Technical Datasheet

CARPENTER

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Carpenter HyMu "80"® Alloy

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Type Analysis

Carbon	0.02 %	**Manganese**	0.50 %
Silicon	0.35 %	**Nickel**	80.00 %
Molybdenum	4.20 %	**Iron**	Balance

General Information

Description

Carpenter HyMu "80"® alloy is an unoriented, 80% nickel-iron-molybdenum alloy which offers extremely high initial permeability as well as maximum permeability with minimum hysteresis loss.

Applications

Carpenter HyMu "80" alloy has been used primarily in transformer cores, tape wound toroids and laminations where compactness and weight factors are important. It has also been used for shielding to protect electrical components from stray magnetic fields.

Corrosion Resistance

This alloy is moderately resistant to moisture and atmospheric corrosion.

Properties

Physical Properties	
Specific Gravity	
--	8.74
Density	
--	8747 kg/m³
Mean Specific Heat	
--	0.4937 kJ/kg/K
Mean CTE	
-75 to 25°C	10.8 x 10^{-6} cm/cm/°C
-50 to 25°C	10.7 x 10^{-6} cm/cm/°C
-24 to 25°C	10.4 x 10^{-6} cm/cm/°C
25 to 50°C	12.3 x 10^{-6} cm/cm/°C
25 to 100°C	12.4 x 10^{-6} cm/cm/°C
25 to 200°C	12.8 x 10^{-6} cm/cm/°C
25 to 300°C	13.0 x 10^{-6} cm/cm/°C
25 to 400°C	13.3 x 10^{-6} cm/cm/°C

Mean coefficient of thermal expansion

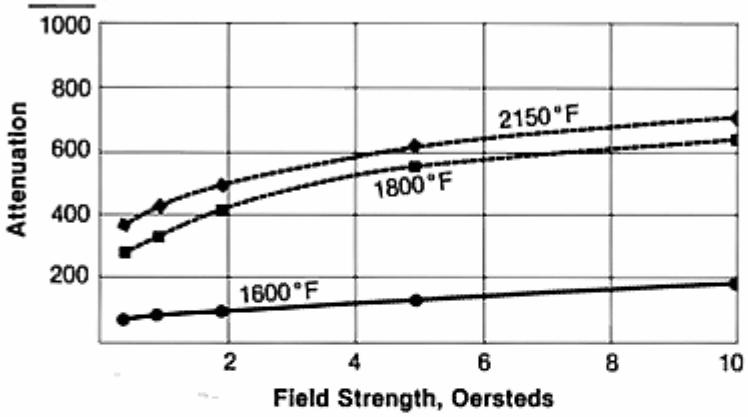
Temperature		Coefficient	
°F	°C	10^{-6}/°F	10^{-6}/°C
-103 to 77	-75 to 25	6.0	10.8
-58 to 77	-50 to 25	5.94	10.7
-11 to 77	-25 to 25	5.78	10.4
77 to 122	25 to 50	6.83	12.30
77 to 212	25 to 100	6.89	12.40
77 to 392	25 to 200	7.09	12.76
77 to 572	25 to 300	7.22	13.00
77 to 752	25 to 400	7.39	13.30

Thermal Conductivity	
--	34.60 W/m/K
Modulus of Elasticity (E)	

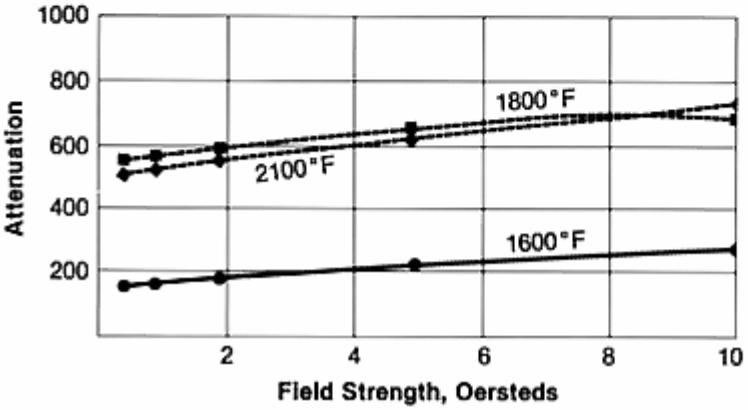
After Process Anneal at 871°C, In Tension	216 x 10^3 MPa
Cold Drawn, In Tension	232 x 10^3 MPa
Hydrogen Annealed at 1177°C, In Tension	230 x 10^3 MPa
Electrical Resistivity	
21°C	580.0 micro-ohm-mm
Temperature Coeff of Electrical Resist	
-18 to 499°C	10.8 x 10^{-4} Ohm/Ohm/°C
Curie Temperature	
--	460 °C
Melting Range	
--	1454.000 °C
Magnetic Properties	

Attenuation vs. Helmholtz Coil Field
Carpenter HyMu "80" alloy
60 Hz fields. Shield 6" (152 mm) long x 2¾" (69.9 mm) OD. ½" (12.7 mm) overlap spot welded.

0.020" thick

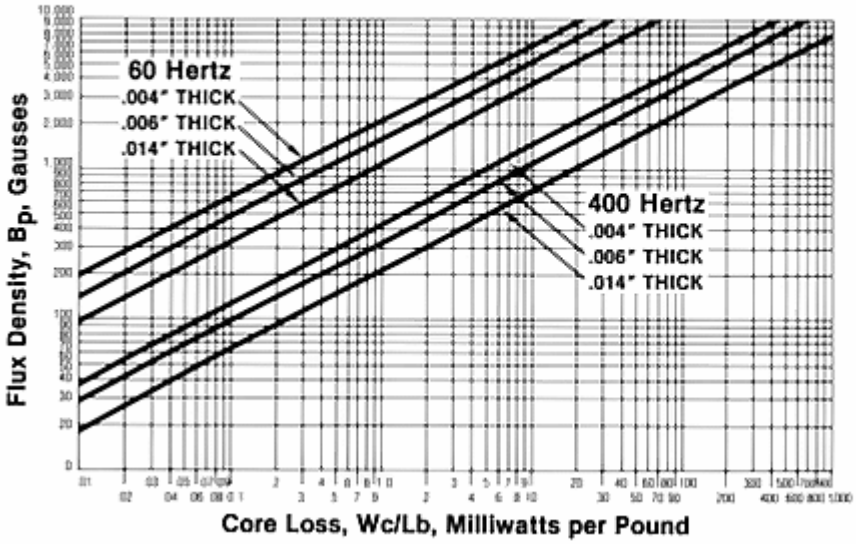


0.031" thick



Core Loss

At 60 Hz and 400 Hz, sine current excitation. Toroid specimen 0.004″ (0.102 mm), ring laminations 0.006″ (0.152 mm) and 0.014″ (0.356 mm) thick, dry hydrogen annealed at 2150°F (1177°C), 4 hours, cooled at 600°F (334°C) per hour



DC magnetic properties

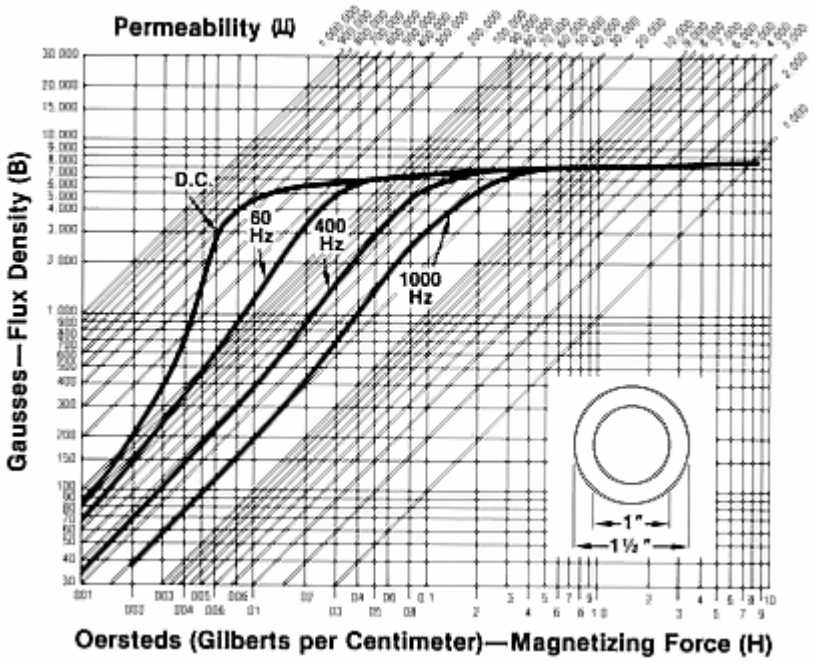
Form	μ at B = 40 G	μ max	H_c from H = 1 Oersted
Bar, Wire	50,000	200,000	0.02 max.

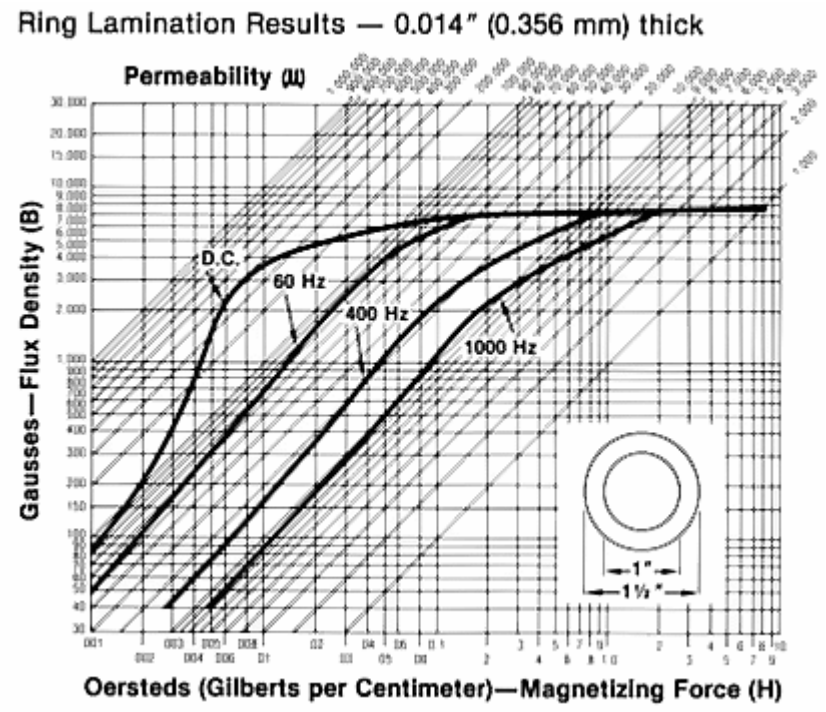
Typical AC magnetic properties, 60 Hz

Thickness		μ 40 G	μ 200 G	μ 2000 G
Inches	Millimeters			
0.025[1]	0.635	35,000	40,000	55,000
0.014[1]	0.356	55,000	65,000	95,000
0.006[1]	0.152	65,000	85,000	135,000
0.002[2]	0.051	70,000	90,000	220,000

[1] Ring laminations 1 ½" (38.1 mm) OD x 1" (25.4 mm) ID specimens
[2] Tape toroid specimen

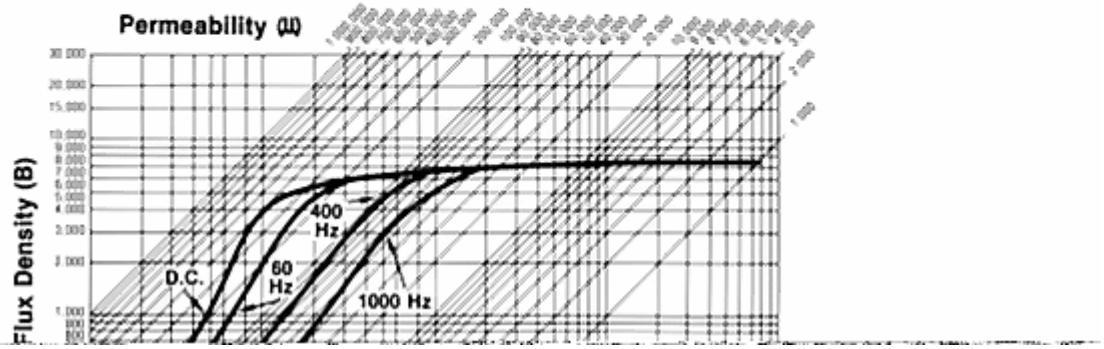
Ring Lamination Results — 0.006″ (0.152 mm) thick





Typical Magnetization Curves
DC and 60, 400 and 1000 hertz, sine current excitation. Dry hydrogen annealed at 2150°F (1177°C), 4 hours, cooled at 600°F (334°C) per hour

Toroid Specimen Results
½″ wide x 0.004″ (12.7 mm x 0.102 mm) thick



Coercivity	
--	0.637 to 1.59 A/m
Maximum Permeability	
--	200000
Residual Induction	
--	0.3500 T
Hysteresis Loss	
--	1.80E-6 to 2.40E-6 J/cm³/cycle

Shielding Properties

Because of its very high permeability and very low coercive force, Carpenter HyMu "80" alloy is particularly well suited for magnetic shielding applications.

Annealed, deep draw quality strip can be fabricated into shields by bending, drawing and spinning. Where joining is required, spot welding or tungsten inert-gas welding can be used, with or without a base metal filler rod.

To develop the best shielding characteristics, shields must be annealed at 1900°F (1040°C) or higher (as described in the heat treatment section) after all fabricating operations have been completed. In general, higher annealing temperatures yield higher permeability and better shielding characteristics.

To determine its relative shielding capability, a material is evaluated as an open-ended cylindrical shield In a uniform magnetic field, such as that produced by a Helmholtz coil. When a pickup unit is centered in the field of the coil, the attenuation (A) is the ratio of the reading with no shield (E1) to that obtained when a shield is positioned over the pickup (E2), with its axis perpendicular to the field (A = E1/E2).

This is a measure of the shielding effectiveness under the particular test conditions, and for a given material depends upon the shield thickness, its length-to-diameter ratio and the diameter of the Helmholtz coil. The detailed procedure is described in ASTM Standard A698, section "Alternating Current Methods of Test for Magnetic Shielding".

Typical Mechanical Properties

Bar

Tensile Strength		Yield Strength		Proportional Limit		% Elongation	% Reduction in Area	Hardness Rb
ksi	MPa	ksi	MPa	ksi	MPa			
As Cold Drawn								
97	669	69	414	19	131	37	71	97
As Hydrogen Annealed at 2050°F (1121°C)								
79	545	22	152	19	131	64	70	62
After Process Anneal at 1600°F (871°C)								
90	620	33	228	28	193	57	74	85

Modulus of Elasticity (in tension)		Izod Impact	
10^3 ksi	10^6 MPa	ft-lb	J
As Cold Drawn			
33.7	232	120	163
As Hydrogen Annealed at 2050°F (1121°C)			
33.3	230	85	115
After Process Anneal at 1600°F (871°C)			
31.4	217	85	115

Strip

Tensile Strength		Yield Strength		Proportional Limit		% Elongation	Hardness Rb
ksi	MPa	ksi	MPa	ksi	MPa		
As Cold Rolled							
135	931	—	—	—	—	4	100
As Hydrogen Annealed at 2050°F (1121°C)							
77	531	21	145	15	103	38	58
After Process Anneal at 1600°F (871°C)							
98	676	38	262	35	241	38	85

Heat Treatment

Annealing

In-process anneal:

To relieve all strains and restore the alloy to a soft condition suitable for drawing, spinning, forming, bending or similar operations, anneal at 1450/1850°F (788/1010°C) for not more than 1 hour. Since the high nickel, high

permeability alloys readily absorb carbon, sulfur, oxygen and other contaminants from combustion furnace gasses, in-process annealing should be conducted in dissociated ammonia, hydrogen, vacuum or inert gas atmospheres.

Hydrogen anneal:

For maximum softness and optimum magnetic and electrical properties, Carpenter HyMu "80" alloy should be annealed in an oxygen-free, dry hydrogen atmosphere with a dew point below -40°F (-40°C) at 2050/2150°F (1121/1177°C) for 2 to 4 hours. Furnace cool to 1100°F (593°C). From 1100 to 700°F (593 to 371°C), cool at a rate between 350 to 600°F (194 to 334°C) per hour.

Oil, grease, lacquer and all other contaminants must be removed before annealing. The individual parts should be separated by an inert insulating powder such as magnesium and aluminum oxide during hydrogen annealing.

Vacuum heat treating can be employed. Generally, there is some small sacrifice in magnetic properties compared to heat treating in a dry hydrogen atmosphere.

Workability

Cold Working

For best blanking characteristics, Carpenter HyMu "80" alloy strip should be ordered in the cold rolled condition (Rockwell B 90 minimum). For best forming characteristics, strip should be ordered in the cold rolled and annealed condition. For best drawing characteristics, strip orders should be endorsed "annealed, deep draw quality".

Machinability

Carpenter HyMu "80" alloy machines somewhat like the austenitic stainless alloys but does not work harden as rapidly. Gummy chips develop in most machining operations. Work-hardened bars (Rockwell B 90 minimum) offer the best machining characteristics.

Lard oil should be used for drilling and machining operations which must be done at slow speeds. If sulfur-bearing and water-soluble cutting compounds are used, the parts should be thoroughly cleaned within 48 hours, then heat treated. High-speed steel or carbide tools are suggested for cutting operations.

Following are typical feeds and speeds for Carpenter HyMu "80" alloy using the high-speed tool materials indicated. When using carbide tools, double the s/fm shown in the chart.

Typical Machining Speeds and Feeds – Carpenter HyMu "80"® Alloy

The speeds and feeds in the following charts are conservative recommendations for initial setup. Higher speeds and feeds may be attainable depending on machining environment.

Turning—Single-Point and Box Tools

Depth of Cut (Inches)	High Speed Tools			Carbide Tools (Inserts)			
	Tool Material	Speed (fpm)	Feed (ipr)	Tool Material	Speed (fpm) Uncoated	Speed (fpm) Coated	Feed (ipr)
.150 .125	M41 M42 M47	30 40	.010 .005	C2 C3	120 130		.010 .005

Turning—Cut-Off and Form Tools

Tool Material		Speed (fpm)	Feed (ipr)						
			Cut-Off Tool Width (inches)			Form Tool Width (inches)			
High Speed Tools	Carbide Tools		1/16	1/8	1/4	1/2	1	1 ½	2
M42		25	.001	.001	.0015	.0015	.001	.0007	.0007
	C2	80	.003	.003	.0045	.003	.002	.002	.002

Rough Reaming

High Speed		Carbide Tools		Feed (ipr) Reamer Diameter (inches)					
Tool Material	Speed (fpm)	Tool Material	Speed (fpm)	1/8	1/4	1/2	1	1 ½	2
M42	30-60	C2	70	.002	.006	.008	.010	.012	.014

Drilling

Tool Material	Speed (fpm)	High Speed Tools: Feed (inches per revolution) Nominal Hole Diameter (inches)							
		1/16	1/8	1/4	1/2	3/4	1	1 ½	2
M42	40	.001	.002	.004	.007	.008	.010	.012	.015

Die Threading

FPM for High Speed Tools				
Tool Material	7 or less, tpi	8 to 15, tpi	16 to 24, tpi	25 and up, tpi
M1, M2, M7, M10	8-20	10-25	15-30	20-35

Milling, End-Peripheral

Depth of Cut (inches)	High Speed Tools						Carbide Tools					
	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)				Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)			
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2
.050	M42	35	.0005	.001	.002	.003	C6	200	.001	.002	.003	.004

Tapping

High Speed Tools	
Tool Material	Speed (fpm)
M1, M7, M10	6-15

Broaching

High Speed Tools		
Tool Material	Speed (fpm)	Chip Load (ipt)
M42	8-12	.002

Additional Machinability Notes

When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of the speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds and feeds should be increased or decreased in small steps.

Weldability

Carpenter HyMu "80" alloy is readily welded by following the usual practices for ferrous alloys.

If a filler metal is required, use the same analysis. Finish annealed parts can be soft or hard soldered.

Do not braze or solder prior to final heat treatment.

Other Information

Applicable Specifications

Carpenter HyMu "80" alloy meets military specification MIL-N-14411 B (MR) (8/19/66) and ASTM A-753-78 standard specification.

- ASTM A753-78
- MIL-N-14411B (MR) (8/19/66)

Forms Manufactured

- Bar-Rounds
- Billet
- Sheet
- Strip
- Wire

Technical Articles

- A Simplified Method of Selecting Soft Magnetic Alloys
- Controlling Annealing and Magnetic Treatment Parameters to Achieve High Permeabilities in 55 Ni-Fe Toroid Cores
- Retail Theft Detection Devices and the Alloys That Make Them Work
- Soft Magnetic Alloys with Improved Corrosion Resistance

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