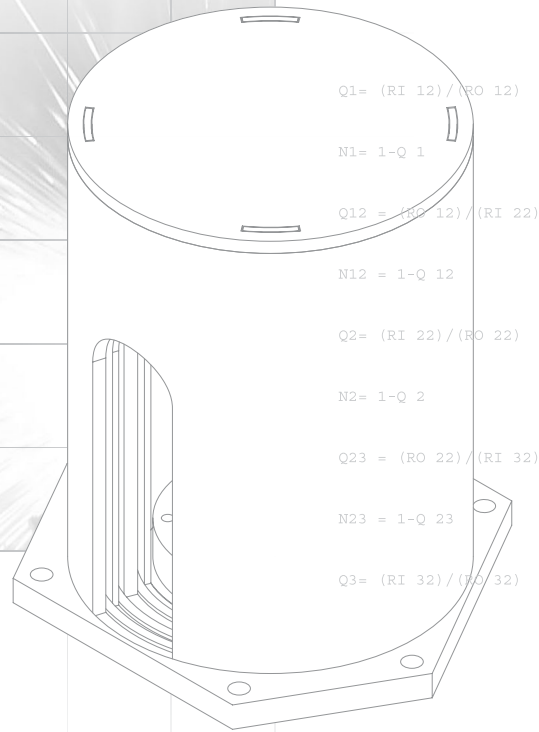


Custom Magnetic Shielding for Low Temperature Applications

DESIGN
FABRICATION
TESTING
MATERIALS



Introduction

Amuneal Manufacturing Corporation was established in 1965 in response to the growing demand for low frequency magnetic shielding. Today, the company is a world leader in the supply of magnetic shield components and assemblies for scientific, medical, and commercial applications. The majority of shields that are designed for these industries are constructed from Amumetal, a high permeability shielding alloy developed for room temperature applications. However, the performance of Amumetal and other high permeability materials is degraded at cryogenic temperatures and is therefore not an appropriate material selection to yield high shielding performance at very low temperatures.

Cryoperm 10[®], a high nickel content shielding alloy, was developed in response to the growing need for higher performance magnetic shielding at cryogenic temperature applications. Cryoperm's magnetic properties at low temperatures are similar to those of standard shielding alloys such as Amumetal at room temperature. Figure 1 compares the permeability of Cryoperm 10[®] and Amumetal as a function of ambient temperature.

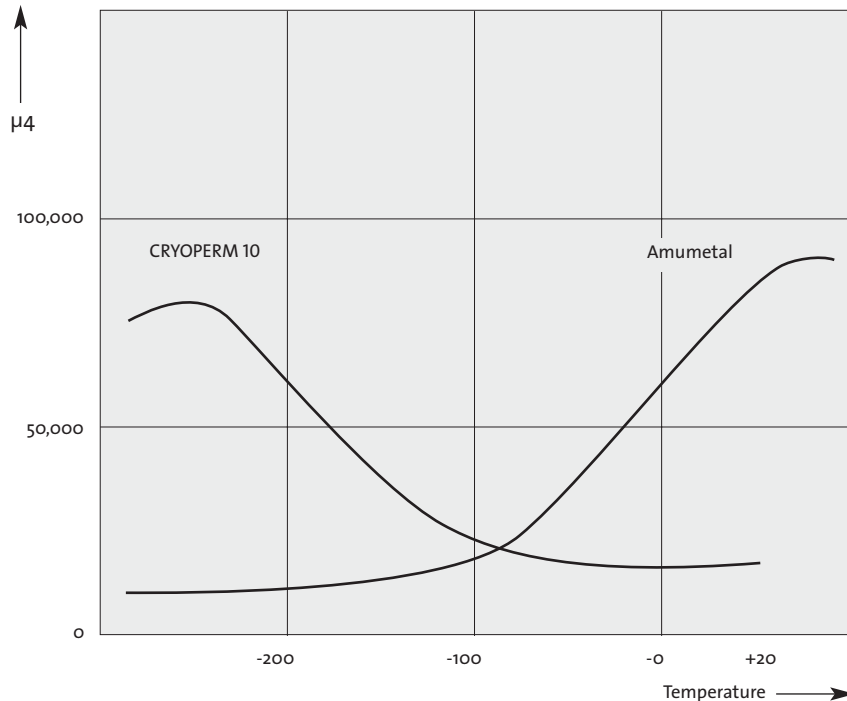


Fig. 1 Permeability of CRYOPERM 10 and Amumetal versus ambient temperature.

Material Availability

Amuneal maintains an inventory of Cryoperm in 0.020" (0.5mm), 0.040"(1.0mm) and 0.060"(1.5mm) thick sheets. Our standard width is 10.23" (260mm). This selection allows us to work with our customers to design the most cost-effective shielding for their specific application. Once the proper thickness and geometry have been calculated, Amuneal employs cutting-edge technology to fabricate each shield ensuring that it conforms to all specified dimensional and magnetic requirements.

After fabrication, each Cryoperm 10® shield is hydrogen annealed using a specific cycle developed to provide optimal performance for its application temperature (4.2K or 77.3K).

Magnetic and Physical Properties

Table 1 lists the typical properties of Cryoperm 10® at 4.2K and 77.3K, based on measurement of fully annealed 0.1mm (0.004") toroids.

Table 1. Typical properties of CRYOPERM 10 at 4.2K/77.3K

Saturation polarization at 10 A/cm (B ₁₀)		T	0.9
Permeability at 4 mA/cm (μ ₄)	static	-	70000
	50Hz		65000
Maximum permeability μ _{max}	static	-	250000
	50Hz		160000
Static coercivity H _c		A/cm	0.012
Flux density at 0.1 A/cm (B _{0.1})		T	0.80
Remanence flux density		-	0.55
Remanence ratio B _r /B _{0.1}		T	0.7
Density		g/cm ³	8.7
Electrical resistivity	20° C	Ω. mm ² /m	0.45
	77.3K		0.35
Curie temperature		°C	430

Magnetic Characteristics

Figures 2 and 3 illustrate the static hysteresis loop and the static and 50Hz permeability-field strength curves for Cryoperm 10[®]. These are mean value curves measured on toroidal cores (strip thickness of 0.004" (0.1mm) at 4.2K and 77.3K. Figure 4 includes a static μ (H) curve measured on 0.040" (1mm) thick solid rings at 77.3K.

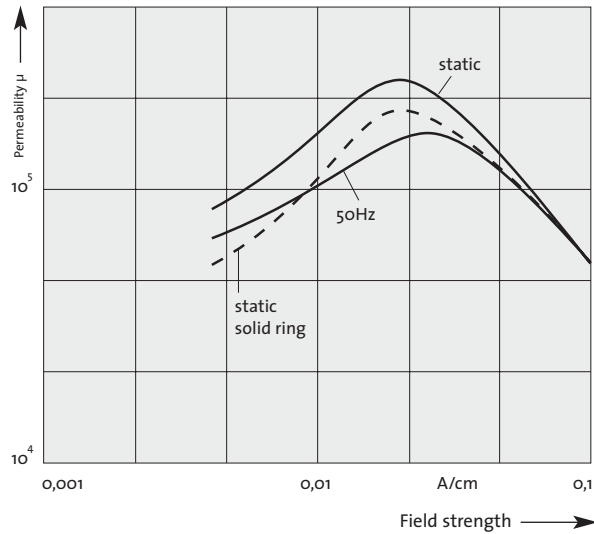
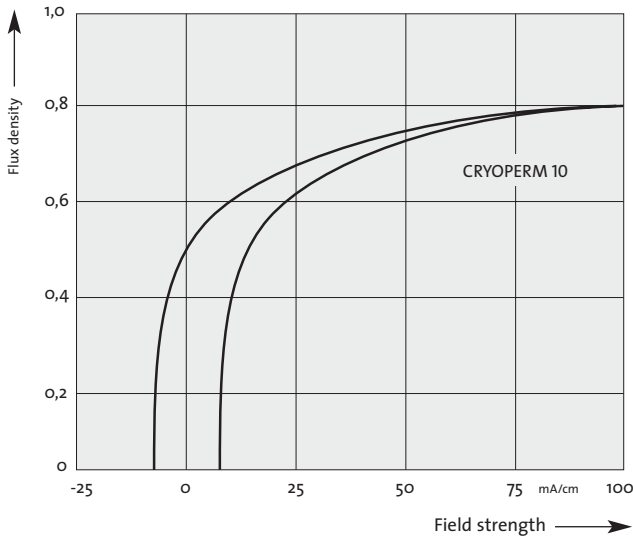


Fig. 2
Static hysteresis loop of CRYOPERM 10[®]. Measurement temperature 4.2K and 77.3 K. Heat treatment according to measurement temperature.

Fig. 3
Static and 50 Hz permeability field strength curves of toroidal strip-wound cores (0.1mm) and solid rings (1 mm) of CRYOPERM 10[®]. Measurement temperature 4.2 K and 77.3 K.

Coefficient of Thermal Expansion

Measurements were taken with a "dilatometer" at a starting temperature of -135°C. The -105° value is influenced by the "starting effect", and is most likely low because the setup settles from the starting temperature. While there is no specific data for temperatures below -105°C, the range of values provides a tendency for the lower temperatures.

Coefficient of Thermal Expansion from -105° to +350°

Temperature (°C)	CTE (10 ⁻⁶)
- 105.9	10.193
- 053.0	11.463
- 000.5	11.925
050.5	13.074
101.4	13.095
151.4	13.900
200.9	13.979
251.0	14.851
300.8	15.198
350.7	15.830

Thermal Conductivity

Different samples of Cryoperm 10 were annealed for use at 4.2K and 77.3K respectively, and tested for thermal conductivity. The results of the tests are shown in Tables 2 and 3.

Table 2. CRYOPERM 10[®] Sample annealed for use at 4.2 K

Temperature (K)	Conductivity (W/m-K)
67.5	13.11
100.6	14.18
128.2	15.20
159.0	16.27
198.1	17.44
240.1	19.32

Table 3. CRYOPERM 10[®] Sample annealed for use at 77.3 K

Temperature (K)	Conductivity (W/m-K)
69.1	13.11
101.3	14.09
134.1	14.67
168.3	15.51
206.4	16.60
241.0	22.63