MagNohl™

Magnetic Wedge Laminate

MagNohl is a magnetic wedge material that provides outstanding performance in demanding induction motor and wind generator applications.

- » Excellent Mechanical Strength
- » Long Term Thermal Stability
- » Outstanding Magnetic Properties
- » RoHS Compliant

Induction motors commonly use magnetic wedges to help improve energy efficiency.

Magnetic laminate wedge materials provide a flux path through the wedge allowing for better magnetic flux distribution to the stator core, thereby reducing losses and heat rise.

The following pages provide a complete set of material data sheets for MagNohl as well as comparative data sheets and test results for various magnetic laminate materials. The information contained herein is proprietary and confidential.

Custom Fabrication

Regardless of the application, The Gund Company's integrated N220 manufacturing capability along with our fabrication capacity delivers quality components that meet the exact requirements of our customers.

Magnetic wedges can be produced to a wide range of profiles with a tolerance of +/- .002" consistently.

Thermal Performance

This paper reviews the various electrical industry standards established by widely known trade organizations and associations. We attempt to educate and illustrate the various test methods used to determine thermal performance specifically for electrical insulation materials.

Availability

Sheets:	.062" (1.6mm) to .400" (50.80mm) Thickness
Profiles:	A Wide Range of Custom & Standard
Parts:	Fabricated Per Customer Drawings

MM&M is well known for specializing in topsticks and wedges for motor and generator applications. Today, MM&M continues to lead the industry with the development and application of magnetic wedge technology.

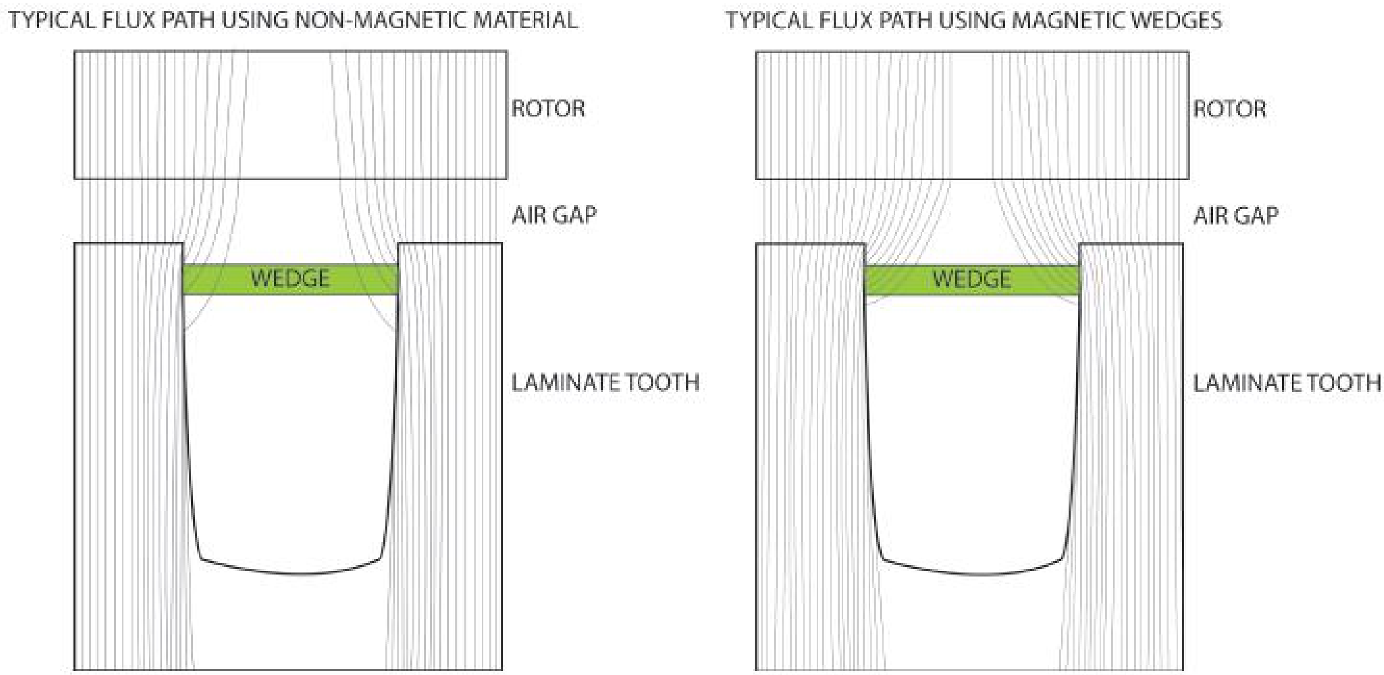
As the world seeks technology to improve energy efficiency, the improved efficiency of motors using magnetic wedges can offer a solution. According to the United States Department of Energy (DOE), electric motor systems account for almost 70% of the electricity consumed by the manufacturing sector. In the same report, the DOE indicates that greater attention to motor system optimization can reduce motor energy costs by up to 18%.

Similar to the energy efficiency gains of motors using magnetic wedges, wind generator manufacturers have realized the benefit of using magnetic wedges to help turn wind energy into electrical energy with greater efficiency.

There are two primary types of magnetic laminate materials, low pressure and high pressure. The primary difference between the two types of materials involve the type of glass reinforcement and the manufacturing process. Low-pressure laminates use a random glass mat reinforcement and a low-pressure compression molding press to produce one sheet at a time. High-pressure laminates typically use a bi-directional woven glass cloth and a high-pressure molding process that produces multiple sheets at a time. There are versions of glass mat high pressure laminates for magnetic wedges as well. To learn more about high and low pressure laminates, visit our website at www.thegundcompany.com for a complete process overview.

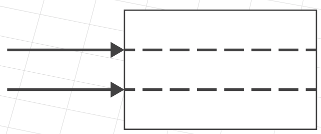
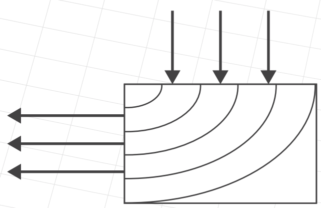
As applied to magnetic wedge laminate technology, there is some industry discussion that high pressure laminates using bi-directional glass cloth can cause the stratification of the iron content between the layers of glass cloth because the iron resin matrix cannot penetrate the tight weave of the glass fabric. Such a stratification issue could potentially cause reduced strength and inconsistent magnetic properties. Alternatively, the random glass mat materials produced most commonly by a low pressure laminate process would have glass orientation that would allow more homogenous dispersion of the iron resin matrix throughout the composite, thus producing better mechanical strength and more consistent magnetic properties.

MM&M has performed and participated in magnetic wedge testing programs both in our laboratory at Nohl Composites as well as at the laboratories of OEM customers. Though many customers focus on the laboratory test values for permeability, we have found the lab test results based on ASTM A927 / A927M-99, “Standard Test Method for Alternating Current Magnetic Properties of Torroidal Core Specimens Using the Voltmeter-Wattmeter Method” to be somewhat misleading due in part to the characteristics of random mat reinforcement versus glass cloth reinforcement of magnetic laminate materials. The following diagram provides a simple illustration of the difference in flux paths when using non-magnetic versus magnetic wedge materials. Note the improve flux path flow provided by the magnetic wedge.



The best performing magnetic wedge material in terms of permeability would maximize the opportunity for a flux flow that moves at a 90-degree radius path. However, the ASTM A927 test method really only measures a material’s permeability parallel to the laminations. High pressure laminates having distinct iron resin matrix layers between drier glass cloth layers, actually show very good permeability parallel to the laminations.

MagNohl permeability data tested per ASTM A927 can be misleading when compared to actual motor performance testing. Several OEM's have been surprised that the higher permeability values achieved in lab testing with high pressure laminates does not necessarily translate into higher performance in motor testing when compared to MagNohl.

Description	Depiction	Flux Flow
Lab Permeability Testing – Parallel to Wedge Laminations		ASTM A927 testing for permeability results in values based on the flux path traveling parallel to the high pressure laminate layers allowing iron stratification to impact permeability positively.
Actual Motor Testing – Flux Path Flow		In actual motor application, the flux path travels both vertically and horizontally across a 90-degree radius. Thus, a material that allows permeability consistently throughout the path would offer the best motor performance.

Based on this information, there is some theoretical and actual performance evidence that a random mat, low-pressure laminate material may offer the best magnetic wedge properties in some designs. Of course, MM&M fabricates wedges from several material options to offer our customers the material that performs best in their application based on their motor design testing. Some of the best performing material options include:

Material Grade	Glass Reinforcement	Manufacturing process
MagNohl	Random Mat Glass	Low Pressure Laminate
H208	Random Mat Glass	Low Pressure Laminate
Magnoval 2067	Woven Glass Cloth	High Pressure Laminate
Magnoval 3193	Random Mat Glass	High Pressure Laminate

Laboratory Testing at our Nohl Composites laboratory as well as at independent and customer labs has resulted in the following test data for four common magnetic laminate wedge materials.

Average Properties of Magnetic Composite Material As Tested at Nohl Composites Laboratory						
Property	Units	Conditioning	MagNohl	Magnoval 3193	Magnoval 2067	H208
Flexural Strength	ksi	lab	24.9	14.7	21.2	16
Flexural Strength	ksi	1/150 T-150	16.1	14.8	18	6.5
Compressive Strength	ksi	lab	48.8	41.6	43.5	27.5
Shear Strength	ksi	lab	19.1	17	17	10.1
Shear Strength	ksi	1/150 T-150	13.7	11.8	12.1	5.8
Shear Strength	ksi	1/180 T-150	12.9	11.3	10.7	4.4
Volume Resistivity	Ohm-cm	lab	2.8 (10^5)	2.6 (10^5)	1.2 (10^7)	1.5 (10^6)
Tested at K.I.S Associates						
Average	mu@4000 Gauss	lab	9.9	9.7	12.6	9.7
Std, Dev.	mu@1500 Gauss	lab	4.3	5.2	6.6	3.9
Magnetic Permeability, 400Hz	mu@1000 Gauss	lab	4.8	6.6	7.2	4.3

Note the Magnetic Permeability values for Magnoval 2067 (a high pressure, glass cloth based material) versus the Magnoval 3193 (a high pressure, glass mat based material). Here, we see in the lab data that the stratification of the iron content in Magnoval 2067 provides impressive permeability numbers. Note the similar permeability numbers between MagNohl and H208 based on the lab test data. As noted, in actual motor testing, it has been realized that random glass mat, low pressure laminate produce the most consistent flux path in application. Although we cannot share actual OEM test data, MM&M would be happy to support any OEMs program to compare various magnetic wedge materials in actual motor testing.

Magnetic permeability is not the only important material characteristic for this application. Mechanical strength and dimensional stability at elevated temperature are critical for long-term performance. As with wedges of all materials, shear strength, flex strength, and compressive strength are the most critical mechanical properties for magnetic wedges.

MM&M has fabricated a wide range of magnetic laminate materials as the technology has advanced over the past 20 years. Those materials include Vetroferrit, H208, Magnatuff, Magnoval, and MagNohl among others. Though MM&M will fabricate wedges using any magnetic laminate specified by our OEM customers, our experience indicates that the best performing materials are MagNohl for low-pressure laminate and Magnoval for high-pressure laminate.

Magnetic wedges can be produced to a wide range of profiles with a tolerance of +/- .002" consistently

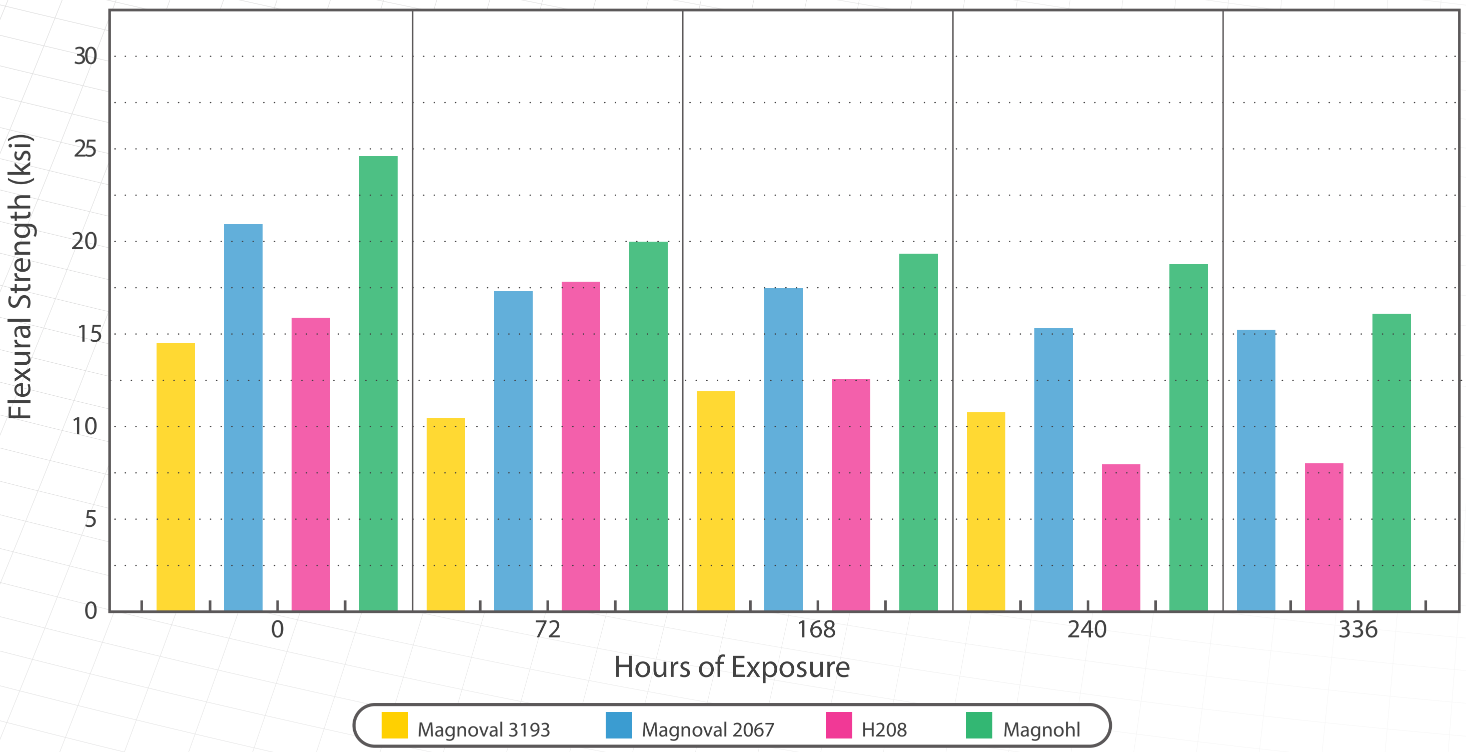
Regardless of the magnetic laminate material used, it is critically important to fabricate magnetic wedges to tight tolerances. With MM&M's experience making magnetic wedges, we have a wide range of tooling as well as the equipment capability to hold tight tolerances on magnetic wedges. In some cases, custom tooling is required for a customer's design. In many cases, MM&M provides samples to check the tightness of fit. Because MM&M's capability allows our wedges to be manufactured to very tight tolerances on a consistent basis, problems related to fit could be avoided.

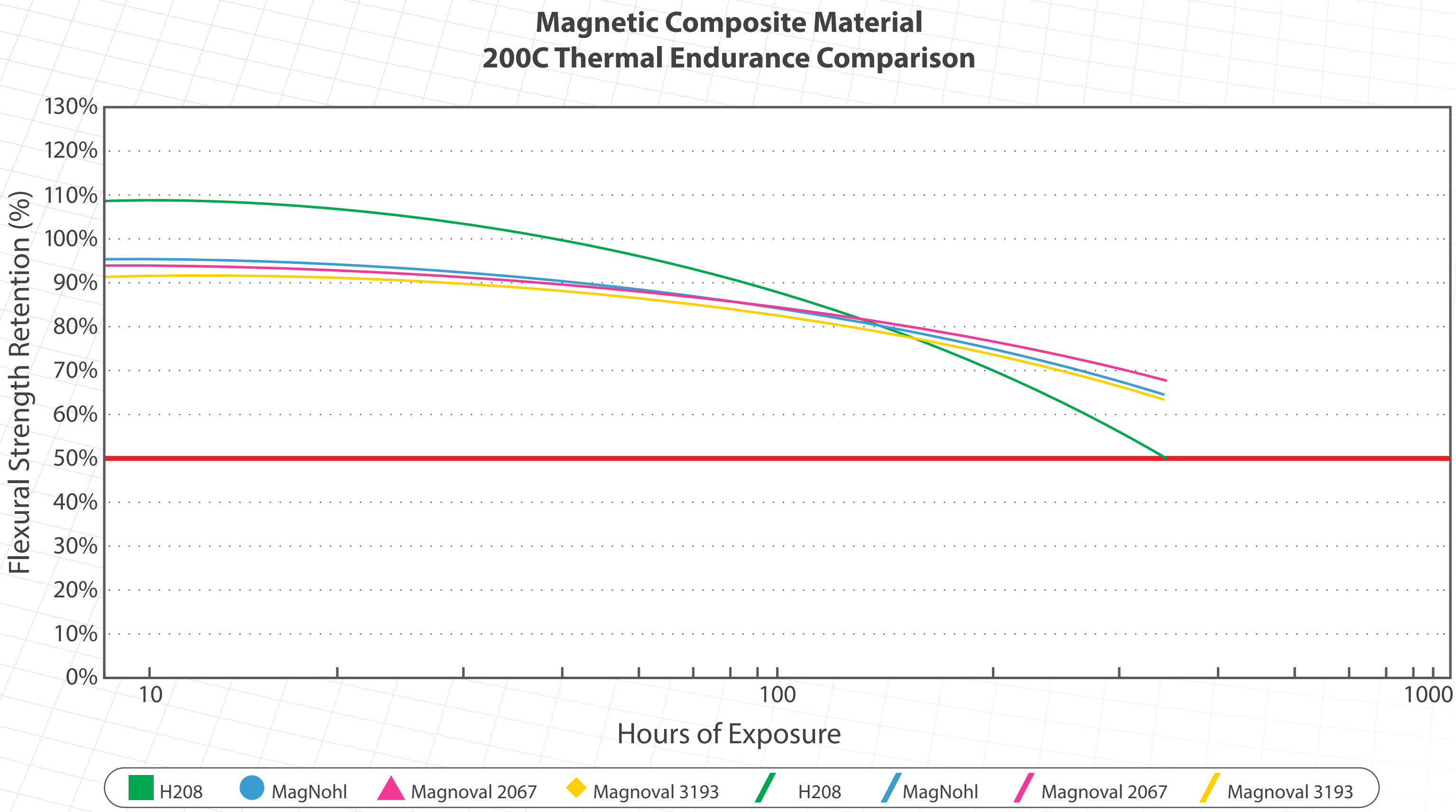
For instance, it is common to see European magnetic wedge tolerances of + .000”,- .012” on thickness and + .000”,- .006” on width. It is also common to hear that the lack of consistency of the wedge dimensions causes loose wedges in the slot. Poor tolerance capability has been noted as one possible cause of magnetic wedge failures in European motors. Consequently, Motor and generator designers not familiar with magnetic wedges have been reluctant to move towards designs incorporating magnetic wedges due to the failures that have occurred in Europe and papers describing problems with magnetic wedges. One published paper by Scollay1, described repetitive breakdowns of motors having magnetic wedges. This paper does not name the magnetic materials or fabricators. After much pontification on the possible causes for the failures, using incorrect units of measure and faulty mechanical engineering principles, this paper does finally conclude that “the root cause of the magnetic wedge failures was therefore derived as incorrectly fitted wedges…”.

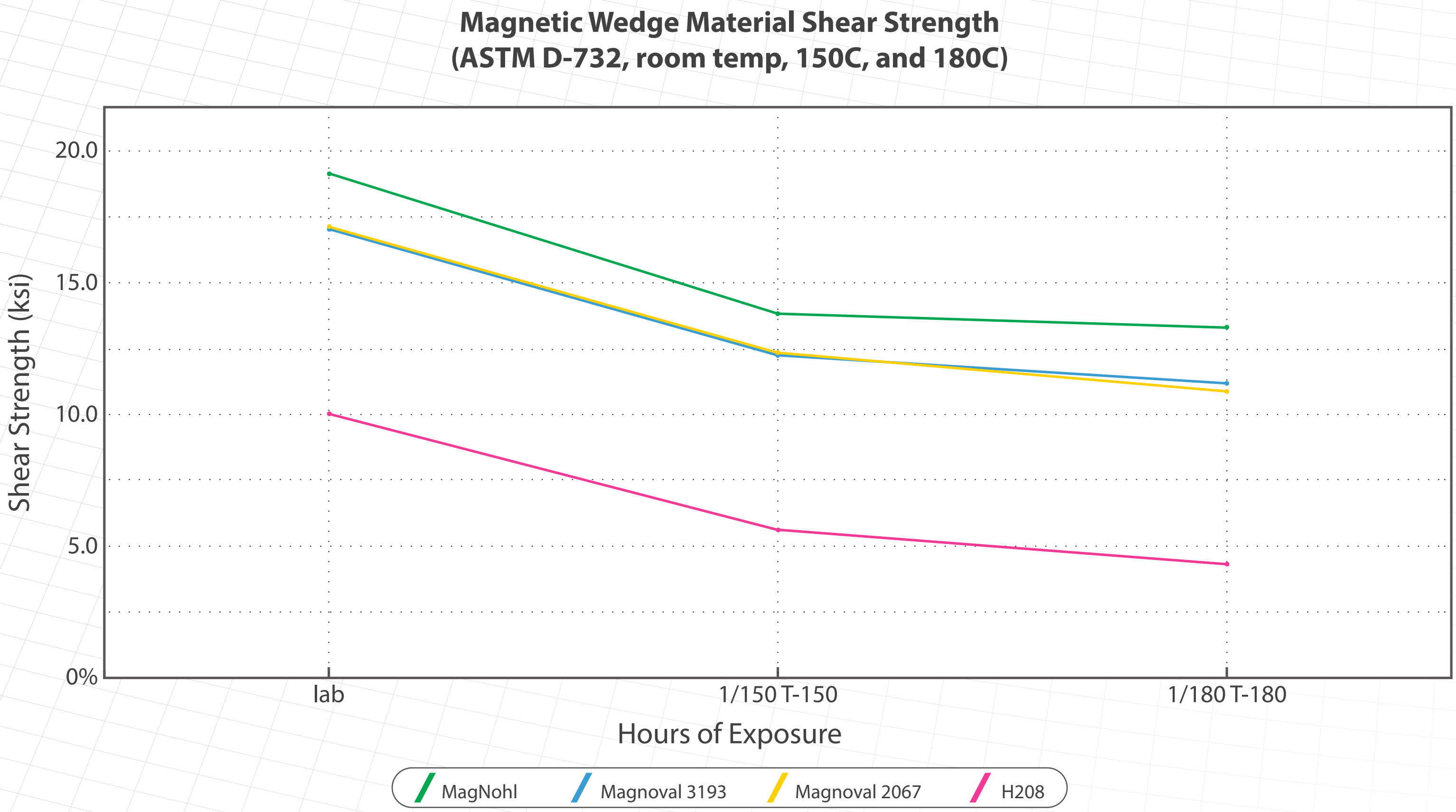
MM&M typically produces wedges with a thickness tolerances as tight as +/- .002” and a width as tight as +/- .002” with consistency. Due to the importance of dimensional capability in magnetic wedges, MM&M is always prepared to provide customers with the exact dimensions and shape required for each application.

The following pages present the test data for the common material options reviewed above. Standard magnetic wedge laminate grades are available with a Class F- 155 °C thermal index. Upon request by special order, Class H- 180 °C versions of MagNohl and Magnoval are available. In addition, The Gund Company's White Paper on Material Thermal Endurance Testing is available upon request. Our company is committed to advancing the magnetic wedge technology and its hope for improved motor and generator efficiency. We will support any OEMs testing program to evaluate the performance various magnetic laminate materials in their design.

Magnetic Composite Material
200C Thermal Endurance Comparison




Magnetic Composite Material
200C Thermal Endurance Comparison
Flexural Strength Retention (%)
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10
100
1000
Hours of Exposure
H208
MagNohl
Magnoval 2067
Magnoval 3193
H208
MagNohl
Magnoval 2067
Magnoval 3193


Magnetic Wedge Material Shear Strength
(ASTM D-732, room temp, 150C, and 180C)
Shear Strength (ksi)
20.0
15.0
10.0
5.0
0%
lab
1/150 T-150
1/180 T-180
Hours of Exposure
MagNohl
Magnoval 3193
Magnoval 2067
H208

THE GUND COMPANY

MANUFACTURERS & FABRICATORS OF ENGINEERED MATERIAL SOLUTIONS

Los Angeles Milwaukee Dallas St. Louis Cedar Lake Canada Mexico China

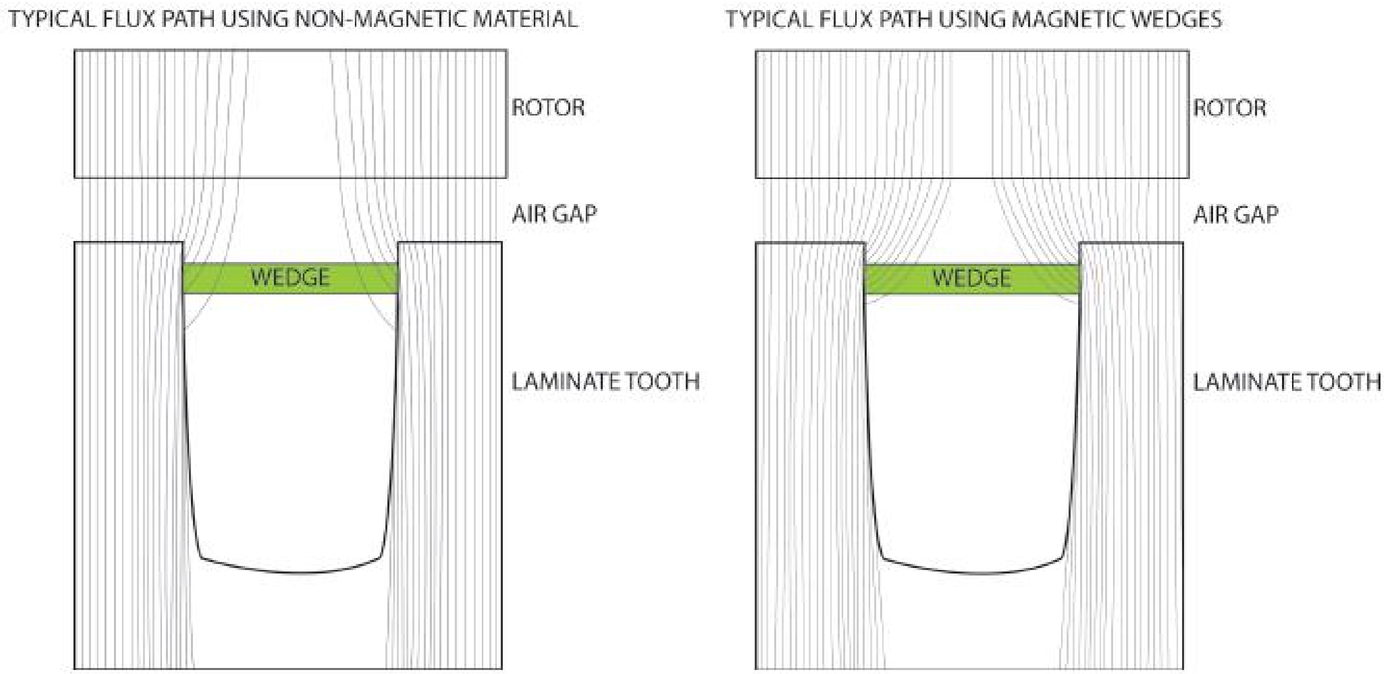
Item:	MagNohl™ Magnetic Wedge Material			
Description:	MAGNOHL™ is a magnetic glass reinforced laminate that is utilized as a wedge material in high performance motors and generators. MAGNOHL™ provides a flux path through the wedge allowing for better magnetic flux distribution to the stator core, thereby reducing losses and heat rise. MAGNOHL™ has mechanical properties that typically meet or exceed those of non-magnetic wedge materials.			
Availability:	Laminate Sheets:		English Units (in)	SI Units (mm)
		Sheet Size:	37″ x 73″	1.6 mm - 10 mm
		Thickness:	0.062″ - 0.4″	94 cm x 185 cm
	Fabricated Parts:	The Gund Company custom fabricates insulation materials to the exact specifications and drawings of our customers.		

Key Characteristics	Test Method	Units - English (SI)	Typical Values
Standard Color	--	--	Black
Density	--	lbs./in^3 (g/cc)	0.108 (3.2)
Compressive Strength, 23C	D-695, Flat	psi (MPa)	48,000
Flexural Strength, 23C	D-790	psi (MPa)	24,000 (167)
Flexural Strength, 150C	D-790	psi (MPa)	16,000 (110)
Shear Strength, 23C	D-732	psi (MPa)	19,000 (131)
Shear Strength, 150C	D-732	psi (MPa)	13,000 (90)
Bond Strength (1/2″ thick)	D-229	lbs. (kg)	1080 (490)
Shear Strength	D-732	psi (MPa)	12,500 (86)
Volume Resistivity	D-257	Ohms-cm	1 (10^5) - 1 (10^6)
Magnetic Properties	--	--	See Attached
Thermal Class	--	--	Class F - 155C

MagNohl™

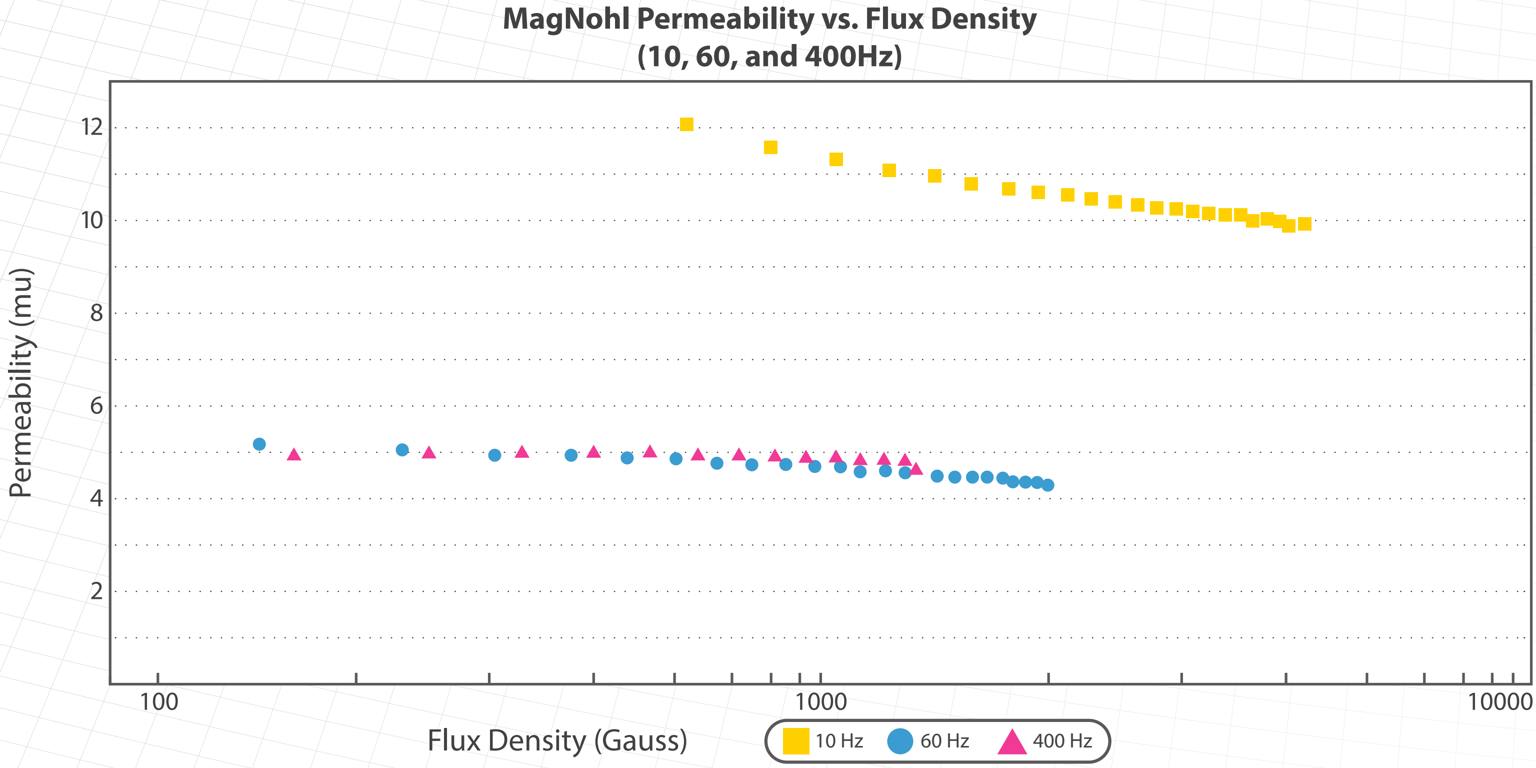
Magnetic Properties

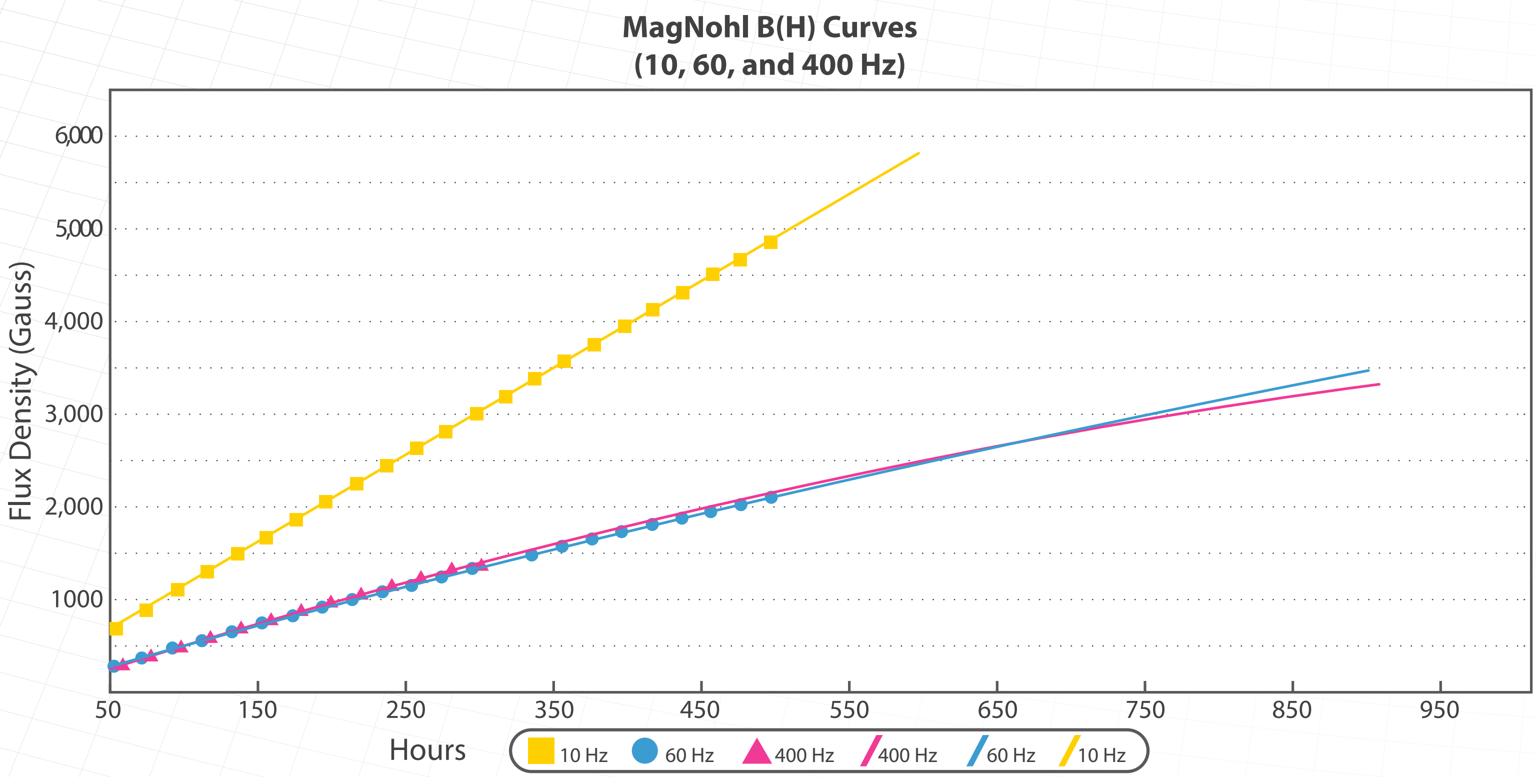
The following diagram provides a simple illustration of the difference in flux paths when using non-magnetic versus magnetic wedge materials.



Magnetic Properties Tested According to ASTM A-927

ASTM A-927 utilizes toroidal specimens and flux paths are parallel to the laminations in the specimen.


MagNohl Permeability vs. Flux Density
(10, 60, and 400Hz)
Permeability (mu)
12
10
8
6
4
2
100
1000
10000
Flux Density (Gauss)
10 Hz
60 Hz
400 Hz


MagNohl B(H) Curves
(10, 60, and 400 Hz)
Flux Density (Gauss)
6,000
5,000
4,000
3,000
2,000
1000
50
150
250
350
450
550
650
750
850
950
Hours
10 Hz
60 Hz
400 Hz
400 Hz
60 Hz
10 Hz

MagNohl Frequency and Core Loss Relationship