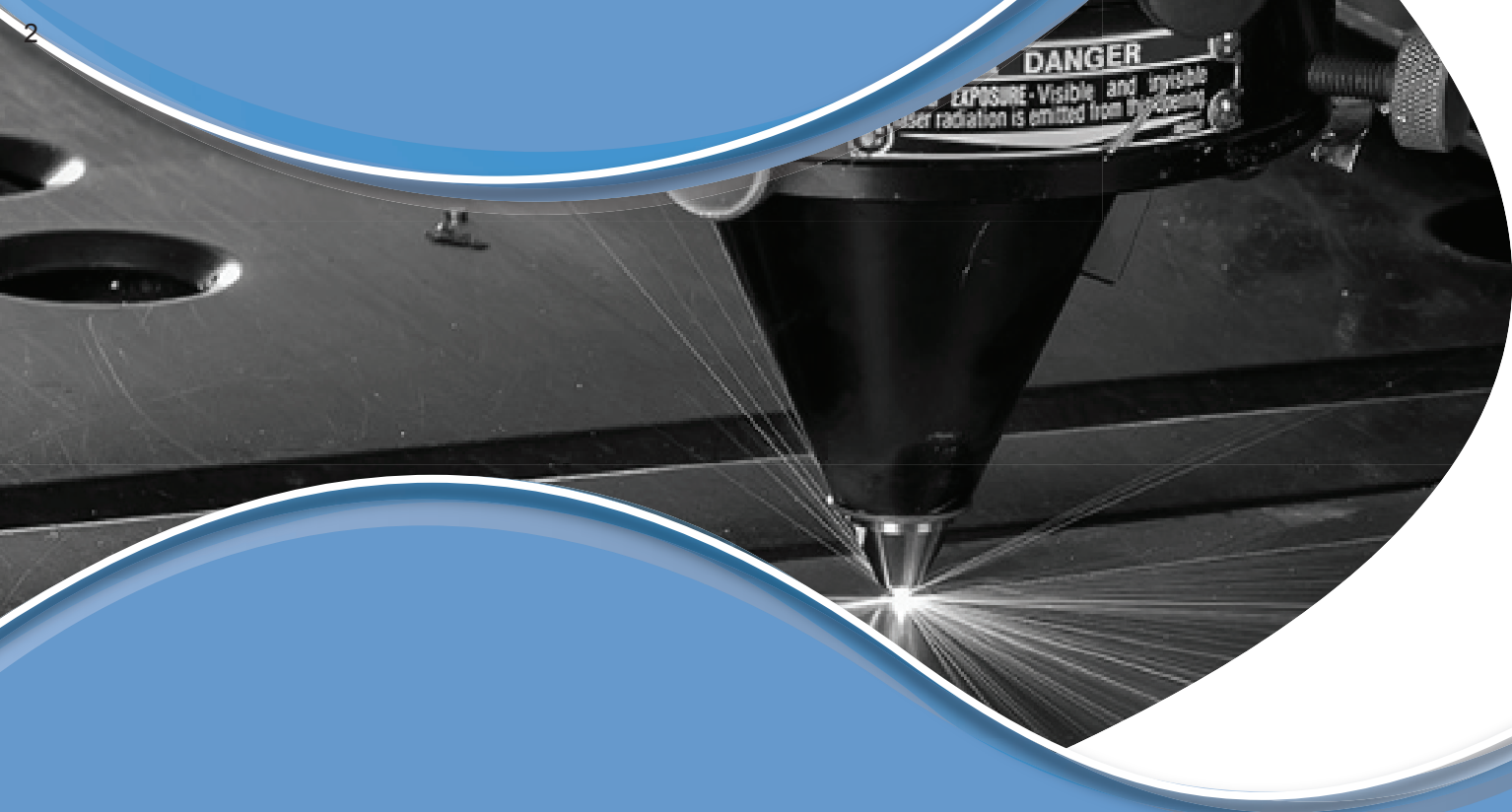




MuShield's High Permeability Magnetic Shielding per ASTM A753 Alloy Type 4

Available in coil, sheet, rod, billet, wire, and bar form, MuShield's High Permeability Magnetic Shielding is a soft magnetic alloy composed of 77-80% nickel, 15-17% iron, and 4.20% molybdenum, creating high permeability characteristics suitable for Medical, Aerospace, Defense, and Oil & Gas Exploration applications.



USEFUL INFORMATION FOR DESIGNING YOUR OWN MAGNETIC SHIELDING

- MuShield's High Permeability material has an extremely high initial permeability with minimal hysteresis loss.
- The material can be easily cut, formed, hydroformed, rolled, spun, and deep drawn.
- MuShield's High Permeability material can be spot welded or TIC welded.
- To achieve the best shielding characteristics, components must be heat treated at 2050 ° F or higher as described under heat treatment.
- Heat treatment is performed after all fabricating operations have been completed.



Form	μ at B = 40 G	μ max	H ₀ from H=1 Oersted
Bar, Wire	50,000	200,000	0.02 max

DC hysteresis loss from
 H = 1 Oe, erg/cm³ per cycle 16
 Induction, gauss 8,000

AC Magnetic Properties, 60Hz

Minimum Limits

Thickness (in)	Thickness (mm)	μ 200G
0.025 ¹	0.635	40,000
0.014 ¹	0.356	65,000
0.006 ¹	0.152	85,000
0.002 ²	0.051	90,000

1. Ring laminations 1 1/2" (38.1mm) OD x 1" (25.4mm) ID specimens
2. Tape toroid specimen

Physical Properties

Specific Gravity	8.75	Electrical Resistivity	Curie temp.	860°F (460°C)
Density (in lbs/in ³)	0.316	ohm-cir mil/ft	Melting point ...	2,650°F (1,454°C)
(in kg/m ³)	8,747	microhm-mm		
Thermal conductivity:		Temperature coefficient of	Specific heat:	
Btu-in/ft ² /hr/°F	240	electrical resistivity:	Btu/lb · °F	0.118
W/m · K	34.6	per °F from 0/930°F	kJ/kg · K	0.494
		per °C from -17.8/499°C		

MuShield Magnetic Shielding Material

Type analysis

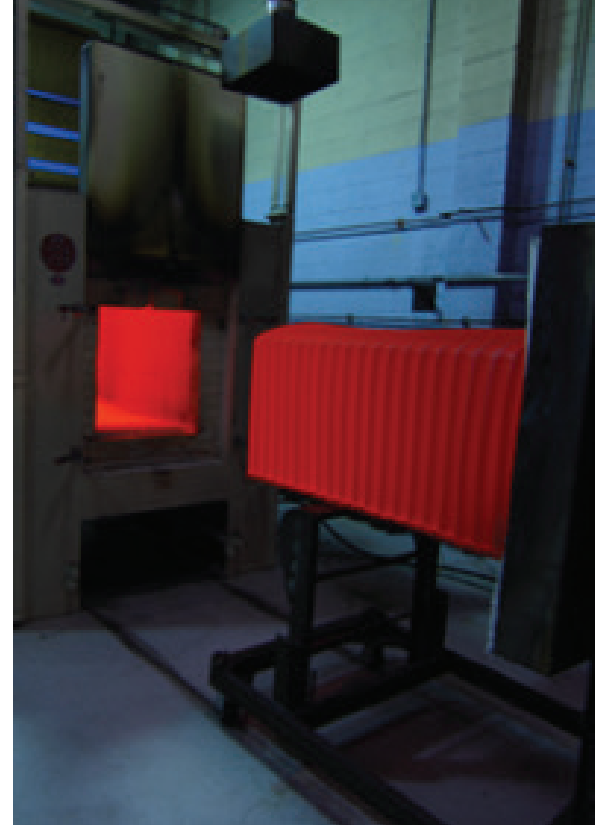
Nickel	80%
Molybdenum	4.20%
Iron	Balance
Manganese	0.50%
Silicon	0.35%
Carbon	0.02%

Coefficient of Thermal Expansion

Temperature		Coefficient	
°F	°C	10 ⁻⁶ /°F	10 ⁻⁶ /°C
-103 to 77	-75 to 25	6.00	10.80
-58 to 77	-50 to 25	5.94	10.70
-11 to 77	-25 to 25	5.78	10.40
77 to 122	25 to 50	6.83	12.30
77 to 212	25 to 100	6.89	12.40
77 to 392	25 to 200	7.09	12.76
77 to 572	25 to 300	7.22	13.00
77 to 752	25 to 400	7.39	13.30

Heat Treatment

- For maximum magnetic permeability, MuShield heat treats finished parts in an oxygen-free dry hydrogen atmosphere with a dew point below -40°F (-40°C) for one to four hours at $2,050^{\circ}\text{F}$ ($1,121^{\circ}\text{C}$)- $2,150^{\circ}\text{F}$ ($1,177^{\circ}\text{C}$).
- Furnace cool to $1,100^{\circ}\text{F}$ (593°C). From $1,100/700^{\circ}\text{F}$ ($593/371^{\circ}\text{C}$), cool at a rate between 350°F (194°C) and 600°F (334°C) per hour.
- Before placing finished parts in the furnace for heat treatment, all oil, grease and other contaminants must be removed.
- Individual parts must be separated by an inert insulation material such as magnesium or aluminum oxide during heat treatment.



Workability - Machine

- MuShield's High Permeability Magnetic Shield material will react similarly to 300 Series Stainless and other austenitic alloys when machined. The material will produce gummy chips, but does not work harden as quickly when compared to stainless alloys.
- It is suggested that bars with a Rockwell B 90 min hardness be used when machining.
- All drilling and machining should be done at slow to medium speeds and with water soluble coolants.
- Clean and heat treat all parts within 48 hours if water-soluble, or sulfur-bearing, cutting compounds are used during machining.
- High-speed steel or carbide tools are suggested for cutting operations.

Workability - Cold Forming

- Like machining, it is suggested that strip material with a Rockwell B 90 min hardness be used when blanking material.
- When forming, material should be in the cold rolled mill annealed condition.
- When drawing, material should be in the deep drawn mill annealed condition.

Corrosion Resistance

- While you can nickel plate MuShield's High Permeability Magnetic Shielding materials for additional corrosion resistance, it is not required. The bare material's resistance to moisture within the atmosphere is sufficient in most applications.

Mechanical Properties (Strip)

	Cold Rolled	As Hydrogen Annealed at 2050° F (1121 ° C)	After Process Anneal at 1600° F (871° C)
Tensile strength, ksi	135	77	98
MPa	931	531	676
Yield point, ksi		21	38
MPa		145	262
Proportional limit, ksi		15	35
MPa		103	241
Elongation %	4	38	38
Rockwell B hardness	100	58	85

Mechanical Properties (Bar)

	As Cold Drawn	As Hydrogen Annealed at 2050° F (1121 ° C)	After Process Anneal at 1600° F (871° C)
Tensile Strength, ksi	97	79	90
MPa	669	545	620
Yield point, ksi	69	22	33
MPa	414	152	228
Proportional limit, ksi	19	19	28
MPa	131	131	193
Elongation %	37	64	57
Reduction of area, %	71	70	74
Modulus of elasticity in tension, 10 ³ ksi	33.7	33.3	31.4
10 ⁶ MPa	232	230	217
Rockwell B hardness	97	62	85
Izod impact, ft-lbs	120	85	85
J	163	115	115

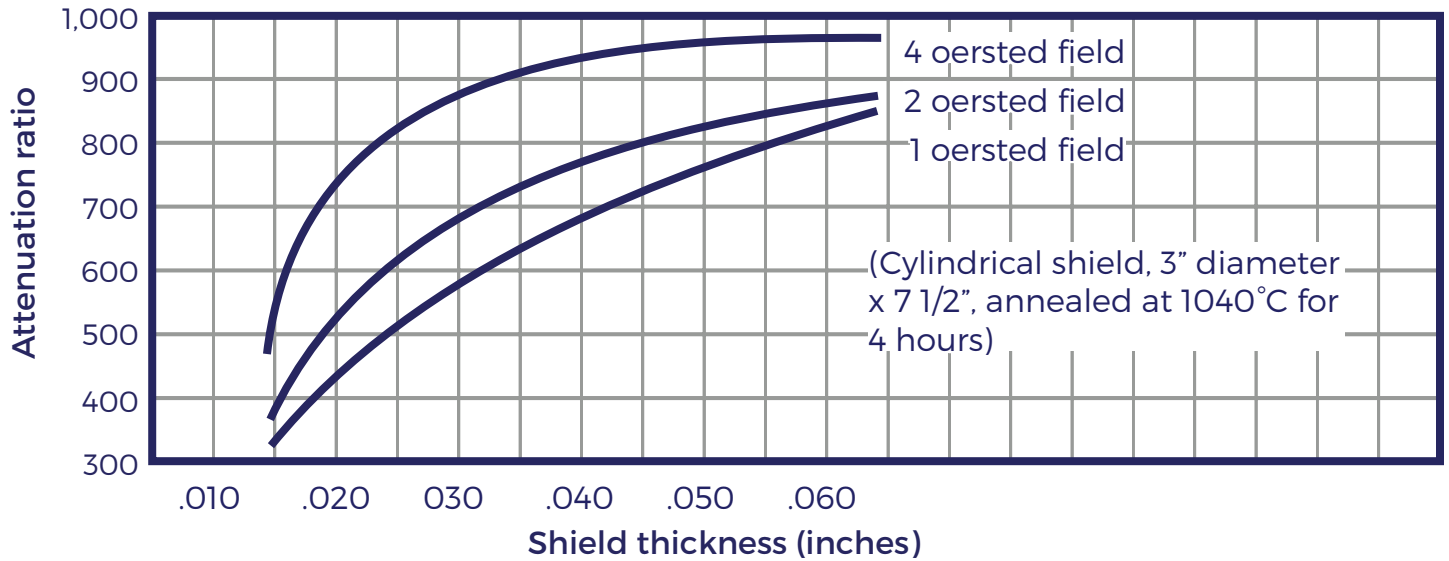
References for Machining

	Operation Speed*		Feed		Tool
	sf/m	m/s	i/r	mm/r	Materials
Turning	50	0.254	0.0007/ 0.002	0.018/ 0.051	M42
Drilling	35	0.18	0.001/ 0.004	0.025/ 0.102	M2
Milling	40	0.20	0.002/ 0.005	0.051/ 0.127	M2
Tapping	10/15	0.05/ 0.08	--	--	M1 or M2

*For carbide tools, double the sf/m

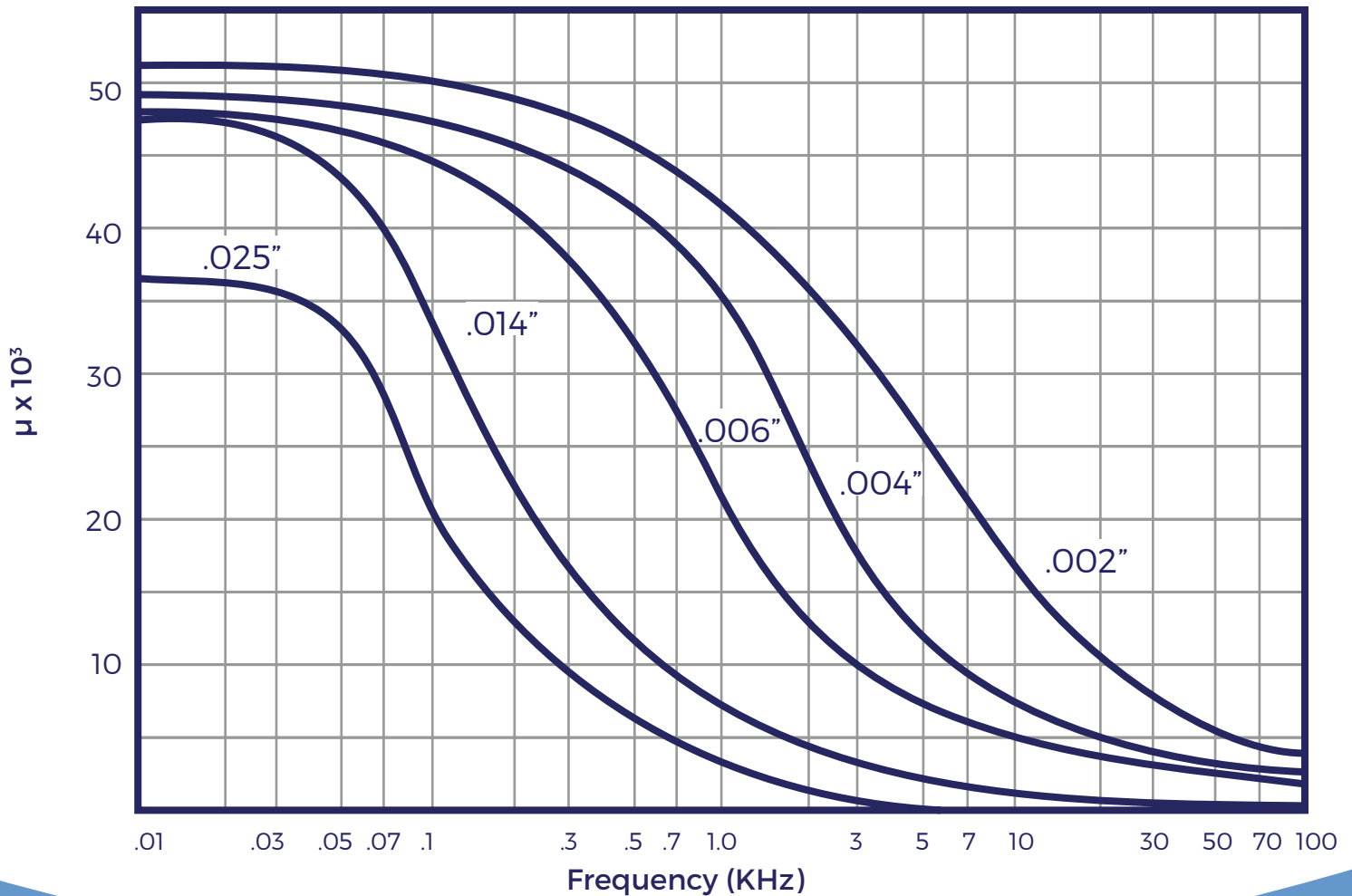
Shield Thickness vs. Attenuation Ratio at 60Hz

High Permeability MuShield Material



Typical Permeability vs. Frequency at B = 40 Gauss

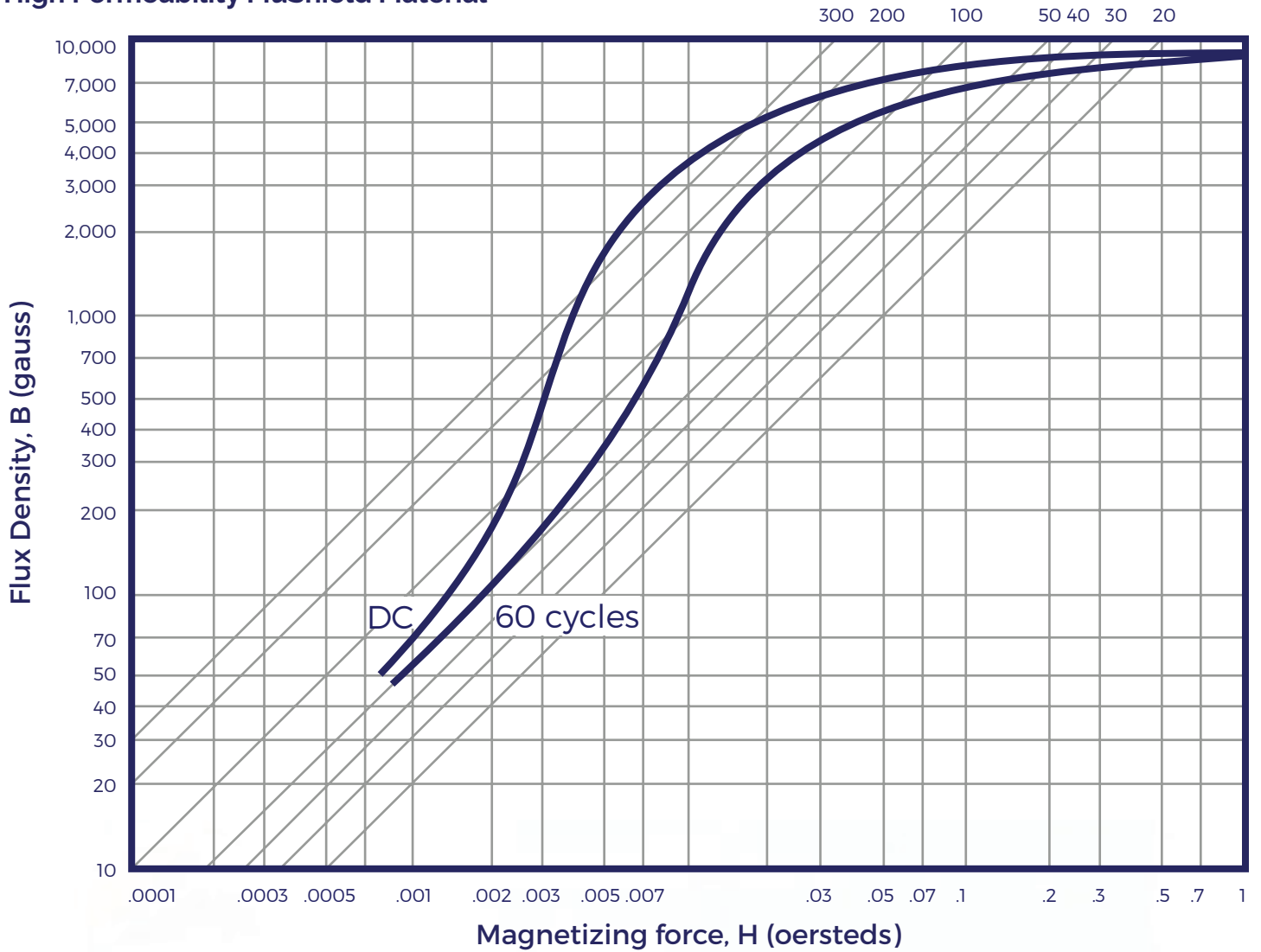
High Permeability MuShield Material



B/H Graph

High Permeability MuShield Material

Permeability, B/H x 10³





MATERIALS PER SPEC ASTM A753 can be offered in the following forms

- Sheets start at either 24" or 30" wide (based on availability) x 120" long. We have the capabilities to cut your custom blank size.
- Sheet Thicknesses available
 - .010"
 - .014"
 - .020"
 - .025"
 - .030"
 - .040"
 - .050"
 - .062"
 - .125"
 - Custom thicknesses available upon request.
- Coils start at either 12" or 15" wide (based on availability) and can be cut to whatever length you require.
- Coil Thicknesses In Stock
 - .002"
 - .004"
 - .006"
 - .010"
- Seamless Tubing (MuMetal IAW ASTM A753 Alloy Type 3)
 - Diameters and lengths based on your custom needs. Please contact sales for pricing.
- Round Bar
 - Standard Diameters available
 - .250"
 - .500"
 - 1.00"
 - 1.50"
 - 1.88"
 - Custom Diameters available upon request. Please contact sales for pricing.
- Flat Bar
 - Custom Diameters available upon request. Please contact sales for pricing.
- Wire
 - Custom Diameters available upon request. Please contact sales for pricing.

MUSHIELD'S MANUFACTURING CAPABILITIES

- Conventional Sheet Metal Fabrication
- 5-Axis Laser Cutting & Trimming
- CNC Machining & Turning
- Hydroforming - Deep Draw
- Hydrogen Annealing
- Laser Welding
- Rolling
- Rotary TIG Welding
- Spinning
- Spot Welding
- Stamping
- TIG Welding
- Tooling Manufacturing
- Turret Punching

CONSULTING & ENGINEERING SERVICES

- Magnetic Shielding Design
- Design for Manufacturing Efficiencies - All Alloys
- Special Process Development

QUALITY CAPABILITIES

- ISO 9001: 2008 Registered
- Conventional Metrology Equipment
- Magnetic Shielding Attenuation Testing
- Mitutoyo QSL-1020Z Vision System
- Sheffield Discovery III D-8 CMM
- Vacuum Leak Checking

MATERIALS WE WORK WITH

- Magnetic Shielding Alloys
 - Materials per spec ASTM A753 AKA MuMetal - Alloys 1-4
 - Cryoperm® 10
 - Hiperco® 50
 - Low Carbon Steel
 - Nickel Iron Alloys
 - Silicon Irons
- Other Industry Alloys
 - Aluminum and Aluminum Alloys
 - Brass
 - Copper
 - Hastelloy®
 - High Temperature Alloys
 - Inconel
 - Low Carbon Steel
 - Stainless Steel
 - Tantalum