HYMU 80®

Type analysis

Single figures are nominal except where noted.

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

Forms manufactured

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

Description

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

HyMu 80 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.

This alloy is moderately resistant to moisture and atmospheric corrosion.

Key Properties:

- Extremely high initial permeability
- Maximum permeability
- Minimum hysteresis loss

Markets:

- Aerospace
- Automotive
- Commercial
- Consumer
- Industrial

Applications:

- Transformer cores
- Tape wound toroids
- Laminations
- Shielding

> HYMU 80

Physical properties

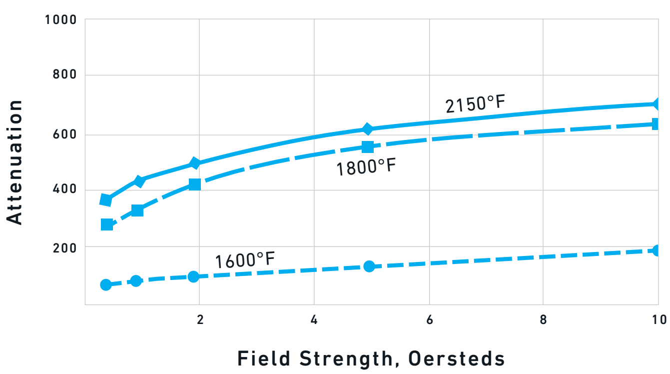
PROPERTY	At or From	English Units	Metric Units
SPECIFIC GRAVITY	—	8.74	8747 kg/m^3
DENSITY	—	0.3160 lb/°F	
MEAN SPECIFIC HEAT	—	0.1180 Btu/lb/°F	494 J/kg·K
MEAN COEFFICIENT OF THERMAL EXPANSION	-103 to 77°F (-75 to 25°C)	6.00 x 10^{-6} length/length/°F	10.8 x 10^{-6} length/length/°C
	-58 to 77°F (-50 to 25°C)	5.94 x 10^{-6} length/length/°F	10.7 x 10^{-6} length/length/°C
	-11 to 77°F (-25 to 25°C)	5.78 x 10^{-6} length/length/°F	10.4 x 10^{-6} length/length/°C
	77 to 122°F (25 to 50°C)	6.83 x 10^{-6} length/length/°F	12.30 x 10^{-6}length/length/°C
	77 to 212°F (25 to 100°C)	6.89 x 10^{-6} length/length/°F	12.40 x 10^{-6} length/length/°C
	77 to 392°F (25 to 200°C)	7.09 x 10^{-6} length/length/°F	12.76 x 10^{-6} length/length/°C
	77 to 572°F (25 to 300°C)	7.22 x 10^{-6} length/length/°F	13.00 x 10^{-6} length/length/°C
	77 to 752°F (25 to 400°C)	7.39 x 10^{-6} length/length/°F	13.30 x 10^{-6} length/length/°C
THERMAL CONDUCTIVITY	—	240.1 Btu-in/hr/ft^2/°F	34.6 W/m·K
ELASTIC MODULUS	—		
AFTER PROCESS ANNEAL AT 871°C, IN TENSION	—	31.4 x 10^3 ksi	
COLD DRAWN, IN TENSION	—	33.7 x 10^3 ksi	
HYDROGEN ANNEALED AT 1177°C, IN TENSION	—	33.3 x 10^3 ksi	
ELECTRICAL RESISTIVITY	70°F (21°C)	349.0 ohm-cir-mil/ft	58 microohm·cm
TEMPERATURE COEFF OF ELECTRICAL RESIST	0 to 930°F (-18 to 499°C)	6.00 x 10^{-4} ohm/ohm/°F	
CURIE TEMPERATURE	—	734°F	390°C
MELTING RANGE	—	2650°F	1454.4°C

Magnetic properties

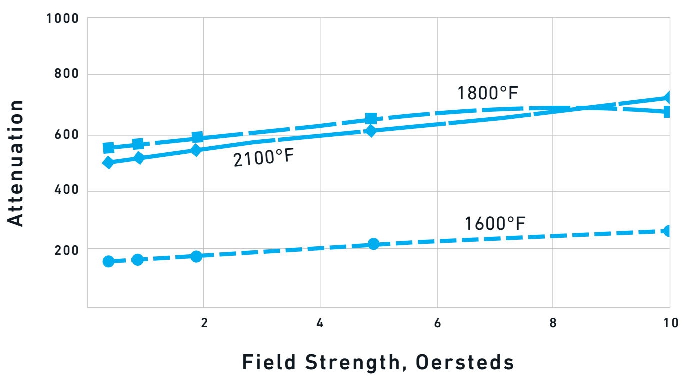
ATTENUATION VS. HELMHOLTZ COIL FIELD

60 Hz fields, Shield 6 in (152 mm) long x 2.75 in (69.9 mm) OD. .5 in (12.7 mm) overlap spot weld

0.020 IN THICK



0.031 IN THICK



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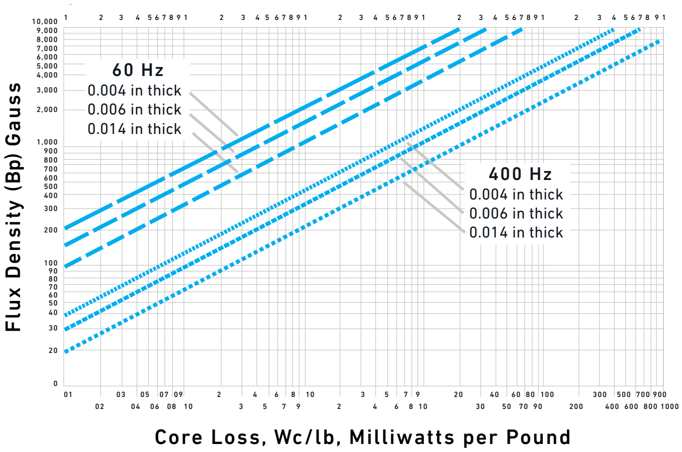
CORE LOSS

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



DC MAGNETIC PROPERTIES			
FORM	μ AT B = 40 G	μ MAX	Hc 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
IN	MM			
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 1.5 in (38.1 mm) OD x 1 in (25.4 mm) ID specimens
[2] Tape toroid specimen

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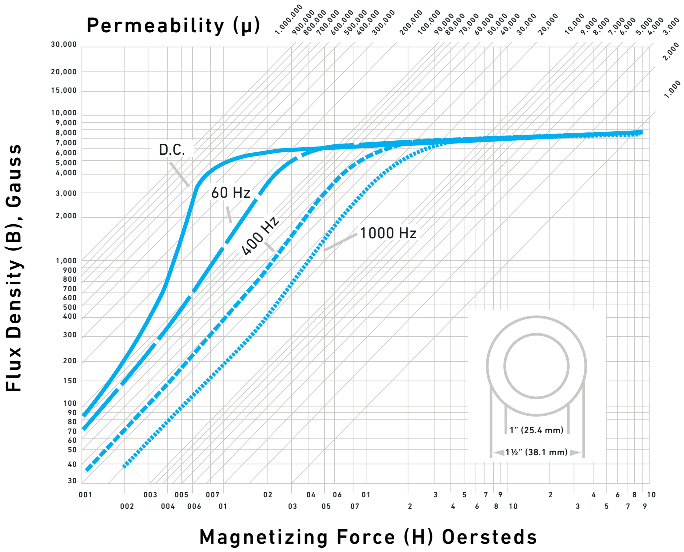
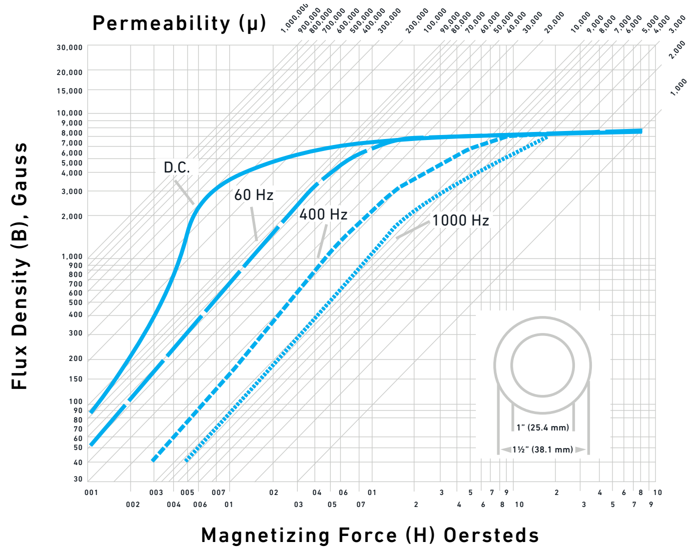
RING LAMINATION RESULTS

0.006 IN (0.152 MM) THICK



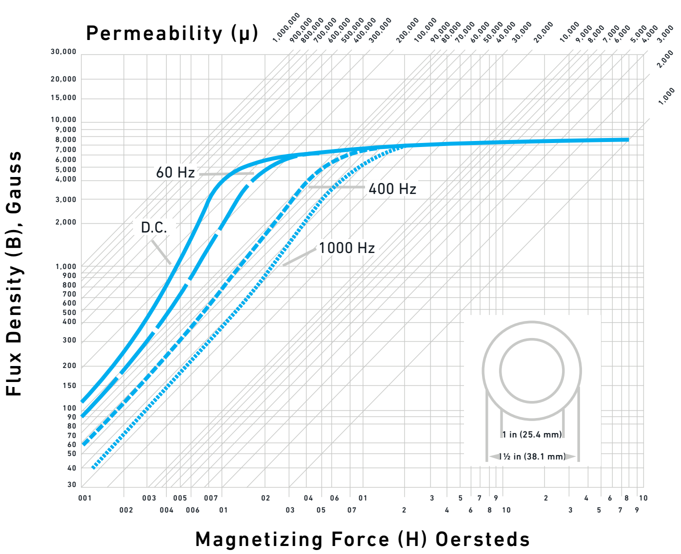
0.014 IN (0.356 MM) THICK



TYPICAL MAGNETIZATION CURVES

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

TOROID SPECIMEN RESULTS 0.5 IN WIDE X 0.004 IN (12.7 MM X 0.102 MM) THICK



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Magnetic properties

COERCIVITY (Hc)	0 00800 to 0.02 Oe
MAXIMUM PERMEABILITY (μMAX)	200000
RESIDUAL INDUCTION (Br)	3500 G
HYSTERESIS LOSS	1. 80E^{-6} to 2.40E^{-6} J/cm^{3}/cycle

Shielding properties

Shielding	Because of its very high permeability and very low coercive force, HyMu 80 is particularly well suited for magnetic shielding applications
Annealing	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
Best characteristics	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 n general, higher annealing temperatures yield higher permeability and better shielding characteristics
Relative capability	To determine its relative shielding capability, a material is evaluated as an open-ended cylindrical shield n 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)
Effectiveness	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"

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Typical mechanical properties

BAR

HEAT TREATMENT	YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		PROPORTIONAL LIMIT		ELONGATION 2 IN (50 MM)	REDUCTION OF AREA	HARDNESS
	ksi	MPa	ksi	MPa	ksi	MPa	%	%	HRB
Cold drawn	69	414	97	669	19	131	37	71	97
Hydrogen annealed 2050°F (1121°C)	22	152	79	545	19	131	64	70	62
After process anneal 1600°F (871°C)	33	228	90	620	28	193	57	70	85

ELASTICITY AND IMPACT

HEAT TREATMENT	ELASTIC MODULUS (IN TENSION)		IZOD IMPACT	
	10^3 ksi	10^3 MPa	FT-LB	J
Cold drawn	33.7	232	120	163
Hydrogen annealed 2050°F (1121°C)	33.3	230	85	115
After process annealed 1600°F (871°C)	31.4	217	85	115

STRIP

HEAT TREATMENT	YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		PROPORTIONAL LIMIT		ELONGATION	HARDNESS
	ksi	MPa	ksi	MPa	ksi	MPa	%	HRB
Cold rolled	—	—	135	931	—	—	4	100
Hydrogen annealed 2050°F (1121°C)	21	145	77	531	15	103	38	58
After process anneal 1600°F (871°C)	38	262	98	676	35	241	38	85

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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 annealing	For maximum softness and optimum magnetic and electrical properties, HyMu 80 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, HyMu 80 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	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 f 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 HyMu 80 using the high-speed tool materials indicated. When using carbide tools, double the s/fm shown in the chart.

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Typical feeds and speeds

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

TURNING — SINGLE-POINT AND BOX TOOLS

DEPTH OF CUT, IN	HIGH-SPEED TOOLS			CARBIDE TOOLS			
	SPEED, FPM	FEED, IPR	TOOL MATERIAL	SPEED, FPM		FEED, IPR	TOOL MATERIAL
				UNCOATED	COATED		
.150	30	.010	M-41	120	—	.010	C-2
.025	40	.005	M-42, M-47	130	—	.005	C-3

TURNING — CUT-OFF AND FORM TOOLS

SPEED, FPM	FEED, IPR							TOOL MATERIAL	
	CUT-OFF TOOL WIDTH, IN				FORM TOOL WIDTH, IN			HIGH-SPEED TOOLS	CARBIDE TOOLS
	1/16	1/8	1/4	1/2	1	1-1/2	2		
25	.001	.001	.0015	.0015	.001	.0007	.0007	M-42	—
80	.003	.003	.0045	.003	.002	.002	.002	—	C-2

ROUGH REAMING

HIGH-SPEED		CARBIDE TOOLS		FEED, IPR, REAMER DIAMETER, IN					
SPEED, FPM	TOOL MATERIAL	SPEED, FPM	TOOL MATERIAL	1/8	1/4	1/2	1	1-1/2	2
30–60	M-48	70	C-2	.002	.006	.008	.010	.012	.014

DRILLING

SPEED, FPM	FEED, IPR								TOOL MATERIAL
	NOMINAL HOLE DIAMETER, IN								
	1/16	1/8	1/4	1/2	3/4	1	1-1/2	2	
40	.001	.002	.004	.007	.008	.010	.012	.015	M-42

TAPPING

SPEED, FPM	TOOL MATERIAL
6–15	M-1; M-7; M-10

BROACHING — HIGH-SPEED TOOLS

SPEED, FPM	CHIP LOAD, IN PER TOOTH	TOOL MATERIAL
8–12	.002	M-42

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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	
8–20	10–25	15–30	20–35	M-1, M-2, M-7, M-10

MILLING — END PERIPHERAL												
DEPTH OF CUT, IN	HIGH-SPEED TOOLS						CARBIDE TOOLS					
	SPEED, FPM	FEED, IN PER TOOTH CUTTER DIAMETER, IN				TOOL MATERIAL	SPEED, FPM	FEED, IN PER TOOTH CUTTER DIAMETER, IN				TOOL MATERIAL
		1/4	*1/2*	*3/4*	*1-2*			*1/4*	*1/2*	*3/4*	*1-2*	
.050	35	.0005	.001	.002	.003	M-42	200	.001	.002	.003	.004	C-6

Other information

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	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.
Applicable specifications	Meets military specification M L-N-14411 B (MR) (8/19/66) and ASTM A-753-78 standard specification. ASTM A753 MIL-N-14411B (MR) (8/19/66)

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