Molybdenum Permalloy, Hi-Flux and Super-MSS Powder cores are wound with magnet wire to make transformers or inductors. Maximum allowable energy dissipation for a given value of energy storage (inductance and current) or transformation (voltage and current), guide the selection of core material and size. Energy dissipation is usually specified in terms of maximum temperature rise, minimum efficiency or minimum Q value. (Q is 2π times the ratio of peak energy stored to energy dissipated during one period of current flow.) Consider the following when choosing a core material:

1. Molybdenum Permalloy Powder (MPP) cores provide the maximum Q and lowest core loss. MPP is the most stable core with respect to temperature and AC Flux. It has the widest range of permeabilities and is considered the premium material for direct current output inductors of Switched Mode Power Supplies. It is useful into the Megahertz range of frequencies. MPP cores are an excellent choice for precision audio frequency tuned circuits, High Q Filters, Loading Coils, RFI Filters and many other precision inductor applications.
2. Hi-Flux cores are a 50% Nickel 50% Iron distributed gapped powder core. HF has up to 15,000 Gauss saturation flux density and core losses significantly lower than iron powder cores. These cores are ideal for Switching Regulator Inductors, In Line Noise Filters, Pulse and Fly-Back Transformer applications. When used in applications with high dc current, HF cores can provide a reduction in inductor size as well as total cost.
3. Super-MSS is an improved Sendust material, originally developed by Arnold Engineering. It is designed to replace iron powder by offering much lower losses, with energy storage capability higher than MPP. Super-MSS cores are an excellent choice for energy storage and filter inductor applications in Switch Mode Power Supplies. The low loss properties of Super-MSS cores minimizes the temperature rise at power frequencies to well below that of a similar sized iron powder core. The DC Bias characteristics of Super-MSS are also excellent compared to iron powder of similar permeabilities and size.

For reference, some basic electromagnetic terms and relationships used to design with magnetic powder cores are defined, followed by graphs showing typical values for material characteristics essential to transformer and inductor design. The final section of this catalogue contains data for specific core sizes and Q curves for Molybdenum Permalloy Powder (MPP) cores.

Units of Measure

For historical reasons, the Centimeter-Gram-Second (CGS) system is used in this catalog. Conversion between the System International (SI) and CGS System is simplified using the following table.

Conversion Table

Quantity	To Convert		Multiply By
	From	To	
Magnetic Flux Density B	Gausses (CGS)	Teslas (SI)	10^{-4}
Magnetizing Force H	Oersteds (CGS)	Amperes per Meter (SI)	1000/(4π)

Also, free space permeability in the CGS System has a magnitude of 1 and no dimensions. Free space permeability is $4\pi \times 10^{-7}$ henries per meter in the System International.

Inductance

Inductance (L) is calculated using the inductance factor (A_L) listed for each core.

$$L = A_L N^2 \text{ nanohenries}$$

A_L = inductance factor in mH for 1000 turns.
N = number of turns.

Therefore,

$$N = \sqrt{\frac{L}{A_L}} \text{ turns}$$

where *L* is in nanohenries.

Inductance can also be determined from the relative permeability (referred to in this catalog as *μ*, "permeability" and "perm") and the effective core parameters shown in Figure 1.

$$L = \frac{4\pi\mu A_e}{l_e} N^2 \text{ nanohenries}$$

A_e = effective core area in square centimeters.
l_e = effective magnetic path length in centimeters.
μ = relative permeability (no dimensions).

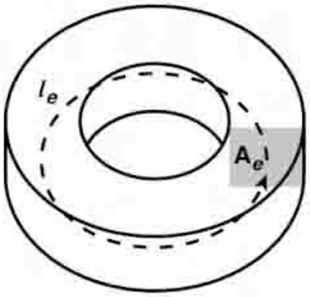


Figure 1.
Effective Core Parameters

For toroidal powder cores, the effective area is the same as the cross sectional area. By definition and Ampere's Law, the effective magnetic path length is the ratio of winding ampere-turns (NI) to the average magnetizing force across the core area from inside diameter to outside diameter. Using Ampere's Law and averaging the magnetizing force gives the formula for effective path length.

$$le = \frac{\pi(O.D. - I.D.)}{\ln(\frac{O.D.}{I.D.})}$$

O.D. = outside diameter of core.
I.D. = inside diameter of core.

Inductance factors are measured using a single layer winding with closely spaced turns. Flux densities and test frequencies are kept as low as practical, usually less than 40 gausses and 10 kHz or below. The "Normal Permeability versus Flux Density" and "Typical Permeability versus Frequency" graphs can be used as guides to define low-level test conditions for the various permeabilities and materials.

Permeability

The inductance factors listed for each core size are based on incremental relative permeabilities. With no direct current bias and at low flux densities, the normal and incremental permeabilities are the same. The incremental permeability decreases with direct current bias as indicated by Figure 2 and shown in the "Incremental Permeability versus DC Bias" graphs.

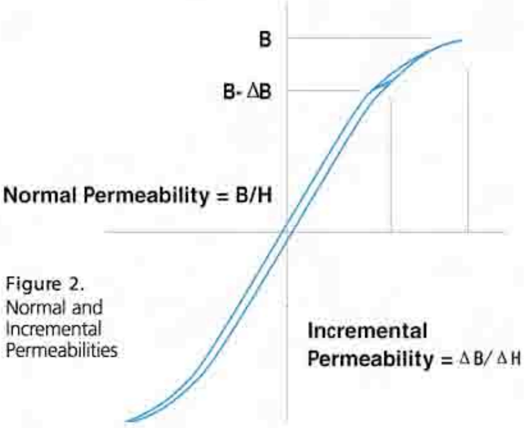


Figure 2.
Normal and Incremental Permeabilities

The "Normal Permeability versus Flux Density" graph shows normal permeability as a function of peak flux density, B.

Most design procedures involve choosing a peak operating magnetic flux density to help determine the core size. Peak operating flux density is limited by the core material saturation flux density or by the core material loss. After choosing the material and operating flux density and determining the core size, Faraday's Law (discussed below) is then used to calculate the number of turns, N. Finally, a permeability is selected to provide the required inductance.

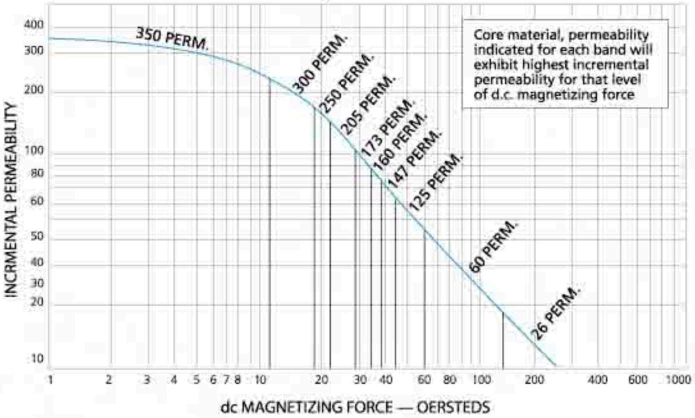
$$\mu = \frac{L\, l_e}{4\, \pi\, A_e\, N^2}$$

L = inductance in nanohenries.
l_e = effective magnetic path length in centimeters.
A_e = effective core area in square centimeters.

A wide range of permeabilities are offered to satisfy various inductance requirements.

Ampere's Law (also discussed below) gives the peak value of magnetizing force, H, based on the number of turns, peak magnetizing current (the total current of an inductor and "no-load" current in a transformer primary) and core magnetic path length. As can be seen in Figure 2, selecting the permeability sets the peak magnetic flux density so it matches the value chosen at the beginning of the design procedure. Also, for Molybdenum Permalloy Powder (MPP), the following selection chart gives the permeability that yields maximum inductance for a given magnetizing force.

Permeability Selection Chart



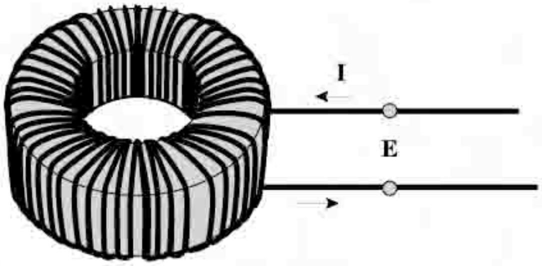
The "Normal Magnetization Curves" can be used with the "Typical Incremental Permeability versus DC Bias Curves" to estimate the direct current magnetic flux density for a chosen percentage of incremental permeability. For example, 125μ Molybdenum Permalloy Powder has 50% incremental permeability at just under 50 oersteds. The corresponding flux density is about 4500 gausses (0.45 tesla) according to the normal magnetization curve. Surveying the other permeabilities suggests that this could be used as an approximation of the DC flux density where Molybdenum Permalloy Powder has 50% of its original incremental permeability.

Magnetic Flux Density and Faraday's Law

The level of flux density (B) affects core loss and permeability. Unless otherwise noted, the data in this catalog is for sinusoidal waveforms and maximum (peak) magnetic flux densities. Using Faraday's Law:

$$B_{max} = \frac{E_{rms} 10^8}{N A_e \sqrt{2} \pi f}$$

B_{max} = maximum (peak) flux density in gausses.
E_{rms} = sinusoidal RMS voltage across winding (V rms).
N = number of turns.
A_e = effective core area in square centimeters.
f = frequency of sinusoidal voltage in hertz.



The effective area is considered the total area of the core cross section as shown in Figure 1. The area occupied by magnetic alloy is less than this area and decreases with decreasing permeability. Catalog data for the different permeabilities include effects from the smaller magnetic alloy areas.

Also, B_{max} is an average maximum flux density value over the core cross section. The flux density is greater toward the inside diameter and smaller toward the outside diameter as shown by Ampere's Law and described in the following.

Magnetizing Force and Ampere's Law

Ampere's Law relates magnetizing force (H) to current, number of turns and magnetic path length.

$$H = \frac{0.4 \pi N I}{l}$$

H = magnetizing force in oersteds.
N = number of turns.
I = current in amperes.
l = magnetic path length in centimeters.

According to Ampere's Law, the magnetizing force is stronger toward the inside diameter (where l is shorter). The effective magnetic path length provides an average value of magnetizing force across the core cross section.

$$H_{average} = \frac{0.4 \pi N I}{l_e}$$

$H_{average}$ = the average magnetizing force across the core from inside to outside diameters in oersteds.
l_e = effective magnetic path length as listed in the individual core specifications in centimeters. (See the section on inductance for the effective path length formula.)
N = number of turns.
I = current in amperes.

Average magnetizing force is used in this catalog unless noted otherwise.

The magnetizing force determines the estimate of magnetic flux density using the normal magnetization curves. See the above section on permeability. The relative permeability is, by definition:

$$\mu = \frac{B}{H}$$

μ = relative permeability.
B = magnetic flux density in gausses.
H = magnetizing force in oersteds.