into a fabric that will cause the results to vary (Collins *et al*. 1990). For paper, fibres are pounded and made into a slurry before being formed into a sheet, and then finished with coatings and fillers. Vulnerable materials include skins, felt, flocked structures, pile weave textiles, and thick papers or textiles. Newer material can withstand longer-term compression better than older material. Other factors include the material's elasticity, thickness, and time under constraint (de Graaf 1980). Surface deformation has been known to occur for works of art on paper if matted for an extended time (Vuori and Dancause 2014).

A term that is used to describe a fibre's ability to return to shape is *resilience*. Resilience is a ratio of energy of retraction to energy of deformation. It is influenced by temperature, moisture content, rate of strain, retraction and strain history (Dillon 1947). Various fibres are rated from high to low on a scale of resiliency (Norton and Hearle 1962; Ballard 1995) (See Table 4). Cellulosic as a group have a low resiliency. This may partially explain why paper conservators often see compression as a result of a mount with magnets. Polyester and wool are on the opposite end of the scale.

6. CONCLUSIONS

The physics of magnet behaviour is not straightforward. Enhanced understanding of magnetic forces is needed among conservators. This is especially the case now that the use of rare earth magnets has gained in popularity. These magnets, with their powerful strength for their size, can easily magnify behaviour. Whenever a magnet is used, its behaviour is not just due to the magnet itself, but as a factor in a three-part system, each part is critical for the optimal functioning of the system. One of the parts of the magnetic system that needs to be better understood and discussed in the conservation field is the field distance ('the gap'), since the specific materials that are positioned between the magnet and ferromagnetic material influence the success of a magnetic system.

Conservators currently use three of the four permanent magnet types discussed. Now Neodymium has replaced ferrite, with the exception of the flexible type that has continued to be used as a tool for mounting of lightweight materials. The importance of storage of magnets, as it impacts their longevity, will need to be increasingly considered, especially as the cost of the stronger Neodymium magnets rises. This will be of further interest as documented systems are developed for reuse.

ACKNOWLEDGEMENTS

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APPENDIX: Proper Storage of Your Magnets

All permanent magnets require special attention for optimal and continual performance (Table 1). As with any equipment, one should use them with care. Areas of concern are mechanical shock, heat, moisture, and a demagnetized field. All of these are issues of handling and environment, which conservators are especially suited to understand. Depending on the class of magnet, the care will vary slightly, but, with proper care, little decay should be noticed (Figure 7).

Fig. 7. Several examples of methods to store magnet; from individual boxes, Ethafoam lined boxes and contact lens cases. All are useful for protecting magnet collections.

Coercivity (Hc) is the process where a magnetic field is reduced or eliminated. Each permanent magnet has its own coercivity rating. The higher the Hc, the greater the resistance to demagnetization (The Magnet Story 1998). Understanding the Hc of permanent magnets, and that of other materials and equipment nearby, is necessary when working with strong magnets. Rare earth magnets currently have the highest coercivity values.

In 2011, the author undertook a survey of 230 conservators related to their use of magnets. One of the survey questions focused specifically on how conservators stored their magnets. As a response, here are a few rules of thumb:

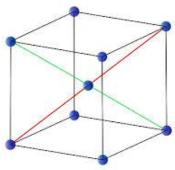
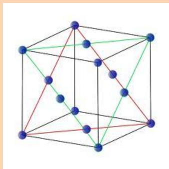
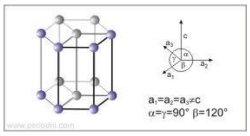
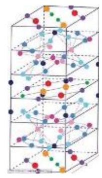
1. Separate the rare earths from all other types of permanent magnets.
2. Provide cushioning between the magnets and prevent any shock.
3. Keep away from all heat sources.

Some types of permanent magnets influence or weaken other magnets. One such case is when ceramic (including flexible type) or samarium magnets are demagnetized by neodymium magnets. As a result, neodymium rare-earth magnets should always be stored away from other magnet types. Similarly, electronics systems that rely on magnets to hold information, such as hard drives and disks, can be altered or demagnetized by a neodymium magnet that is placed nearby. Magnetic strips on credit cards and other cards can also be affected.

Ferrite magnets can be demagnetized when their poles are alternated, a reason to carefully stack the magnets. This is especially the case with the bonded flexible type; sliding a magnet side-ways perpendicular to the polar rows demagnetizes the array. Alnico type magnets are unique in that they can be remagnetized by realigning the internal domains via another strong magnetic field. This is not the case with other magnets, especially neodymium ones, where once demagnetized, the magnetism cannot be recovered.

Each type of permanent magnet should be segregated and spaced well outside other magnetic fields. As more magnets are concentrated together, the field increases. A safe approach is to separate each type in the work area.

Table 1: Magnet Fact Sheet

Type	Alnico	Ferrite or Ceramic		Rare Earth	
		Block-shape, non-bonded	Flexible-bonded	Samarium-Cobalt	Neodymium
Date Introduced	1935	1951	1960s	1969	1983
Chemical Structure	AlNiFeCo	Fe_2O_3		$SmCo_2$	$Nd_2Fe_{14}B$
Structure	Body-centred cubic 	Face-centred 		Hexagonal crystal structure 	Multi-phase structure; tetragonal crystal structure 
Strength of Magnetic Field) (Br(T))	0.6-1.4	0.2-0.4		0.8-1.1	1.0-1.4
(Br(gauss))	12,500	3,900		10,500	12,800
Temperature at which demagnetized (Curie temperature) (Tc)	700-860°C (1,292° - 1,580° F)	450°C (842° F)		720°C (1,328° F)	310-400°C (590°-752° F)
Maximum Working Temperature (TMax)	540° C (1004° F)	300° C (572° F)	**Flexible Magnet** 180° C (356° F)	300° C (572° F)	150° C (302° F)
Energy (BH)max (kJ/m^3)	10-88	10-40	9-17	120-200	200-440 / 540-1,350
Maximum Energy (mills of Gauss – Ørsteds) Mgoe	1	8	1.1-1.5	16-29	50
Demagnetizing Field (coercivity) (Hci) (kA/m)	275	100 - 300	200 - 240	600 – 2,000	600-2000
Storage	Use keeper for horseshoe shape	Group by size; stack, orienting north to south; Wrap to prevent abrasion Keep away from Rare Earth magnets.		Group by size; stack, orienting north to south; place separator between	Group by size; stack, orienting north to south; place separator between
Mechanical Shock Tolerance	Very resistant to shock	Brittle, chip or crack easily	Very resistant	Brittle and chip or crack easily. Best to separate with a cushioning material.	Brittle and chip or crack easily. Best to separate with a cushioning material.
Moisture/Oxidation	Resistant to corrosion	Resistant to corrosion	Resistant to corrosion	Relatively resistant to corrosion.	Corrodes easily and requires a coating. Neodymium magnets

					must be coated to prevent oxidation.
Common use and comments	First man-made permanent magnet. Also referred to as a cast magnet. Used in engines and generators. Can be easily demagnetized. When repetitively placed north-pole-to-north-pole ends together, it quickly weakens itself.	Electronic inductors, transformers, and electromagnets. Ferrite powders are used to coat magnetic recording taps.	Commonly referred to refrigerator magnets	Hard drives, printers and other computer components. Can be demagnetized by NdFeB magnets. But they do not weaken others.	Used predominately in the Green energy, hybrid cars, wind turbines, earphones, and cell phones. Tough to demagnetize. However, they can easily demagnetize other classes of magnets like SmCo or Alnico, or Ferrite.
Manufacturing Method	Cast or sintered	Sintered	**Flexible** bonded (rigid or flexible)	Reduction Diffusion and Melting Process	Sintered or bonded (rigid or flexible)
Source of raw material	Uses Colbalt from Zaire.	By-product from industry		Uses Colbalt from Zaire.	Uses Rare-earths from China

Table 2: Various materials tested (Billot 2016)

Comparison of the two magnets (1/2" x 1/8" disc; 13mm x 3mm.)

	Thickness (in.)	**N42**	***Converted***	**N52**	***Converted***
Control	0	317.8	*11.21 oz*	342.4	*12.07*
Mylar	0.003	307.4	*10.83*	293.2	*10.34*
Tissue paper	0.0036	240.2	*8.47 oz*	270.6	*9.54*
Muslin	0.011	214.4	*7.6*	235.8	*8.31*
Twill tape	0.02	209.4	*7.37*	224	*7.9*
Ultra-suede	0.025	317.4	*11.19*	343.8	*12.13*
Polyester Batting	0.095	213.8	*7.54*	230.6	*8.13*

Ranked in order of weight held (grams)

Material in Gap	**N42**
Control	317.8
Ultra-suede	317.4
Mylar	307.4
Tissue paper	240.2
Muslin	214.4
Polyester Batting	213.8
Twill tape	209.4

Material in Gap	**N52**
Ultra-suede	343.8
Control	342.4
Mylar	293.2
Tissue paper	270.6
Muslin	235.8
Polyester Batting	230.6
Twill tape	224

Table 3: Material order of the triboelectric series**.**

Charge	***Material***	***Notes***
+ + +	Air	
	Polyurethane foam	
	Hair	
	Nylon, Dry skin	Dry skin has the greatest tendency to give up electrons and becoming highly positive in charge.
	Glass	This is why TV screens collect dust on their surfaces.
	Acrylic, Lucite	This is why these materials are not used to frame pastels.
	Leather	
	Rabbit's fur	Fur is often used to create static electricity.
	Quartz	
	Mica	
	Lead	Surprisingly close to cat fur.
	Cat's fur	
	Silk	
	Aluminium	
	Paper	
	Cotton	Best for non-static clothes
	Wool	
NEUTRAL		
	Steel	Not useful for static electricity
	Wood	Attracts some electrons, but is almost neutral
	Amber	
	Sealing wax	
	Polystyrene	
	Rubber balloon	
	Resins	
	Hard rubber	
	Nickel, Copper	
	Sulphur	
	Brass, Silver	

	Gold, Platinum	
	Acetate, Rayon	
	Synthetic rubber	
	Polyester	
	Styrene and Polystyrene	Why packing peanuts seems to stick to everything.
	Plastic wrap	A.k.a. "Cling" wrap
	Polyethylene	
	Polypropylene	
	Vinyl, PVC	
	Silicon	
	Teflon	Teflon has the greatest tendency of gathering electrons on its surface and becoming highly negative in charge.
	Silicone rubber	
- - -	Ebonite	

Table 4: General Resiliency Ranking by Material

Material	Resiliency
Polyester	High
Wool	
Nylon	
Acrylic	
Olefin (PE, PP)	
Triacetate	
Silk	
Acetate (secondary)	
Cotton	
Rayon	
Flax	Low or poor

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