

Power & Line Filter Applications



Issue L
February 2007





**RoHS
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Directive
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MICROMETALS, INC. established in 1951, is committed to supplying high quality iron powder cores to meet the needs of the electronics industry. As the technology has changed, new shapes, sizes and materials have been introduced to become industry standards.



TEL. (714) 970-9400
FAX (714) 970-0400

MICROMETALS

INTRODUCTION

Iron powder as a core material has been widely used in RF applications for years. The distributed air gap properties inherent in iron powder cores also make them extremely well-suited for a variety of energy storage inductor applications. Iron powder is a **cost-effective** design alternative to molypermalloy powder (MPP), high flux, or sendust cores. It can also be used in place of ferrites and iron-alloy laminations requiring a gap.

The iron powder cores described in this catalog are typically used for DC output chokes, differential-mode input chokes, power factor correction inductors, continuous-mode flyback inductors, light dimmer chokes and other EMI/RFI applications.

WARRANTY

Parts are warranted to conform to the specifications in the latest issue of this catalog. Micrometals' liability is limited to return of parts and repayment of price; or replacement of nonconforming parts. Notice of nonconformance must be made within 30 days after delivery. Before using these products, buyer agrees to determine suitability of the product for their intended use or application. Micrometals shall not be liable for any other loss or damage, including but not limited to incidental or consequential damages.

GENERAL MATERIAL PROPERTIES

INTRODUCTION

| Material Mix No. | Reference Permeability (μ_0) | Material Density (g/cm ³) | Relative Cost | Color* Code |
|------------------|------------------------------------|---------------------------------------|---------------|--------------|
| -2 | 10 | 5.0 | 2.7 | Red/Clear |
| -8 | 35 | 6.5 | 5.0 | Yellow/Red |
| -14 | 14 | 5.2 | 3.6 | Black/Red |
| -18 | 55 | 6.6 | 3.4 | Green/Red |
| -19 | 55 | 6.8 | 1.7 | Red/Green |
| -26 | 75 | 7.0 | 1.0 | Yellow/White |
| -30 | 22 | 6.0 | 1.4 | Green/Gray |
| -34 | 33 | 6.2 | 1.5 | Gray/Blue |
| -35 | 33 | 6.3 | 1.4 | Yellow/Gray |
| -40 | 60 | 6.9 | 1.0 | Green/Yellow |
| -45 | 100 | 7.2 | 2.6 | Black/Black |
| -52 | 75 | 7.0 | 1.2 | Green/Blue |

* All Micrometals color codes are protected by US Trademark law. Formal registration numbers have been issued for the -8, -18, -26 and -52 color codes by the United States Patent and Trademark office.

CORE LOSS COMPARISON (mW/cm³)

PERMEABILITY WITH DC BIAS

| Material Mix No. | 60 Hz | 1kHz | 10kHz | 50kHz | 100kHz | 500kHz | HDC = 50 Oersteds | |
|------------------|--------|--------|-------|-------|--------|--------|-------------------|--------------------------|
| | @5000G | @1500G | @500G | @225G | @140G | @50G | % μ_0 | $\mu_{\text{effective}}$ |
| -2 | 19 | 32 | 32 | 28 | 19 | 12 | 99 | 10.0 |
| -8 ** | 45 | 64 | 59 | 48 | 32 | 15 | 91 | 31.9 |
| -14 | 19 | 32 | 32 | 29 | 21 | 17 | 99 | 14.0 |
| -18 | 48 | 72 | 70 | 63 | 46 | 37 | 74 | 40.7 |
| -19 | 31 | 60 | 72 | 71 | 54 | 49 | 74 | 40.7 |
| -26 | 32 | 60 | 75 | 89 | 83 | 139 | 51 | 38.3 |
| -30 | 37 | 80 | 120 | 149 | 129 | 129 | 91 | 20.0 |
| -34 | 29 | 61 | 87 | 100 | 82 | 78 | 84 | 27.7 |
| -35 | 33 | 73 | 109 | 137 | 119 | 123 | 84 | 27.7 |
| -40 | 29 | 62 | 93 | 130 | 127 | 223 | 62 | 37.2 |
| -45 | 26 | 49 | 60 | 69 | 61 | 92 | 46 | 46.0 |
| -52 | 30 | 56 | 68 | 72 | 58 | 63 | 59 | 44.3 |

** Revised since last issue.

MATERIAL APPLICATIONS

| Typical Application | -2 | -8 | -14 | -18 | -19 | -26 | -30 | -34 | -35 | -40 | -45 | -52 |
|---|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Light Dimmer Chokes | | | | | | X | | | | X | X | |
| 60 Hz Differential-mode EMI Line Chokes | | | | | | X | | | | X | X | X |
| DC Chokes: <50kHz or low Et/N (Buck/Boost) | | | | | | X | X | X | X | X | X | |
| DC Chokes: ≥50kHz or higher Et/N (Buck/Boost) | | X | X | X | X | | X | X | X | | | X |
| Power Factor Correction Chokes: <50kHz | | | | | | X | X | X | X | X | | |
| Power Factor Correction Chokes: ≥50kHz | X | X | X | X | X | | X | X | X | | | |
| Resonant Inductors: ≥50kHz | X | | X | | | | | | | | | |

MATERIAL DESCRIPTION

-2/-14 Materials The low permeability of these materials will result in lower operating AC flux density than with other materials with no additional gap-loss. The -14 Material is similar to -2 Material with slightly higher permeability.

-8 Material This material has low core loss and good linearity under high bias conditions. A good high frequency material. The highest cost material.

-18 Material This material has low core loss similar to the -8 Material with higher permeability and a lower cost. Good DC saturation characteristics.

-19 Material An inexpensive alternate to the -18 Material with the same permeability and somewhat higher core losses.

-26 Material The most popular material. It is a cost-effective general purpose material that is useful in a wide variety of power conversion and line filter applications.

-30 Material The good linearity, low cost, and relatively low permeability of this material make it popular in large sizes for high power UPS chokes.

-34/-35 Materials An inexpensive alternate to the -8 material for applications where high frequency core loss is not critical. Good linearity with high bias.

-40 Material The least expensive material. It has characteristics quite similar to the very popular -26 Material. Popular in large sizes.

-45 Material The highest permeability material. A high permeability alternate to -52 Material with slightly higher core losses.

-52 Material This material has lower core loss at high frequency and the same permeability as the -26 Material. It is very popular for high frequency choke designs.

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MICROMETALS

INTRODUCTION

AVAILABILITY

Part numbers in this catalog which appear in **bold** print are considered standard items and are generally available from stock. Other items are available on a build-to-order basis. Orders may be placed directly with the factory in Anaheim, California, or with any of our sales representatives.

Micrometals has factories in Anaheim, California, Abilene, Texas, and Zhongshan, China. In addition Micrometals maintains stocking warehouses in Hong Kong and Dietzenbach, Germany for immediate delivery to the Far East and Europe. The details regarding our warehouses are as follows:

Hong Kong:

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Fo Tan, Shatin Hong Kong

Phone: +852-2604-8222

Fax: +852-2693-2093

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Assar Gabreilsson Str.1
63128 Dietzenbach Germany

+49-6074-40980

+49-6074-4098-10

ipe.de@bfioptilas.com

Pricing, delivery and lead-time information as well as technical support are available through our headquarters in Anaheim, California or with any of our local representatives. Please refer to page 69 for complete list of representatives. Also, Micrometals will gladly extend sample cores to aid in your core selection.

CUSTOM SHAPES AND SIZES

In addition to the items shown in this catalog, Micrometals will gladly produce custom shapes and sizes. Several key benefits of iron powder as a core material are: 1) Custom and proprietary tooling are relatively inexpensive, 2) Special prototypes can be machined from blocks of material for preliminary evaluation, and 3) cores can be manufactured in a variety of heights from any of the materials shown without additional tooling charges. Please do not hesitate to contact the factory with any special requests.

ENGINEERING KITS

For a wide selection of cores for engineering design and evaluation, the engineering kits described below are available at a modest charge:

ENGINEERING KIT #14

T20, T25, T26, T30, T37, T38,
T44, T50, T51C, T60, T68, T72, T80,
E49, E75, E100, (Including Bobbins)
42 Items, 425 pieces

ENGINEERING KIT #16

T130, T131, T157, T175, T184, T200, T225,
E162, E168, E187, E220, E225,
(Including Bobbins)
35 Items, 114 pieces

ENGINEERING KIT #15

T80, T90, T106, T130, T131,
E100, E137, E162, (Including Bobbins)
30 Items, 239 pieces

ENGINEERING KIT #17

T225, T250, T300, T400,
E220, E305, E450, (Including Bobbins)
15 Items, 44 pieces

HANDLING AND STORAGE CONSIDERATIONS

Micrometals has designed standard packaging for shipment to customers around the world. We recommend the cores remain in the original factory packaging and be sheltered from rain or high humidity since uncoated iron can eventually form surface rust.

Iron powder cores tend to be heavier than many other products and special consideration must be given to the weight of the carton. (Please refer to page 66 for package increments and weights.) Do not stack more than 5 cartons high to avoid crushing the bottom cartons.

Please be aware the cores are quite dense and package size can be deceptively heavy. Damage will occur to cores if boxes are handled incorrectly or dropped. Additionally, if individual cores are dropped on a hard surface a crack or chip can result on the core coating.

Special consideration for electrostatic discharge (ESD) is not necessary with iron powder cores since they have a "distributed air gap structure" and will not retain an electrostatic charge.

Finally, as with most magnetic material, iron powder cores need to be kept free of metal shavings, oil, solvents, dirt, dust and acids.

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MICROMETALS

INTRODUCTION

INDUCTANCE RATINGS

In this catalog the inductance ratings, also known as A_L values, are expressed in nanohenries (10^{-9} Henries) per turn (N) squared (nH/N^2). An example of a conversion from mH for 100 turns to nH/N^2 is:

$$350 \mu H \text{ for } 100 \text{ turns} = 35.0 \text{ nH}/N^2$$

To calculate the number of turns required for a desired inductance (L) in nanohenries (nH) use the following formula:

$$\text{Required turns} = \left[\frac{\text{desired L (nH)}}{A_L \text{ (nH}/N^2)} \right]^{1/2}$$

THERMAL CONSIDERATION

| Material Mix No. | Temp. Coef. of Permeability (+ppm/C°) | Coef. of Lin. Expansion (+ppm/C°) | Thermal Conductivity (mW/cm-C°) |
|------------------|---------------------------------------|-----------------------------------|---------------------------------|
| -2 | 95 | 10 | 10 |
| -8 | 255 | 10 | 29 |
| -14 | 150 | 10 | 11 |
| -18 | 385 | 11 | 21 |
| -19 | 650 | 12 | 30 |
| -26 | 825 | 12 | 42 |
| -30 | 510 | 11 | 20 |
| -34 | 565 | 12 | 28 |
| -35 | 665 | 12 | 30 |
| -40 | 950 | 11 | 36 |
| -45 | 1043 | 12 | 43 |
| -52 | 650 | 12 | 34 |

TEMPERATURE EFFECTS

Micrometals iron powder cores have an organic content and undergo thermal aging. When cores are exposed to or generate elevated temperatures, a permanent decrease in both inductance and quality factor (Q) will gradually occur. The extent of these changes is highly dependent on time, temperature, core size, frequency, and flux density. It is essential that these properties are considered in any design operating at or above 75°C. Iron powder cores tolerate temperatures down to -65°C with no permanent effects.

In high power applications where core loss is contributing to the total temperature, a decrease in quality factor will translate into an increase in eddy current losses which will further heat the core and can lead to thermal runaway. Designs where core loss exceeds copper loss should be avoided. Hysteresis losses are unaffected by the thermal aging process.

A more thorough and detailed discussion regarding thermal considerations for iron powder core designs is given on pages 38-40 of this catalog. Micrometals has also incorporated a thermal aging predictor into our standard design software. Please contact us directly to receive a free copy or download directly from our web site at <http://www.micrometals.com>. Furthermore, we are also pleased to provide free design consultation.

FINISH

The toroidal and bus bar cores listed in this catalog are provided with a protective coating. The T14, T16 and T20 size cores are coated under vacuum with Parylene C. The larger cores are coated with a two color code finish that is **UL approved** for Flame Class UL94V-0 per file #E140098 (S). A copy of the Yellow card can be provided upon request. All finishes have a minimum dielectric strength of 500 Vrms at 60 Hz and resist most cleaning solvents. Extended exposure to certain solvents may have detrimental effects.

The toroidal cores can be double or triple coated for greater dielectric strength. We can also provide uncoated cores upon special request. Please contact the factory for information on optional finishes or core caps for larger size toroids. The E-cores and U-cores are treated to help resist rust. Micrometals recommends that all uncoated cores should be sheltered from high humidity or rain since they will eventually form surface rust. Lastly, Micrometals color codes are protected by U.S. trademark law.

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MICROMETALS

TOLERANCES

MAGNETIC TOLERANCE

| Material (Mix No.) | -2 | -8 | -14 | -18 | -19 | -26 | -30 | -34 | -35 | -40 | -45 | -52 | -267 | -275 |
|--------------------------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|
| A _L Tolerance | +5% | +10% | +10% | +10% | +10% | +10% | +10% | +10% | +10% | +10% | +10% | +10% | +35% | +35% |
| | -5% | -10% | -10% | -10% | -10% | -10% | -10% | -10% | -10% | -10% | -10% | -10% | -25% | -25% |

The cores are manufactured to the A_L values listed; the permeability for each material is for reference only. In all cases, the A_L values are based on a peak AC flux density of 10 gauss (1 mT) at a frequency of 10 kHz. Measurements made under other conditions will produce results in accordance with the magnetic curves shown on page 27.

The toroidal cores are tested with an evenly-spaced full single-layer winding in order to minimize leakage effects. Iron powder cores tested with a small number of turns which are not evenly distributed will produce higher inductance readings than expected. The E Cores are tested with 100 turns.

The Magnetic Characteristic curves shown on pages 26-27 have a typical tolerance of +20%,-10%. The curves on Core Loss characteristics have a typical tolerance of ±15%.

DIMENSIONAL TOLERANCE (inches)

| TOROIDS* | OD | ID | Ht | TOROIDS* | OD | ID | Ht |
|---------------|-------------|-------|-------------|-------------|-------|-------|-------------|
| T14 - T20 | ±.010 | ±.010 | ±.010 | T150 - T225 | ±.025 | ±.025 | ±.030 |
| T22 - T38 | ±.015 | ±.015 | ±.020 | T249 - T400 | ±.030 | ±.030 | ±.030 |
| T40 - T72** | ±.020 | ±.020 | ±.020 | T520 - T650 | ±.050 | ±.050 | ±.050 |
| T80 - T141 | ±.020 | ±.020 | ±.025 | | | | |
| COMPOSITE* | OD | ID | Ht | COMPOSITE* | OD | ID | Ht |
| ST50 | ±.015 | ±.015 | ±.020 | ST150 | ±.040 | ±.030 | ±.030 |
| ST83 - ST102 | ±.030 | ±.020 | ±.025 | ST200 | ±.050 | ±.040 | ±.040 |
| BUS BAR* | A | B | D | E | L | | |
| HS300 - HS400 | ±.015 | ±.020 | ±.005 | ±.005 | ±.020 | | |
| U CORES | A | B | C | E | F | G | |
| U61 - U80 | ±.010 | ±.010 | ±.010 | ±.010 | ±.010 | ±.010 | |
| U350 | ±.020 | ±.020 | ±.015 | ±.020 | ±.015 | ±.030 | |
| E CORES | A | B | C | D | F | G | Max. Gap*** |
| E49 - E118 | ±.010 | ±.010 | ±.005 | ±.007 | ±.005 | ±.007 | .0015 |
| E125 - E162 | ±.015 | ±.015 | ±.007 | ±.010 | ±.007 | ±.010 | .0015 |
| E168 - E225 | ±.015 | ±.015 | ±.010 | ±.010 | ±.007 | ±.010 | .0020 |
| E305 - E450 | ±.030 | ±.030 | ±.015 | ±.020 | ±.015 | ±.020 | .0030 |
| E610 | ±.040 | ±.040 | ±.025 | ±.030 | ±.025 | ±.030 | .0050 |
| EH CORES | A | B | C | D | E/H | G | Max. Gap*** |
| EH220 | ±.015 | ±.015 | ±.010 | ±.020 | ±.015 | ±.010 | .0030 |
| EM CORES | A | B | C | D | G | H | Max. Gap |
| EM145 | ±.015 | ±.015 | ±.010 | ±.020 | ±.010 | ±.015 | .0020 |
| EM168 - EM220 | ±.015 | ±.015 | ±.010 | ±.020 | ±.010 | ±.015 | .0030 |
| PLAIN CORES | OD | | L | | | | |
| Pxx24 - Pxx40 | +.000/-.005 | | ±.015 | | | | |
| Pxx48 - Pxx76 | +.000/-.005 | | ±.020 | | | | |
| HOLLOW CORES | OD | | ID | L | | | |
| Hx10 - Hx12 | +.000/-.005 | | | +.005/-.000 | | ±.010 | |
| Hxx14 - Hxx20 | +.000/-.005 | | | +.005/-.000 | | ±.015 | |
| Hxx21 - Hxx25 | +.000/-.005 | | | +.005/-.000 | | ±.020 | |
| DISCS | OD | | CB | ID | T | | |
| D45 - D80 | +.000/-.010 | | +.005/-.000 | +.005/-.000 | ±.007 | | |

*Tolerance includes coating
 ***Gap per piece.

**OD for T50-8/90 and T50-8B/90 is +.025/- .015

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T14-26A | 12.5 | .135/3.43 | .067/1.70 | .060/1.52 | .810 | .012 | .0098 |
| T14-45A | 16.5 | | | | | | |
| T14-52A | 11.5 | | | | | | |
| T16-2 | 2.2 | .160/4.06 | .078/1.98 | .060/1.52 | .930 | .015 | .014 |
| T16-8/90 | 6.0 | | | | | | |
| T16-18 | 9.5 | | | | | | |
| T16-26 | 14.5 | | | | | | |
| T16-40 | 12.5 | | | | | | |
| T16-45 | 17.0 | | | | | | |
| T16-52 | 13.5 | | | | | | |
| T20-2 | 2.5 | .200/5.08 | .088/2.24 | .070/1.78 | 1.15 | .023 | .026 |
| T20-8/90 | 7.8 | | | | | | |
| T20-18 | 13.0 | | | | | | |
| T20-26 | 18.5 | | | | | | |
| T20-40 | 16.0 | | | | | | |
| T20-45 | 22.5 | | | | | | |
| T20-52 | 17.5 | | | | | | |
| T22-26 | 38.5 | .223/5.66 | .097/2.46 | .143/3.63 | 1.28 | .052 | .067 |
| T22-52 | 38.5 | | | | | | |
| T25-2 | 3.4 | .255/6.48 | .120/3.05 | .096/2.44 | 1.50 | .037 | .055 |
| T25-8/90 | 10.0 | | | | | | |
| T25-18 | 17.0 | | | | | | |
| T25-26 | 24.5 | | | | | | |
| T25-40 | 20.5 | | | | | | |
| T25-45 | 31.0 | | | | | | |
| T25-52 | 23.0 | | | | | | |
| T26-8/90 | 24.0 | .265/6.73 | .105/2.67 | .190/4.83 | 1.47 | .090 | .133 |
| T26-18 | 41.5 | | | | | | |
| T26-26 | 57.0 | | | | | | |
| T26-45 | 77.0 | | | | | | |
| T26-52 | 56.0 | | | | | | |
| T27-2 | 3.3 | .280/7.11 | .151/3.84 | .128/3.25 | 1.71 | .047 | .080 |
| T27-8/90 | 11.5 | | | | | | |
| T27-18 | 18.5 | | | | | | |
| T27-26 | 27.5 | | | | | | |
| T27-52 | 25.5 | | | | | | |
| T30-2 | 4.3 | .307/7.80 | .151/3.84 | .128/3.25 | 1.84 | .060 | .110 |
| T30-8/90 | 14.0 | | | | | | |
| T30-18 | 22.0 | | | | | | |
| T30-26 | 33.5 | | | | | | |
| T30-40 | 28.0 | | | | | | |
| T30-45 | 40.5 | | | | | | |
| T30-52 | 30.5 | | | | | | |

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TOROIDAL CORES

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Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _t nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T32-52 | 35.0 | .327/8.31 | .169/4.29 | .158/4.01 | 1.96 | .073 | .144 |
| T37-2 | 4.0 | .375/9.53 | .205/5.21 | .128/3.25 | 2.31 | .064 | .147 |
| T37-8/90 | 12.0 | | | | | | |
| T37-18 | 19.0 | | | | | | |
| T37-19 | 19.0 | | | | | | |
| T37-26 | 28.5 | | | | | | |
| T37-40 | 24.5 | | | | | | |
| T37-45 | 34.0 | | | | | | |
| T37-52 | 26.0 | | | | | | |
| T38-2 | 7.4 | .375/9.53 | .175/4.45 | .190/4.83 | 2.18 | .114 | .248 |
| T38-8/90 | 20.0 | | | | | | |
| T38-18 | 36.0 | | | | | | |
| T38-19 | 36.0 | | | | | | |
| T38-26 | 49.0 | | | | | | |
| T38-40 | 41.5 | | | | | | |
| T38-45 | 65.0 | | | | | | |
| T38-52 | 49.0 | | | | | | |
| T40-26 | 36.0 | .400/10.2 | .205/5.21 | .163/4.14 | 2.41 | .093 | .223 |
| T40-52 | 36.0 | | | | | | |
| T44-2 | 5.2 | .440/11.2 | .229/5.82 | .159/4.04 | 2.68 | .099 | .266 |
| T44-8/90 | 18.0 | | | | | | |
| T44-14 | 6.2 | | | | | | |
| T44-18 | 25.5 | | | | | | |
| T44-19 | 25.5 | | | | | | |
| T44-26 | 37.0 | | | | | | |
| T44-40 | 31.0 | | | | | | |
| T44-45 | 46.5 | | | | | | |
| T44-52 | 35.0 | | | | | | |
| T44-52C | 55.0 | .440/11.2 | .229/5.82 | .250/6.35 | 2.68 | .157 | .419 |
| T44-52D | 70.0 | .440/11.2 | .229/5.82 | .338/8.59 | 2.68 | .212 | .567 |
| T50-2 | 4.9 | .500/12.7 | .303/7.70 | .190/4.83 | 3.19 | .112 | .358 |
| T50-8/90* | 17.5 | | | | | | |
| T50-14 | 5.9 | | | | | | |
| T50-18 | 24.0 | | | | | | |
| T50-19 | 24.0 | | | | | | |
| T50-26 | 33.0 | | | | | | |
| T50-40 | 29.5 | | | | | | |
| T50-45 | 44.0 | | | | | | |
| T50-52 | 33.0 | | | | | | |

* Non-Standard dimensional tolerance, refer to page 4 for details

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T50-8B/90* | 23.0 | .500/12.7 | .303/7.70 | .250/6.35 | 3.19 | .148 | .471 |
| T50-18B | 32.0 | | | | | | |
| T50-19B | 32.0 | | | | | | |
| T50-26B | 43.5 | | | | | | |
| T50-40B | 38.5 | | | | | | |
| T50-45B | 58.0 | | | | | | |
| T50-52B | 43.5 | | | | | | |
| T50-8C/90 | 28.3 | .500/12.7 | .303/7.70 | .335/8.51 | 3.19 | .200 | .637 |
| T50-26C | 61.0 | | | | | | |
| T50-26D | 72.0 | .500/12.7 | .303/7.70 | .375/9.53 | 3.19 | .223 | .711 |
| T50-40D | 59.0 | | | | | | |
| T50-52D | 66.0 | | | | | | |
| T51-8C/90 | 37.0 | .500/12.7 | .200/5.08 | .250/6.35 | 2.79 | .223 | .622 |
| T51-18C | 55.0 | | | | | | |
| T51-26C | 83.0 | | | | | | |
| T51-40C | 67.0 | | | | | | |
| T51-52C | 75.0 | | | | | | |
| T57-45 | 67.0 | .573/14.6 | .273/6.93 | .196/4.98 | 3.38 | .178 | .601 |
| T57-52 | 49.5 | | | | | | |
| T57-45A | 88.0 | .573/14.6 | .273/6.93 | .263/6.68 | 3.38 | .239 | .805 |
| T57-52A | 66.0 | | | | | | |
| T60-2 | 6.5 | .600/15.2 | .336/8.53 | .234/5.94 | 3.74 | .187 | .699 |
| T60-8/90 | 19.0 | | | | | | |
| T60-14 | 8.3 | | | | | | |
| T60-18 | 34.5 | | | | | | |
| T60-19 | 34.5 | | | | | | |
| T60-26 | 50.0 | | | | | | |
| T60-40 | 41.5 | | | | | | |
| T60-52 | 47.0 | | | | | | |
| T60-26D | 97.0 | .600/15.2 | .336/8.53 | .470/11.9 | 3.74 | .374 | 1.400 |
| T60-52D | 94.0 | | | | | | |
| T68-2 | 5.7 | .690/17.5 | .370/9.40 | .190/4.83 | 4.23 | .179 | .759 |
| T68-8/90 | 19.5 | | | | | | |
| T68-14 | 7.0 | | | | | | |
| T68-18 | 29.0 | | | | | | |
| T68-19 | 29.0 | | | | | | |
| T68-26 | 43.5 | | | | | | |
| T68-40 | 35.0 | | | | | | |
| T68-45 | 53.0 | | | | | | |
| T68-52 | 40.0 | | | | | | |

* Non-standard dimensional tolerance, refer to page 4 for details.

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T68-2A | 7.0 | .690/17.5 | .370/9.40 | .250/6.35 | 4.23 | .242 | 1.03 |
| T68-8A/90 | 26.0 | | | | | | |
| T68-14A | 9.5 | | | | | | |
| T68-18A | 39.5 | | | | | | |
| T68-19A | 39.5 | | | | | | |
| T68-26A | 58.0 | | | | | | |
| T68-40A | 47.0 | | | | | | |
| T68-45A | 71.0 | | | | | | |
| T68-52A | 54.0 | | | | | | |
| T68-2D | 11.4 | .690/17.5 | .370/9.40 | .375/9.53 | 4.23 | .358 | 1.52 |
| T68-14D | 14.2 | | | | | | |
| T68-26D | 87.0 | | | | | | |
| T68-40D | 70.0 | | | | | | |
| T68-52D | 80.0 | | | | | | |
| T69-45 | 120.0 | .690/17.5 | .336/8.53 | .367/9.32 | 4.09 | .394 | 1.61 |
| T72-2 | 12.8 | .720/18.3 | .280/7.11 | .260/6.60 | 4.01 | .349 | 1.40 |
| T72-8/90 | 36.0 | | | | | | |
| T72-18 | 60.0 | | | | | | |
| T72-26 | 90.0 | | | | | | |
| T72-40 | 71.0 | | | | | | |
| T72-52 | 82.0 | | | | | | |
| T80-2 | 5.5 | .795/20.2 | .495/12.6 | .250/6.35 | 5.14 | .231 | 1.19 |
| T80-8/90 | 18.0 | | | | | | |
| T80-14 | 7.4 | | | | | | |
| T80-18 | 31.0 | | | | | | |
| T80-19 | 31.0 | | | | | | |
| T80-26 | 46.0 | | | | | | |
| T80-40 | 39.5 | | | | | | |
| T80-45 | 56.0 | | | | | | |
| T80-52 | 42.0 | | | | | | |
| T80-8B/90 | 29.5 | .795/20.2 | .495/12.6 | .375/9.53 | 5.14 | .347 | 1.78 |
| T80-14B | 11.0 | | | | | | |
| T80-18B | 46.5 | | | | | | |
| T80-19B | 46.5 | | | | | | |
| T80-26B | 71.0 | | | | | | |
| T80-40B | 59.0 | | | | | | |
| T80-45B | 84.0 | | | | | | |
| T80-52B | 63.0 | | | | | | |
| T80-26D | 92.0 | .795/20.2 | .495/12.6 | .500/12.7 | 5.14 | .453 | 2.33 |
| T80-40D | 79.0 | | | | | | |
| T80-52D | 83.0 | | | | | | |

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T90-8/90 | 30.0 | .900/22.9 | .550/14.0 | .375/9.53 | 5.78 | .395 | 2.28 |
| T90-18 | 47.0 | | | | | | |
| T90-19 | 47.0 | | | | | | |
| T90-26 | 70.0 | | | | | | |
| T90-40 | 57.0 | | | | | | |
| T90-45 | 85.0 | | | | | | |
| T90-52 | 64.0 | | | | | | |
| T94-2 | 8.4 | .942/23.9 | .560/14.2 | .312/7.92 | 5.97 | .362 | 2.16 |
| T94-8/90 | 25.0 | | | | | | |
| T94-14 | 10.0 | | | | | | |
| T94-18 | 42.0 | | | | | | |
| T94-19 | 42.0 | | | | | | |
| T94-26 | 60.0 | | | | | | |
| T94-40 | 49.0 | | | | | | |
| T94-45 | 76.0 | | | | | | |
| T94-52 | 57.0 | | | | | | |
| T95-26B | 84.0 | .942/23.9 | .495/12.6 | .375/9.53 | 5.72 | .510 | 2.91 |
| T95-52B | 84.0 | | | | | | |
| T106-2 | 13.5 | 1.060/26.9 | .570/14.5 | .437/11.1 | 6.49 | .659 | 4.28 |
| T106-8/90 | 45.0 | | | | | | |
| T106-14 | 17.0 | | | | | | |
| T106-18 | 70.0 | | | | | | |
| T106-19 | 70.0 | | | | | | |
| T106-26 | 93.0 | | | | | | |
| T106-30 | 30.0 | | | | | | |
| T106-34 | 40.0 | | | | | | |
| T106-35 | 40.0 | | | | | | |
| T106-40 | 81.0 | | | | | | |
| T106-45 | 125.0 | | | | | | |
| T106-52 | 95.0 | | | | | | |
| T106-18A | 49.0 | 1.060/26.9 | .570/14.5 | .312/7.92 | 6.49 | .461 | 3.00 |
| T106-26A | 67.0 | | | | | | |
| T106-40A | 58.0 | | | | | | |
| T106-52A | 67.0 | | | | | | |
| T106-18B | 91.0 | 1.060/26.9 | .570/14.5 | .575/14.6 | 6.49 | .858 | 5.57 |
| T106-19B | 91.0 | | | | | | |
| T106-26B | 124.0 | | | | | | |
| T106-40B | 106.0 | | | | | | |
| T106-52B | 124.0 | | | | | | |
| T124-26 | 58.0 | 1.245/31.6 | .710/18.0 | .280/7.11 | 7.75 | .459 | 3.55 |
| T130-2 | 11.0 | 1.300/33.0 | .780/19.8 | .437/11.1 | 8.28 | .698 | 5.78 |
| T130-8/90 | 35.0 | | | | | | |
| T130-14 | 14.0 | | | | | | |
| T130-18 | 58.0 | | | | | | |
| T130-19 | 58.0 | | | | | | |

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T130-26 | 81.0 | 1.300/33.0 | .780/19.8 | .437/11.1 | 8.28 | .698 | 5.78 |
| T130-30 | 25.0 | | | | | | |
| T130-34 | 33.5 | | | | | | |
| T130-35 | 33.5 | | | | | | |
| T130-40 | 69.0 | | | | | | |
| T130-45 | 105.0 | | | | | | |
| T130-52 | 79.0 | | | | | | |
| T130-26A | 41.0 | 1.300/33.0 | .780/19.8 | .225/5.72 | 8.28 | .361 | 2.99 |
| T130-40A | 34.0 | | | | | | |
| T131-8/90 | 52.5 | 1.300/33.0 | .640/16.3 | .437/11.1 | 7.72 | .885 | 6.84 |
| T131-18 | 79.0 | | | | | | |
| T131-19 | 79.0 | | | | | | |
| T131-26 | 116.0 | | | | | | |
| T131-34 | 46.5 | | | | | | |
| T131-35 | 46.5 | | | | | | |
| T131-40 | 93.0 | | | | | | |
| T131-52 | 108.0 | | | | | | |
| T132-26 | 103.0 | 1.300/33.0 | .700/17.8 | .437/11.1 | 7.96 | .805 | 6.41 |
| T132-40 | 83.0 | | | | | | |
| T132-52 | 95.0 | | | | | | |
| T141-8/90 | 32.0 | 1.415/35.9 | .880/22.4 | .412/10.5 | 9.14 | .674 | 6.16 |
| T141-26 | 75.0 | | | | | | |
| T141-40 | 60.0 | | | | | | |
| T141-52 | 69.0 | | | | | | |
| T150-18 | 65.0 | 1.510/38.4 | .845/21.5 | .437/11.1 | 9.38 | .887 | 8.31 |
| T150-26 | 96.0 | | | | | | |
| T150-40 | 78.0 | | | | | | |
| T150-52 | 89.0 | | | | | | |
| T150-26A | 66.0 | 1.510/38.4 | .845/21.5 | .325/8.26 | 9.38 | .657 | 6.16 |
| T150-45A | 84.0 | | | | | | |
| T157-2 | 14.0 | 1.570/39.9 | .950/24.1 | .570/14.5 | 10.1 | 1.06 | 10.7 |
| T157-8/90 | 42.0 | | | | | | |
| T157-14 | 17.5 | | | | | | |
| T157-18 | 73.0 | | | | | | |
| T157-19 | 73.0 | | | | | | |
| T157-26 | 100.0 | | | | | | |
| T157-30 | 31.5 | | | | | | |
| T157-34 | 43.5 | | | | | | |
| T157-35 | 43.5 | | | | | | |
| T157-40 | 86.0 | | | | | | |
| T157-45 | 130.0 | | | | | | |
| T157-52 | 99.0 | | | | | | |

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
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- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T175-2 | 15.0 | 1.750/44.5 | 1.070/27.2 | .650/16.5 | 11.2 | 1.34 | 15.0 |
| T175-8/90 | 48.0 | | | | | | |
| T175-18 | 82.0 | | | | | | |
| T175-26 | 105.0 | | | | | | |
| T175-40 | 90.0 | | | | | | |
| T175-52 | 105.0 | | | | | | |
| T184-2 | 24.0 | 1.840/46.7 | .950/24.1 | .710/18.0 | 11.2 | 1.88 | 21.0 |
| T184-8/90 | 72.0 | | | | | | |
| T184-14 | 28.0 | | | | | | |
| T184-18 | 116.0 | | | | | | |
| T184-19 | 116.0 | | | | | | |
| T184-26 | 169.0 | | | | | | |
| T184-30 | 51.0 | | | | | | |
| T184-34 | 70.0 | | | | | | |
| T184-35 | 70.0 | | | | | | |
| T184-40 | 143.0 | | | | | | |
| T184-52 | 159.0 | | | | | | |
| T200-2 | 12.0 | 2.000/50.8 | 1.250/31.8 | .550/14.0 | 13.0 | 1.27 | 16.4 |
| T200-8/90 | 42.5 | | | | | | |
| T200-18 | 67.0 | | | | | | |
| T200-19 | 67.0 | | | | | | |
| T200-26 | 92.0 | | | | | | |
| T200-34 | 37.0 | | | | | | |
| T200-35 | 37.0 | | | | | | |
| T200-40 | 79.0 | | | | | | |
| T200-52 | 92.0 | | | | | | |
| T200-2B | 21.8 | 2.000/50.8 | 1.250/31.8 | 1.000/25.4 | 13.0 | 2.32 | 30.0 |
| T200-8B/90 | 78.5 | | | | | | |
| T200-18B | 120.0 | | | | | | |
| T200-19B | 120.0 | | | | | | |
| T200-26B | 160.0 | | | | | | |
| T200-30B | 51.0 | | | | | | |
| T200-35B | 74.0 | | | | | | |
| T200-40B | 142.0 | | | | | | |
| T200-52B | 155.0 | | | | | | |
| T201-8/90 | 104.0 | 2.000/50.8 | .950/24.1 | .875/22.2 | 11.8 | 2.81 | 33.2 |
| T201-18 | 164.0 | | | | | | |
| T201-26 | 224.0 | | | | | | |
| T201-40 | 194.0 | | | | | | |
| T201-52 | 224.0 | | | | | | |
| T224-26C | 155.0 | 2.250/57.2 | 1.250/31.8 | .750/19.1 | 14.0 | 2.31 | 32.2 |
| T224-52C | 155.0 | | | | | | |
| T225-2 | 12.0 | 2.250/57.2 | 1.405/35.7 | .550/14.0 | 14.6 | 1.42 | 20.7 |
| T225-8/90 | 42.5 | | | | | | |
| T225-18 | 67.0 | | | | | | |
| T225-19 | 67.0 | | | | | | |

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MICROMETALS

TOROIDAL CORES

COLOR CODE

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- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T225-26 | 98.0 | 2.250/57.2 | 1.405/35.7 | .550/14.0 | 14.6 | 1.42 | 20.7 |
| T225-30 | 28.0 | | | | | | |
| T225-34 | 37.0 | | | | | | |
| T225-35 | 37.0 | | | | | | |
| T225-40 | 78.0 | | | | | | |
| T225-52 | 92.0 | | | | | | |
| T225-2B | 21.5 | 2.250/57.2 | 1.405/35.7 | 1.000/25.4 | 14.6 | 2.59 | 37.8 |
| T225-14B | 28.0 | | | | | | |
| T225-26B | 160.0 | | | | | | |
| T225-34B | 67.0 | | | | | | |
| T225-52B | 155.0 | | | | | | |
| T249-26 | 203.0 | 2.500/63.5 | 1.405/35.7 | 1.000/25.4 | 15.6 | 3.36 | 52.3 |
| T249-34 | 89.0 | | | | | | |
| T249-52 | 203.0 | | | | | | |
| T250-8/90 | 113.0 | 2.500/63.5 | 1.250/31.8 | 1.000/25.4 | 15.0 | 3.84 | 57.4 |
| T250-14 | 43.0 | | | | | | |
| T250-18 | 177.0 | | | | | | |
| T250-19 | 177.0 | | | | | | |
| T250-26 | 242.0 | | | | | | |
| T250-30 | 71.0 | | | | | | |
| T250-34 | 106.0 | | | | | | |
| T250-40 | 194.0 | | | | | | |
| T250-52 | 242.0 | | | | | | |
| T300-2 | 11.4 | 3.040/77.2 | 1.930/49.0 | .500/12.7 | 19.8 | 1.68 | 33.4 |
| T300-8/90 | 37.0 | | | | | | |
| T300-18 | 58.0 | | | | | | |
| T300-19 | 58.0 | | | | | | |
| T300-26 | 80.0 | | | | | | |
| T300-30 | 23.0 | | | | | | |
| T300-34 | 34.5 | | | | | | |
| T300-35 | 34.5 | | | | | | |
| T300-40 | 71.0 | | | | | | |
| T300-52 | 80.0 | | | | | | |
| T300-2D | 22.8 | 3.040/77.2 | 1.930/49.0 | 1.000/25.4 | 19.8 | 3.38 | 67.0 |
| T300-14D | 28.0 | | | | | | |
| T300-18D | 116.0 | | | | | | |
| T300-19D | 116.0 | | | | | | |
| T300-26D | 160.0 | | | | | | |
| T300-30D | 46.0 | | | | | | |
| T300-34D | 69.0 | | | | | | |
| T300-35D | 69.0 | | | | | | |
| T300-40D | 142.0 | | | | | | |
| T300-52D | 160.0 | | | | | | |

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MICROMETALS

TOROIDAL CORES

COLOR CODE

- 2 Red/Clear
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- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

Refer to page 4 for tolerances.

TYPICAL PART NO.

T 106-26 /

OD in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate Height
 Code Area For Other Characteristics

Note: For information on Mix 0, 1, 3, 4, 6, 7, 10, 12, 15, 17, and 42 see Micrometals RF Catalog.
 For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

| MICROMETALS Part No. | A _L nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------------------|---------------------|-------------|-------------|---------|----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A cm ² | V cm ³ |
| T400-2* | 18.0 | 4.000/102 | 2.250/57.2 | .650/16.5 | 25.0 | 3.46 | 86.4 |
| T400-8/90 | 60.0 | | | | | | |
| T400-18 | 96.0 | | | | | | |
| T400-19 | 96.0 | | | | | | |
| T400-26 | 131.0 | | | | | | |
| T400-30 | 40.5 | | | | | | |
| T400-34 | 55.0 | | | | | | |
| T400-35 | 55.0 | | | | | | |
| T400-40 | 115.0 | | | | | | |
| T400-52 | 131.0 | | | | | | |
| T400-26B* | 205.0 | 4.000/102 | 2.250/57.2 | 1.000/25.4 | 25.0 | 5.35 | 133 |
| T400-2D* | 36.0 | 4.000/102 | 2.250/57.2 | 1.300/33.0 | 25.0 | 6.85 | 171 |
| T400-14D | 45.5 | | | | | | |
| T400-26D | 262.0 | | | | | | |
| T400-30D | 81.0 | | | | | | |
| T400-34D | 110.0 | | | | | | |
| T400-35D | 110.0 | | | | | | |
| T400-40D | 230.0 | | | | | | |
| T520-2* | 20.0 | 5.200/132 | 3.080/78.2 | .800/20.3 | 33.1 | 5.24 | 173 |
| T520-8/90 | 65.0 | | | | | | |
| T520-26 | 149.0 | | | | | | |
| T520-30 | 45.0 | | | | | | |
| T520-34 | 65.0 | | | | | | |
| T520-35 | 65.0 | | | | | | |
| T520-40 | 119.0 | | | | | | |
| T520-52 | 137.0 | | | | | | |
| T520-30D* | 90.0 | 5.200/132 | 3.080/78.2 | 1.600/40.6 | 33.1 | 10.5 | 347 |
| T520-34D | 130.0 | | | | | | |
| T520-35D | 130.0 | | | | | | |
| T520-40D | 240.0 | | | | | | |
| T650-2 | 58.0 | 6.500/165 | 3.500/88.9 | 2.000/50.8 | 39.9 | 18.4 | 734 |
| T650-8/90 | 200.0 | | | | | | |
| T650-26 | 434.0 | | | | | | |
| T650-30 | 127.0 | | | | | | |
| T650-34 | 191.0 | | | | | | |
| T650-35 | 191.0 | | | | | | |
| T650-40 | 376.0 | | | | | | |
| T650-52 | 405.0 | | | | | | |

* T400 and T520 can be provided uncoated by adding the suffix "/18" for use with core covers. Please refer to page 20 for more details

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MICROMETALS

COMPOSITE CORES

COLOR CODE
-267 Green
-275 Green

TYPICAL PART NO. ST 102-275B

OD in 100th inches
Code to indicate iron powder mix
Indicates percent iron
Letter indicates different Ht.

Refer to page 4 for tolerances.

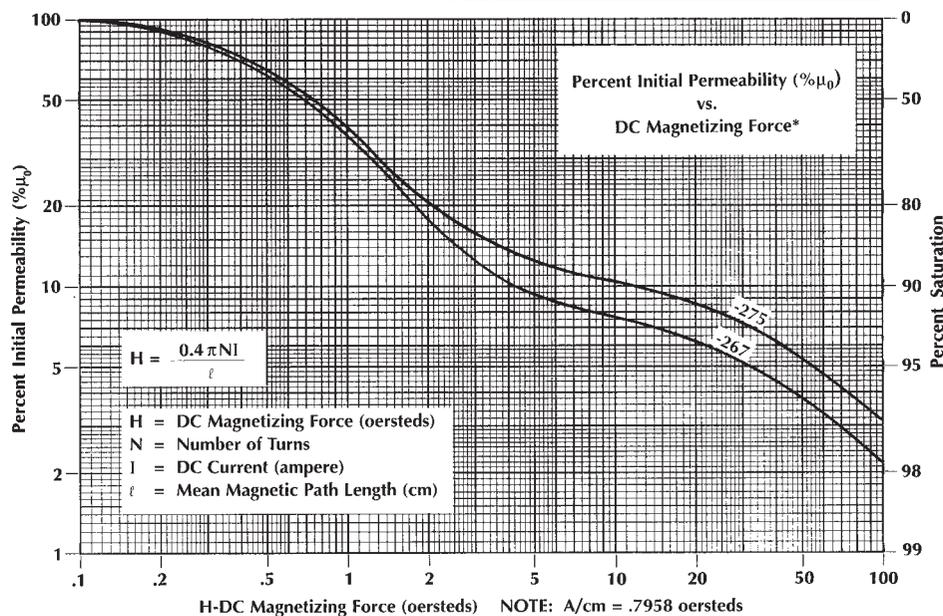
| MATERIAL COMPOSITION | | |
|----------------------|--|--|
| | Ferrite Core ($\mu \approx 2300$) | Micrometals -52 Material ($\mu = 75$) |
| -267 | 33% | 67% |
| -275 | 25% | 75% |

Typical Applications: These Ferrite/Iron Powder Composite Cores produce a large change in inductance with DC bias such that 10 to 20 times more inductance will exist at low current than at maximum current. This characteristic is particularly useful for producing DC output chokes for switching power supplies that must maintain continuous operation to very low loads as well as some EMI Filter applications. See page 51 for DC energy storage curves. Micrometals "ST" cores are composed of a ferrite and iron powder core and may contain a small gap or parting line between materials.

| MICROMETALS Part No. | Al nH/N ² | MAGNETIC DIMENSIONS | | | | | |
|-------------------------|-------------------------|---------------------|-------------|-------------|--------------|-----------------------|----------------------|
| | | OD in/mm | ID in/mm | Ht in/mm | ℓ cm | A* cm ² | V cm ³ |
| ST50-267 | 450 | .510/13.0 | .290/7.37 | .280/7.11 | 3.19 | .189 | .603 |
| ST50-275B | 475 | .510/13.0 | .290/7.37 | .365/9.27 | 3.19 | .246 | .786 |
| ST83-267 | 625 | .835/21.2 | .510/13.0 | .400/10.2 | 5.37 | .398 | 2.14 |
| ST83-275B | 650 | .835/21.2 | .510/13.0 | .525/13.3 | 5.37 | .523 | 2.81 |
| ST102-267 | 800 | 1.025/26.0 | .600/15.2 | .475/12.1 | 6.48 | .619 | 4.01 |
| ST102-275B | 825 | 1.025/26.0 | .600/15.2 | .625/15.9 | 6.48 | .814 | 5.28 |
| ST150-267 | 1250 | 1.520/38.6 | .835/21.2 | .625/15.9 | 9.40 | 1.31 | 12.3 |
| ST150-275B | 1300 | 1.520/38.6 | .835/21.2 | .825/21.0 | 9.40 | 1.73 | 16.3 |
| ST200-267 | 1275 | 2.010/51.1 | 1.240/31.5 | .775/19.7 | 13.0 | 1.83 | 23.7 |
| ST200-275B | 1325 | 2.010/51.1 | 1.240/31.5 | 1.025/26.0 | 13.0 | 2.42 | 31.4 |

| CURVE FIT FORMULA | | | | | | | | | | | |
|--|-----|------|-------|------|------|------------------------|-------|------------------------|-----------------------|-----------------------|------------------------|
| $\% \mu = \frac{(a+cH+eH^2+gH^3+iH^4+kH^5)}{(1+bH+dH^2+fH^3+hH^4+jH^5)}$ <p>Where: %μ = Percentage (ie:90% =90) H = DC Magnetizing Force (oersteds)</p> | | | | | | | | | | | |
| Material | a | b | c | d | e | f | g | h | i | j | k |
| -267 | 115 | 1.11 | -17.6 | .844 | 10.7 | 2.74x10 ⁻⁴ | -.359 | -7.17x10 ⁻⁴ | 3.33x10 ⁻³ | 7.50x10 ⁻⁶ | -5.30x10 ⁻⁶ |
| -275 | 113 | .999 | -9.80 | .924 | 13.1 | -2.19x10 ⁻² | -.580 | -4.31x10 ⁻⁴ | 5.54x10 ⁻³ | 3.32x10 ⁻⁶ | -1.75x10 ⁻⁵ |

*Combined A



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MICROMETALS

E CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

TYPICAL PART NO. **E 168 - 26 A / G 015**

"A" dimension in 100th inches
 Micrometals Mix No. _____
 Letter Indicates Alternate "C" dimension
 Indicates Center-leg gap per half in .001 inches

E CORES ORDERED PER HALF

For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

Refer to page 4 for tolerances.
 *E-Core sizes from E49 to E100 do not receive color stripes

MICROMETALS

MAGNETIC DIMENSIONS

| Part No. (Bobbin) | A _L nH/N ² (Ref. Size) | A in/mm | B in/mm | C in/mm | D in/mm | F in/mm | G in/mm | ℓ cm | A cm ² | V cm ³ | W cm ² |
|-------------------------------|--|------------|------------|------------|------------|------------|------------|---------|----------------------|----------------------|----------------------|
| E49-8 | 20.5 | .500/12.7 | .437/11.1 | .125/3.18 | .312/7.93 | .125/3.18 | .375/9.53 | 2.86 | .101 | .288 | .252 |
| E49-18 | 29.0 | | | | | | | | | | |
| E49-26 | 38.0 | | | | | | | | | | |
| E49-52 (PB49) | 38.0 (US LAM: EE-28-29) | | | | | | | | | | |
| E50-26 | 48.0 | .505/12.8 | .504/12.8 | .148/3.76 | .354/8.99 | .149/3.78 | .354/8.99 | 3.08 | .143 | .441 | .234 |
| E50-52 (No Bobbin Offered) | 47.0 (DIN:13/4) | | | | | | | | | | |
| E65-8 | 30.5 | .645/16.4 | .640/16.3 | .182/4.62 | .471/12.0 | .182/4.62 | .445/11.3 | 3.98 | .224 | .861 | .399 |
| E65-26 | 58.0 | | | | | | | | | | |
| E65-40 | 51.0 | | | | | | | | | | |
| E65-52 (No Bobbin Offered) | 56.0 (DIN: 16/5) | | | | | | | | | | |
| E75-2 | 14.5 | .750/19.1 | .635/16.1 | .187/4.75 | .455/11.6 | .187/4.75 | .562/14.3 | 4.20 | .226 | .936 | .551 |
| E75-8 | 33.5 | | | | | | | | | | |
| E75-26 | 64.0 | | | | | | | | | | |
| E75-40 | 55.0 | | | | | | | | | | |
| E75-52 (PB75) | 59.0 (US LAM: EI-187) | | | | | | | | | | |
| E80-8 | 38.0 | 0.795/20.2 | .784/19.9 | .230/5.84 | .550/14.0 | .230/5.84 | .575/14.6 | 4.84 | .333 | 1.63 | .613 |
| E80-26 | 73.0 | | | | | | | | | | |
| E80-52 (PB80) | 73.0 (DIN: 20/6) | | | | | | | | | | |
| E99-8 | 51.0 | 1.000/25.4 | 1.000/25.4 | .287/7.29 | .690/17.5 | .287/7.29 | .695/17.7 | 6.08 | .548 | 3.38 | .908 |
| E99-26 | 96.0 | | | | | | | | | | |
| E99-52 (PB99) | 96.0 (DIN: 25/7) | | | | | | | | | | |
| E100-2 | 21.0 | 1.000/25.4 | .750/19.1 | .250/6.35 | .500/12.7 | .250/6.35 | .750/19.1 | 5.08 | .403 | 2.05 | .806 |
| E100-8 | 48.0 | | | | | | | | | | |
| E100-18 | 65.0 | | | | | | | | | | |
| E100-26 | 92.0 | | | | | | | | | | |
| E100-40 | 81.0 | | | | | | | | | | |
| E100-52 (PB100E) | 85.0 (US LAM: EE-24-25) | | | | | | | | | | |
| E118-26 | 90.0 | 1.185/30.1 | 1.185/30.1 | .278/7.06 | .782/19.9 | .278/7.06 | .782/19.9 | 7.14 | .498 | 4.60 | 1.27 |
| E118-40 | 80.0 | | | | | | | | | | |
| E118-52 (PB118) | 90.0 (DIN: 30/7) | | | | | | | | | | |

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MICROMETALS

E CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

TYPICAL PART NO. **E 168 - 26 A / G 015**

"A" dimension in 100th inches
 Micrometals Mix No. _____
 Letter Indicates Alternate "C" dimension
 Indicates Center-leg gap per half in .001 inches

E CORES ORDERED PER HALF

For information on -60, -61, -63, -66, -70 and -M125
 see Micrometals 200C Series Catalog.

Refer to page 4 for tolerances.

| MICROMETALS Part No. (Bobbin) | Al nH/N ² (Ref. Size) | MAGNETIC DIMENSIONS | | | | | | | | | |
|--|--|---|------------|------------|------------|------------|------------|---------|----------------------|----------------------|----------------------|
| | | A in/mm | B in/mm | C in/mm | D in/mm | F in/mm | G in/mm | l cm | A cm ² | V cm ³ | W cm ² |
| E125-26 E125-40 (No Bobbin Available) | 134.0 113.0 (US LAM: EE-27-38) | 1.255/31.8 | 1.215/30.8 | .378/9.60 | .835/21.2 | .378/9.60 | .885/22.5 | 7.45 | .922 | 6.82 | 1.37 |
| E137-2 E137-8 E137-18 E137-26 E137-40 E137-52 (PB137) | 32.0 67.0 100.0 134.0 113.0 131.0 (US LAM: EI-375) | 1.375/34.9 | 1.145/29.1 | .375/9.53 | .770/19.6 | .375/9.53 | 1.000/25.4 | 7.40 | .907 | 6.72 | 1.55 |
| E145-18 E145-26 E145-52 (No Bobbin Available) | 112.0 146.0 146.0 | 1.455/37.0 | 1.370/34.8 | .425/10.8 | .950/24.1 | .425/10.8 | 1.035/26.3 | 8.50 | 1.17 | 9.89 | 1.84 |
| E162-8 E162-18 E162-26 E162-40 E162-52 (PB162) | 105.0 149.0 210.0 175.0 199.0 (US LAM: EI-21) | 1.625/41.3 | 1.342/34.1 | .500/12.7 | .842/21.4 | .500/12.7 | 1.125/28.6 | 8.41 | 1.61 | 13.6 | 1.70 |
| E168-2 E168-8 E168-18 E168-26 E168-40 E168-52 (PB168) | 43.5 97.0 135.0 195.0 163.0 179.0 (DIN: 42/15) | 1.685/42.8 | 1.660/42.2 | .590/15.0 | 1.210/30.7 | .475/12.0 | 1.210/30.7 | 10.4 | 1.81 | 18.5 | 2.87 |
| E168-26/G015 E168-40/G015 E168-52/G015 | 125.0 114.0 125.0 | Gapped E168 with center gap .030in./.76mm per set | | | | | | | | | |
| E168-2A E168-8A E168-18A E168-26A E168-40A E168-52A (PB168A) | 55.0 116.0 170.0 232.0 196.0 230.0 (DIN: 42/20) | 1.685/42.8 | 1.660/42.2 | .787/20.0 | 1.210/30.7 | .475/12.0 | 1.210/30.7 | 10.4 | 2.41 | 24.6 | 2.87 |
| E168-52A/G015 | 161.0 | Gapped E168A with center gap .030in./.76mm per set. | | | | | | | | | |

MICROMETALS
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E CORES

COLOR CODE

- 2 Red/Clear
- 8 Yellow/Red
- 14 Black/Red
- 18 Green/Red
- 19 Red/Green
- 26 Yellow/White
- 30 Green/Gray
- 34 Gray/Blue
- 35 Yellow/Gray
- 40 Green/Yellow
- 45 Black/Black
- 52 Green/Blue

TYPICAL PART NO. **E 168 - 26 A / G 015**

"A" dimension in 100th inches
 Micrometals Mix No. _____
 Letter Indicates Alternate "C" dimension
 Indicates Center-leg gap per half in .001 inches

E CORES ORDERED PER HALF

For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.

Refer to page 4 for tolerances.

| MICROMETALS Part No. (Bobbin) | Al nH/N ² (Ref. Size) | MAGNETIC DIMENSIONS | | | | | | | | | |
|--|--|---------------------|------------|------------|------------|------------|------------|---------|----------------------|----------------------|----------------------|
| | | A in/mm | B in/mm | C in/mm | D in/mm | F in/mm | G in/mm | l cm | A cm ² | V cm ³ | W cm ² |
| E187-8 | 144.0 | 1.865/47.4 | 1.552/39.4 | .620/15.7 | .952/24.2 | .620/15.7 | 1.250/31.8 | 9.53 | 2.48 | 23.3 | 1.93 |
| E187-18 | 213.0 | | | | | | | | | | |
| E187-26 | 265.0 | | | | | | | | | | |
| E187-40 | 240.0 | | | | | | | | | | |
| E187-52 (PB187) | 265.0 (US LAM: EI-625) | | | | | | | | | | |
| E220-2 | 69.0 | 2.210/56.1 | 2.180/55.4 | .820/20.8 | 1.510/38.3 | .680/17.3 | 1.520/38.6 | 13.2 | 3.60 | 47.7 | 4.09 |
| E220-8 | 143.0 | | | | | | | | | | |
| E220-18 | 196.0 | | | | | | | | | | |
| E220-26 | 275.0 | | | | | | | | | | |
| E220-30 | 107.0 | | | | | | | | | | |
| E220-34 | 136.0 | | | | | | | | | | |
| E220-40 | 240.0 | | | | | | | | | | |
| E220-52 (PB220) | 262.0 (DIN: 55/21) | | | | | | | | | | |
| E220-26/G020 | 183.0 | | | | | | | | | | |
| E220-40/G020 | 168.0 | | | | | | | | | | |
| E220-52/G020 | 183.0 | | | | | | | | | | |
| Gapped E220 with center gap .040 in./1.02mm per set | | | | | | | | | | | |
| E225-2 | 76.0 | 2.240/56.9 | 1.875/47.6 | .745/18.9 | 1.140/29.0 | .745/18.9 | 1.500/38.1 | 11.5 | 3.58 | 40.8 | 2.78 |
| E225-8 | 173.0 | | | | | | | | | | |
| E225-18 | 240.0 | | | | | | | | | | |
| E225-26 | 325.0 | | | | | | | | | | |
| E225-40 | 290.0 | | | | | | | | | | |
| E225-52 (PB225) | 325.0 (US LAM: EI-75) | | | | | | | | | | |
| E305-2 | 75.0 | 3.051/77.5 | 3.051/77.5 | .933/23.7 | 2.118/53.8 | .933/23.7 | 2.118/53.8 | 18.5 | 5.62 | 104 | 8.10 |
| E305-8 | 156.0 | | | | | | | | | | |
| E305-18 | 222.0 | | | | | | | | | | |
| E305-26 | 287.0 | | | | | | | | | | |
| E305-30 | 124.0 | | | | | | | | | | |
| E305-34 | 150.0 | | | | | | | | | | |
| E305-40 | 255.0 | | | | | | | | | | |
| E305-52 (PB305 or PB305/V0) | 287.0 | | | | | | | | | | |
| E305-26/G050 | 165.0 | | | | | | | | | | |
| E305-52/G050 | 165.0 | | | | | | | | | | |
| Gapped E305 with center gap .100 in./2.54 mm per set | | | | | | | | | | | |
| E305-8A | 208.0 | 3.051/77.5 | 3.051/77.5 | 1.244/31.6 | 2.118/53.8 | .933/23.7 | 2.118/53.8 | 18.5 | 7.49 | 139 | 8.10 |
| E305-18A | 280.0 | | | | | | | | | | |
| E305-26A | 382.0 | | | | | | | | | | |
| E305-30A | 165.0 | | | | | | | | | | |
| E305-40A | 339.0 | | | | | | | | | | |
| E305-52A (PB305A) | 382.0 | | | | | | | | | | |

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MICROMETALS

E CORES

| | | |
|--|--|---|
| <p>COLOR CODE</p> <ul style="list-style-type: none"> -2 Red/Clear -8 Yellow/Red -14 Black/Red -18 Green/Red -19 Red/Green -26 Yellow/White -30 Green/Gray -34 Gray/Blue -35 Yellow/Gray -40 Green/Yellow -45 Black/Black -52 Green/Blue | | <p style="text-align: right;">TYPICAL PART NO. E 168 - 26 A / G 015</p> <p>"A" dimension in 100th inches Micrometals Mix No. _____ Letter Indicates Alternate "C" dimension Indicates Center-leg gap per half in .001 inches</p> <p style="text-align: center;">E CORES ORDERED PER HALF</p> <p style="text-align: center;">For information on -60, -61, -63, -66, -70 and -M125 see Micrometals 200C Series Catalog.</p> |
|--|--|---|

Refer to page 4 for tolerances.

MICROMETALS

MAGNETIC DIMENSIONS

| Part No. (Bobbin) | Al nH/N ² (Ref. Size) | A in/mm | B in/mm | C in/mm | D in/mm | F in/mm | G in/mm | l cm | A cm ² | V cm ³ | W cm ² |
|-----------------------------|--|---|------------|------------|------------|------------|------------|---------|----------------------|----------------------|----------------------|
| E305-26A/G050 | 219.0 | 3.051/77.5 | 3.051/77.5 | 1.244/31.6 | 2.118/53.8 | .933/23.7 | 2.118/53.8 | 18.5 | 7.49 | 139 | 8.10 |
| E305-52A/G050 | 219.0 | Gapped E305A with center gap .100 in./2.54 mm per set | | | | | | | | | |
| E450-2 | 132.0 | 4.500/114 | 3.636/92.4 | 1.375/34.9 | 2.250/57.2 | 1.375/34.9 | 3.120/79.3 | 22.9 | 12.2 | 280 | 12.7 |
| E450-8 | 260.0 | | | | | | | | | | |
| E450-18 | 400.0 | | | | | | | | | | |
| E450-26 | 540.0 | | | | | | | | | | |
| E450-30 | 235.0 | | | | | | | | | | |
| E450-34 | 300.0 | | | | | | | | | | |
| E450-40 | 480.0 | | | | | | | | | | |
| E450-52 | 500.0 | | | | | | | | | | |
| (PB450/V0) | (US LAM: EI-30) | | | | | | | | | | |
| E450-8H | 140.0 | 4.500/114 | 3.636/92.4 | .688/17.5 | 2.250/57.2 | 1.375/34.9 | 3.120/79.3 | 22.9 | 6.1 | 140 | 12.7 |
| E450-18H | 200.0 | | | | | | | | | | |
| E450-52H | 270.0 | | | | | | | | | | |
| (PB450/V0 for double stack) | | | | | | | | | | | |
| E610-2 | 163.0 | 6.102/155 | 6.102/155 | 1.866/47.4 | 4.236/108 | 1.866/47.4 | 4.236/108 | 37.0 | 22.5 | 832 | 32.4 |
| E610-26 | 588.0 | | | | | | | | | | |
| E610-34 | 314.0 | | | | | | | | | | |

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MICROMETALS

BANDING, STRAPPING AND MOUNTING PRECAUTIONS

Iron powder as a core material is susceptible to performance changes when wrapped with a ferrous material. Iron powder cores are manufactured with a distributed air gap and occasionally a center leg gap. When a ferrous material is added to this type of magnetic structure the core is essentially "shorted out" decreasing the overall "Q" of the coil.

This decrease in "Q" indicates an increase in core loss which will result in a higher than expected operating temperature. This effect will be more significant with the lower permeability materials.

Micrometals suggests using the following nonferrous materials to mount and band iron powder cores:

1. Phosphor bronze or nonmagnetic stainless steel banding material
2. Brass hardware
3. Various electrical tapes
4. Cable Tie wraps
5. Filled epoxy or filled super glue

EH/EM CORES

TYPICAL PART NO. **E 168 - 26 A / G 015**

"A" dimension in 100th inches
 Micrometals Mix No.
 Letter Indicates Alternate "C" dimension
 Indicates Center-leg gap per half in .001 inches

EH AND EM CORES ORDERED PER HALF

Refer to page 4 for tolerances.
 Refer to page 16 and 17 for appropriate "F" Dimensions.

| MICROMETALS Part No. | A _L Value nH/N ² | MAGNETIC DIMENSIONS | | | | | | | | | |
|---|--|---------------------|------------|------------|------------|------------|------------|------------|---------|----------------------|----------------------|
| | | A in/mm | B in/mm | C in/mm | D in/mm | E in/mm | G in/mm | H in/mm | ℓ cm | A cm ² | V cm ³ |
| EH220-8 | 114.0 | 2.210/56.1 | 2.180/55.4 | 0.820/20.8 | 1.510/38.3 | 1.700/43.2 | 1.520/38.6 | 0.780/19.8 | 13.3 | 2.19 | 29.1 |
| EH220-40/13 | 191.0 | | | | | | | | | | |
| EH220-40/G070/13 | 76.4 | 2.210/56.1 | 2.180/55.4 | 0.820/20.8 | 1.510/38.3 | 1.700/43.2 | 1.520/38.6 | 0.780/19.8 | 13.3 | 2.19 | 29.1 |
| Gapped EH220 with center gap .140 in./3.56mm per set. | | | | | | | | | | | |

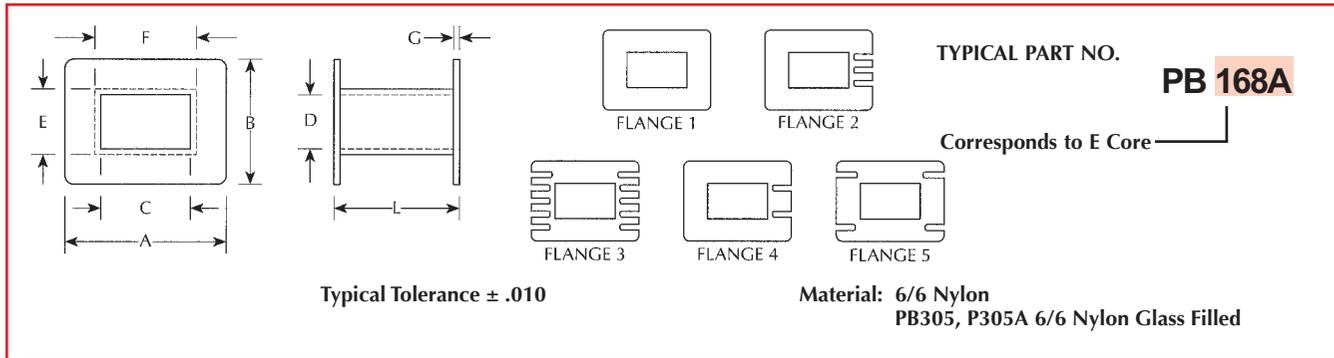
| MICROMETALS Part No. | A _L Value nH/N ² | MAGNETIC DIMENSIONS | | | | | | | | | |
|---|--|---------------------|------------|------------|------------|------------|------------|---------|----------------------|----------------------|--|
| | | A in/mm | B in/mm | C in/mm | D in/mm | G in/mm | H in/mm | ℓ cm | A cm ² | V cm ³ | |
| EM102-8 | 40.1 | 1.000/25.4 | 1.000/25.4 | 0.500/12.7 | 0.800/20.3 | 0.800/20.3 | 0.350/8.89 | 6.28 | 0.637 | 4.00 | |
| EM102-52 | 84.8 | | | | | | | | | | |
| EM126-8 | 48.7 | 1.250/31.8 | 1.250/31.8 | 0.570/14.5 | 0.916/23.3 | 1.010/25.7 | 0.438/11.1 | 7.46 | 0.960 | 7.43 | |
| EM126-52 | 119.0 | | | | | | | | | | |
| EM126-52/G040 | 49.9 | | | | | | | | | | |
| Gapped EM126 with center gap .080 in./2.03mm per set. | | | | | | | | | | | |
| EM145-26 | 125.0 | 1.455/37.0 | 1.370/34.8 | 0.425/10.8 | 0.950/24.1 | 1.035/26.3 | 0.425/10.8 | 8.50 | 0.915 | 9.28 | |
| EM145-52 | 125.0 | | | | | | | | | | |
| EM150-8 | 63.7 | 1.500/38.1 | 1.500/38.1 | 0.750/19.1 | 1.200/30.5 | 1.190/30.2 | 0.536/13.6 | 9.46 | 1.45 | 13.7 | |
| EM150-52 | 127.0 | | | | | | | | | | |
| EM169-8 | 82.3 | 1.685/42.8 | 1.654/42.0 | 0.766/19.5 | 1.204/30.6 | 1.360/34.5 | 0.580/14.7 | 9.90 | 1.79 | 17.7 | |
| EM169-40/13 | 148.0 | | | | | | | | | | |
| EM169-52 | 151.0 | | | | | | | | | | |
| EM169-40/G052/13 | 61.3 | | | | | | | | | | |
| Gapped EM169 with center gap .104 in./2.64mm per set. | | | | | | | | | | | |
| EM193-8 | 77.0 | 1.930/49.0 | 1.930/49.0 | 0.877/22.3 | 1.530/38.9 | 1.530/38.9 | 0.676/17.2 | 12.1 | 2.28 | 27.5 | |
| EM193-52 | 168.0 | | | | | | | | | | |
| EM193-40/G060/13 | 70.6 | | | | | | | | | | |
| Gapped EM193 with center gap .120 in./3.05mm per set. | | | | | | | | | | | |
| EM220-26* | 230.0 | 2.210/56.1 | 2.180/55.4 | .820/20.8 | 1.510/38.3 | 1.520/38.6 | 0.780/19.8 | 13.2 | 2.90 | 45.0 | |
| EM220-40 | 196.0 | | | | | | | | | | |
| EM220-26/G020 | 173.0 | | | | | | | | | | |
| EM220-40/G020 | 143.0 | | | | | | | | | | |
| Gapped EM220 with center gap .040 in./1.02mm per set. | | | | | | | | | | | |
| EM221-8 | 89.9 | 2.210/56.1 | 2.200/55.9 | 1.070/27.2 | 1.760/44.7 | 1.760/44.7 | 0.850/21.6 | 13.7 | 3.22 | 44.0 | |
| EM221-40/13 | 188.0 | | | | | | | | | | |
| EM221-52 | 228.0 | | | | | | | | | | |

* Center post not completely round on EM220 series.

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MICROMETALS

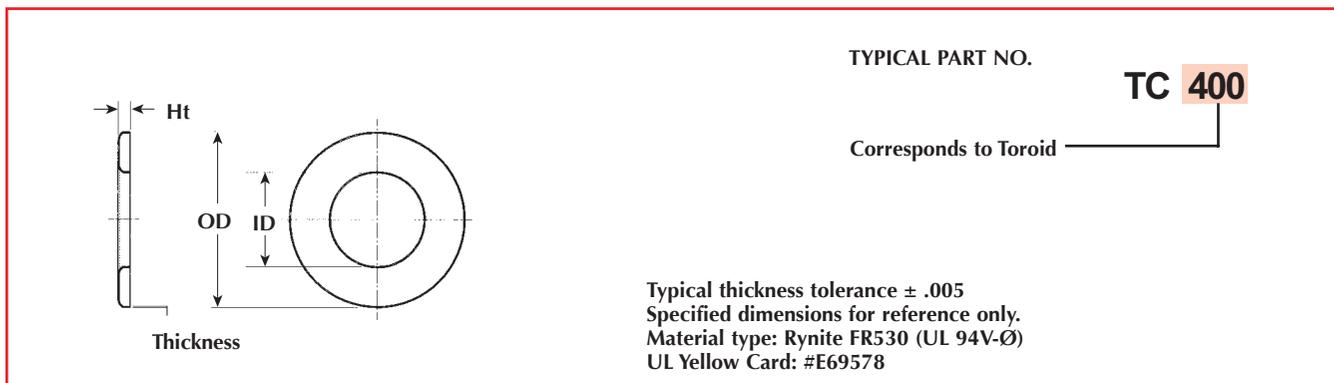
E CORE BOBBINS



Bobbin Notes: All bobbins are composed of 6/6 Nylon material except PB305, PB305A and any bobbin with the suffix “/V0”. The PB305 and PB305A are composed of 6/6 Nylon Glass Filled. The “/V0” indicates a material that is rated for UL 94 V0 flame class. Micrometals also offers bobbins for the following metric and custom E-core sizes for sample and small quantity orders; E80, E99. Their part numbers are, respectively, PB80, and PB99.

| MICROMETALS Part No. | A in/mm | B in/mm | C in/mm | D in/mm | L in/mm | E in/mm | F in/mm | G in/mm | Flange No. |
|----------------------|------------|------------|------------|------------|------------|------------|------------|-----------|------------|
| PB49 | .360/9.14 | .360/9.14 | .130/3.30 | .130/3.30 | .307/7.80 | .160/4.06 | .160/4.06 | .020/.508 | 1 |
| PB75 | .535/13.6 | .535/13.6 | .205/5.21 | .205/5.21 | .420/10.7 | .250/6.35 | .250/6.35 | .025/.635 | 1 |
| PB100E | .740/18.8 | .740/18.8 | .265/6.73 | .265/6.73 | .475/12.1 | .305/7.75 | .305/7.75 | .035/.889 | 1 |
| PB137 | .865/22.0 | .865/22.0 | .385/9.78 | .385/9.78 | .680/17.3 | .445/11.3 | .445/11.3 | .032/.813 | 1 |
| PB162 | 1.100/27.9 | 1.100/27.9 | .510/13.0 | .510/13.0 | .796/20.2 | .575/14.6 | .575/14.6 | .032/.813 | 1 |
| PB168 | 1.370/34.8 | 1.165/29.9 | .640/16.3 | .490/12.4 | 1.150/29.2 | .570/14.5 | .720/18.3 | .060/1.52 | 2 |
| PB168A | 1.465/37.2 | 1.157/29.4 | .799/20.3 | .492/12.5 | 1.142/29.0 | .570/14.5 | .880/22.4 | .060/1.52 | 3 |
| PB187 | 1.215/30.9 | 1.225/31.1 | .645/16.4 | .645/16.4 | .925/23.5 | .715/18.2 | .715/18.2 | .025/.635 | 4 |
| PB220 | 1.640/41.7 | 1.425/36.2 | .840/21.3 | .680/17.3 | 1.440/36.6 | .760/19.3 | .920/23.4 | .060/1.52 | 2 |
| PB225 | 1.480/37.6 | 1.480/37.6 | .765/19.4 | .765/19.4 | 1.115/28.3 | .845/21.5 | .845/21.5 | .035/.889 | 5 |
| PB305 | 2.020/51.3 | 2.020/51.3 | .965/24.5 | .965/24.5 | 2.040/51.8 | 1.055/26.8 | 1.055/26.8 | .060/1.52 | 2 |
| PB305/V0 | 2.020/51.3 | 2.020/51.3 | .965/24.5 | .965/24.5 | 2.040/51.8 | 1.055/26.8 | 1.055/26.8 | .060/1.52 | 2 |
| PB305A | 2.330/59.2 | 2.020/51.3 | 1.275/32.4 | .965/24.5 | 2.040/51.8 | 1.055/26.8 | 1.365/34.7 | .060/1.52 | 2 |
| PB450/V0 | 3.050/77.5 | 3.050/77.5 | 1.412/35.9 | 1.412/35.9 | 2.200/55.9 | 1.544/39.2 | 1.544/39.2 | .066/1.68 | 1 |

TOROIDAL CORE CAPS



Typical Applications: The toroidal core caps can be used as an alternate to the standard insulating coating when winding cores with very heavy gauge wire or when a greater dielectric strength is required. Core caps will fit either coated or uncoated cores. To specify a core that is uncoated add the suffix “/18” to standard part numbers. (Example: T400-26 is a standard part which includes coating, T400-26/18 specifies a standard part without coating.)

| MICROMETALS PART NO. | OD in/mm | ID in/mm | Ht in/mm | THICKNESS in/mm |
|----------------------|-------------|------------|-----------|-----------------|
| TC400 | 4.030/102.4 | 2.235/56.8 | .250/6.35 | .030/.762 |
| TC520 | 5.250/133.4 | 3.062/77.8 | .250/6.35 | .030/.762 |

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MICROMETALS

BUS BAR CORES

COLOR CODE

- 8 Red
- 26 Yellow
- 52 Green

TYPICAL PART NO. **HS 300 - 26 A /**

Code To Indicate Max. Current
 Micrometals Mix No.
 Letter Indicates Alternate Length
 Code Area For Other Characteristics

Refer to page 4 for tolerances. HS CORES ORDERED PER HALF

| MICROMETALS Part No. | Al* nH/N ² | MAGNETIC DIMENSIONS | | | | | | | |
|---|--------------------------|---------------------|------------|---|------------|------------|---------|------------------------------|------------------------------|
| | | A in/mm | B in/mm | L in/mm | D in/mm | E in/mm | ℓ cm | A cm ² | V cm ³ |
| HS300-8 HS300-26 HS300-52 | 68 147 147 | 1.020/25.9 | .650/16.5 | .500/12.7 | .520/13.2 | .140/3.56 | 5.92 | .806 | 4.61 |
| HS300-8A HS300-26A HS300-52A | 83 179 179 | 1.020/25.9 | .650/16.5 | .625/15.9 | .520/13.2 | .140/3.56 | 5.92 | 1.01 | 5.77 |
| HS300-8B HS300-26B HS300-52B | 95 208 208 | 1.020/25.9 | .650/16.5 | .750/19.1 | .520/13.2 | .140/3.56 | 5.92 | 1.21 | 6.92 |
| HS300-8C HS300-26C HS300-52C | 107 232 232 | 1.020/25.9 | .650/16.5 | .875/22.2 | .520/13.2 | .140/3.56 | 5.92 | 1.41 | 8.06 |
| HS400-26 HS400-26A HS400-26B HS400-26C | 221 286 335 371 | 1.500/38.1 | .960/24.4 | .750/19.1 1.000/25.4 1.250/31.8 1.500/38.1 | .765/19.4 | .205/5.21 | 8.71 | 1.78 2.37 2.96 3.56 | 15.1 20.1 25.2 30.2 |

*Based on 25 turn test winding

U CORES

COLOR CODE

- 8 Red
- 26 Yellow
- 52 Green

TYPICAL PART NO. **U 80 - 26 A /**

"A" dim to 1000th inches
 Micrometals Mix No.
 Letter Indicates Alternate "C" dim.
 Code Area For Other Characteristics

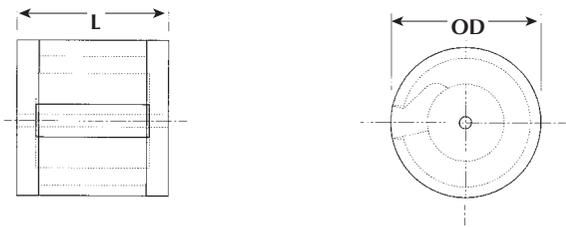
Refer to page 4 for tolerances. U CORES ORDERED PER HALF

| MICROMETALS Part No. | Al nH/N ² | MAGNETIC DIMENSIONS | | | | | | | | |
|-------------------------------------|------------------------------|---------------------|------------|------------|------------|------------|------------|---------|----------------------|----------------------|
| | | A in/mm | B in/mm | C in/mm | E in/mm | F in/mm | G in/mm | ℓ cm | A cm ² | V cm ³ |
| U61-26 | 71.0 | .610/15.5 | .900/22.9 | .250/6.35 | .510/13.0 | .195/4.95 | .210/5.33 | 5.66 | .315 | 1.81 |
| U80-8 U80-26 U80-40 U80-52 | 42.4 71.0 64.0 70.0 | .800/20.3 | 1.250/31.8 | .250/6.35 | .750/19.1 | .250/6.35 | .300/7.62 | 7.87 | .403 | 3.18 |
| U350-2 U350-40 | 59.0 235.5 | 3.500/88.9 | 5.750/146 | 1.000/25.4 | 3.250/82.6 | 1.000/25.4 | 1.500/38.1 | 35.6 | 6.45 | 250 |

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MICROMETALS

POT CORE ASSEMBLIES

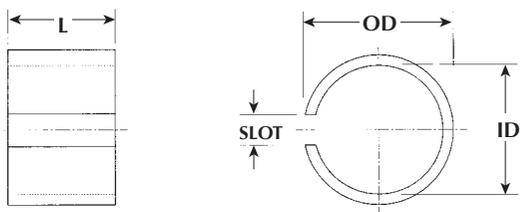


The Pot Core Assemblies provide a closed-path structure for high current designs where the round winding form and efficient packaging shape are beneficial. The geometry also provides the added flexibility of using lower permeability materials for the hollow core instead of gapping the structure.

Typical assemblies are illustrated. This configuration is not available assembled. Order 2 Disks, 1 Hollow Core and 1 sleeve per set.

| SLEEVE Part No. | DISC Part No. | HOLLOW CORE Part No. | AL nH/N ² | OD in/mm | L in/mm | Window cm ² | ℓ cm | A cm ² | V cm ³ |
|--------------------|------------------|-------------------------|-------------------------|-------------|------------|---------------------------|---------|----------------------|----------------------|
| S101-1002 | D101-1002 | H2526-1002 | 165.8* | 3.150/80.0 | 2.402/61.0 | 5.49 | 15.3 | 12.7 | 204 |
| S101-1040 | D101-1040 | H2526-1040 | 600* | | | | | | |

SLEEVE



TYPICAL PART NO.

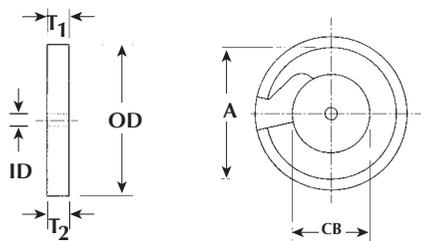
S 101-10 40

OD in 100th inches
Code area for other characteristics
Micrometals Mix No.

Typical Tolerance ± .050 inches

| SLEEVE Part No. | OD in/mm | ID in/mm | L in/mm | Slot in/mm |
|--------------------|-------------|-------------|------------|---------------|
| S101-1002 | 3.150/80.0 | 2.680/68.1 | 1.615/41.0 | .760/19.3 |
| S101-1040 | | | | |

DISC



TYPICAL PART NO.

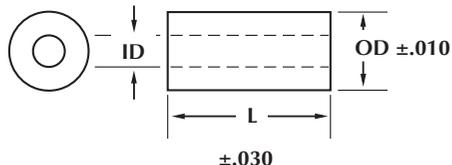
D 101-10 40

OD in 100th inches
Code area for other characteristics
Micrometals Mix No.

Typical Tolerance ± .030 inches

| DISC Part No. | OD in/mm | CB in/mm | ID in/mm | T ₁ in/mm | T ₂ in/mm | A in/mm |
|------------------|-------------|-------------|-------------|-------------------------|-------------------------|------------|
| D101-1002 | 3.150/80.0 | 1.614/41.0 | .250/6.35 | .394/10.0 | .374/9.50 | 2.675/67.9 |
| D101-1040 | | | | | | |

HOLLOW CORE



TYPICAL PART NO.

H 25 26 -10 40

OD in 16th inches
Length in 16th inches
Code area for other characteristics
Micrometals Mix No.

±.030

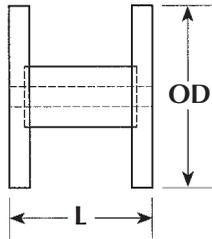
| HOLLOW CORE Part No. | OD in/mm | ID in/mm | L in/mm |
|-------------------------|-------------|-------------|------------|
| H2526-1002 | 1.600/40.6 | .250/6.35 | 1.615/41.0 |
| H2526-1040 | | | |

*AL value is approximate and is for indication only

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MICROMETALS

BOBBIN ASSEMBLIES



Various bobbins can be assembled from the Hollow Cores and Disks shown on the following page. These bobbin assemblies provide an alternative shape for high current choke applications which can tolerate some electro-magnetic radiation. This configuration can be especially effective for high power speaker crossover coils.

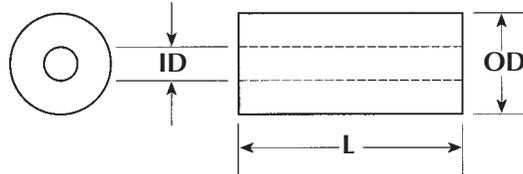
Typical assemblies are illustrated. This configuration is not available assembled. Order 2 Disks and one Hollow Core per set.

| DISC Part No. | HOLLOW Core Part No. | Al* nH/N2 | OD in/mm | L in/mm | WINDOW in/mm |
|-----------------|----------------------|-----------|------------|------------|--------------|
| D45-1040 | H811-1140 | 85 | 1.420/36.1 | 937/23.8 | 1.84 |
| D45-1040 | H817-1140 | 60 | 1.420/36.1 | 1.312/33.3 | 2.95 |
| D59-1040 | H1015-1040 | 100 | 1.845/46.9 | 1.250/31.8 | 3.43 |
| D59-1040 | H1021-1040 | 80 | 1.845/46.9 | 1.625/41.3 | 4.90 |
| D80-2040 | H1217-1040 | 130 | 2.500/63.5 | 1.375/34.9 | 5.66 |
| D80-2040 | H1225-1040 | 95 | 2.500/63.5 | 1.875/47.6 | 8.49 |

* Al value listed is approximate and is for indication only

HOLLOW CORES

Core outside and inside diameters listed are standard with variations in length possible upon request.



Refer to page 4 for tolerances.

TYPICAL PART NO.

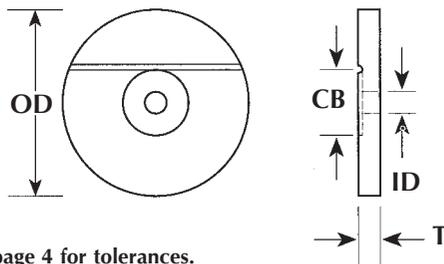
H 10 20-10 40

OD in 16th inches
Length in 16th inches
Code area for other characteristics
Micrometals Mix No.

Note: For information on Mix 1, 3, 4, 6, 7, 10, 12, 15, 17, 42, and 0 see **Micrometals RF Catalog**

| MICROMETALS Part No. | OD in/mm | ID in/mm | Length in/mm |
|----------------------|------------|-----------|--------------|
| H512-1026 | .312/7.95 | .137/3.48 | .750/19.1 |
| H811-1140 | .500/12.7 | .172/4.37 | .688/17.5 |
| H817-1140 | .500/12.7 | .172/4.37 | 1.064/27.0 |
| H822-1140 | .500/12.7 | .172/4.34 | 1.375/34.9 |
| H1014-1040 | .625/15.9 | .219/5.56 | .900/22.9 |
| H1015-1040 | .625/15.9 | .219/5.56 | .955/24.3 |
| H1020-1040 | .625/15.9 | .219/5.56 | 1.250/31.8 |
| H1021-1040 | .625/15.9 | .219/5.56 | 1.330/33.8 |
| H1217-1040 | .750/19.1 | .260/6.60 | 1.080/27.4 |
| H1225-1040 | .750/19.1 | .260/6.60 | 1.580/40.1 |
| H1616-1040 | 1.000/25.4 | .250/6.35 | 1.000/25.4 |

DISCS



Refer to page 4 for tolerances.

TYPICAL PART NO.

D 59-10 40

OD in 32nd inches
Code area for other characteristics
Micrometals Mix No.

Variations in T are available upon request.

Variations in CB possible with a modest tooling charge.

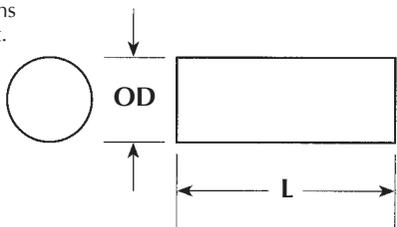
| MICROMETALS Part No. | OD in/mm | CB in/mm | ID in/mm | T in/mm |
|----------------------|------------|-----------|-----------|-----------|
| D45-1040 | 1.420/36.1 | .500/12.7 | .172/4.37 | .156/3.96 |
| D59-1040 | 1.845/46.9 | .635/16.1 | .188/4.78 | .187/4.75 |
| D80-2040 | 2.500/63.5 | .755/19.2 | .255/6.48 | .187/4.75 |

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MICROMETALS

PLAIN CORES

Core diameters are standard with variations from listed core lengths possible upon request.



TYPICAL PART NO.

P 16 32 -1 40

OD in 64th inches
Length in 32nd inches
Code area for other characteristics
Micrometals Mix No.

Note: For information on Mix 1, 3, 4, 6, 7, 10, 12, 15, 17, 42, and 0 see **Micrometals RF Catalog**

| MICROMETALS Part No. | A_L^* nH/N ² | OD in/mm | Length in/mm |
|----------------------|---------------------------|------------|--------------|
| P816-340 | 8.0 | .134/3.40 | .500/12.7 |
| P1224-140 | 12.5 | .190/4.83 | .750/19.1 |
| P1624-140 | 16.0 | .250/6.35 | .750/19.1 |
| P1632-140 | 16.0 | .250/6.35 | 1.000/25.4 |
| P1640-240 | 15.0 | .255/6.48 | 1.250/31.8 |
| P2032-240 | 20.0 | .313/7.95 | 1.000/25.4 |
| P2040-240 | 20.0 | .313/7.95 | 1.250/31.8 |
| P2432-240 | 25.5 | .375/9.53 | 1.000/25.4 |
| P2440-240 | 26.5 | .375/9.53 | 1.250/31.8 |
| P2448-240 | 25.0 | .375/9.53 | 1.500/38.1 |
| P2456-240 | 22.5 | .375/9.53 | 1.750/44.5 |
| P3240-140 | 34.5 | .500/12.7 | 1.250/31.8 |
| P3248-140 | 33.0 | .500/12.7 | 1.500/38.1 |
| P3256-140 | 32.0 | .500/12.7 | 1.750/44.5 |
| P3264-140 | 31.0 | .500/12.7 | 2.000/50.8 |
| P4040-140 | 37.5 | .625/15.9 | 1.250/31.8 |
| P4048-140 | 41.5 | .625/15.9 | 1.500/38.1 |
| P4876-140 | 49.5 | .750/19.1 | 2.375/60.3 |
| P6464-140 | 80.0 | 1.000/25.4 | 2.000/50.8 |

* A_L is approximate and for reference only

CYLINDRICAL CORE APPLICATIONS

The inductance and required number of turns for cylindrical shapes such as plain and hollow cores can be closely approximated from the following equations:

SINGLE-LAYER COIL

$$L = \frac{\mu_{eff} (rN)^2}{9r + 10\ell}$$

$$N = \frac{1}{r} \left[\frac{L(9r + 10\ell)}{\mu_{eff}} \right]^{1/2}$$

MULTI-LAYER COIL

$$L = \frac{(0.8)(\mu_{eff})(rN)^2}{6r + 9\ell + 10b}$$

$$N = \frac{1}{r} \left[\frac{L(6r + 9\ell + 10b)}{(0.8)(\mu_{eff})} \right]^{1/2}$$

WHERE:

L = Inductance

μ_{eff} = Effective permeability of core (See graph below)

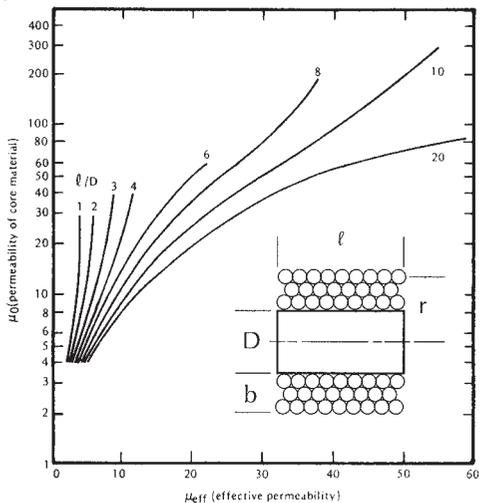
N = Number of turns

r = Radius of coil (inches)

D = Diameter of core (inches)

ℓ = Length of coil/core (inches)

b = Coil build



The family of curves to the left shows how the effective permeability (μ_{eff}) of a wound cylindrical core is a function of the core's wound length to diameter ratio (ℓ/D) as well as the initial material permeability (μ_{eff}).

These curves indicate that in many cases variations in the length/diameter ratio will more significantly affect the effective permeability than increases in permeability of the core material.

This group of curves was calculated using a cylindrical core with a single layer winding closely wound over 95% of its length. It is also possible to use as a fair approximation of the effective permeability for multi-layer windings.

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MICROMETALS

MAGNETIC CHARACTERISTICS

INTRODUCTION TO MAGNETIC CHARACTERISTICS

General Information: The magnetic characteristics shown on pages 26-36 result from testing toroidal cores. The magnetization curves on pages 26 and 27 have a typical tolerance of +20%, -10%. Other configurations such as E Cores and U Cores will produce slightly different results due to the effects of leakage associated with the geometry.

These characteristics were measured at room temperature. The temperature coefficient of initial permeability for each material is listed on page 3. The temperature coefficient of percent permeability versus both DC magnetizing force and peak AC flux density ranges from -100 to -400 ppm/C°. The combination of these coefficients will generally result in an increase in inductance with increasing temperature even under biased conditions.

The percent change in permeability is directly proportional to the percent change in A_L value. The cores are manufactured to the A_L value rather than to the referenced permeability.

Since iron powder cores are normally used in inductor applications the magnetization curves provided on page 26 and 27 are in relation to permeability. B-H curves are shown below.

DC Magnetization: The curves at the bottom of page 26 illustrate the effect of DC Magnetizing force on percent initial permeability for the materials shown. As the level of DC magnetizing force increases, the materials gradually experience a reduction in permeability. This "soft" saturation characteristic results from the distributed air-gap in the iron powder core materials.

The formula in the body of the graph is used to calculate

the DC Magnetizing Force in oersteds. The mean magnetic path (ℓ) for each core is included in the part number listing.

These curves are based on a peak AC flux density of 10 gauss (1 mT). The response to DC magnetizing force is affected by the level of peak AC flux density present.

AC Magnetization: The curves at the top of page 27 illustrate the effect of Peak AC Flux Density on percent initial permeability. As the level of peak AC flux density increases, the materials experience an increase in permeability up to an AC flux density of between 3000 and 6000 gauss. Beyond this level, the material begins to saturate. These curves are the result of tests performed from 60 Hz to 10 kHz.

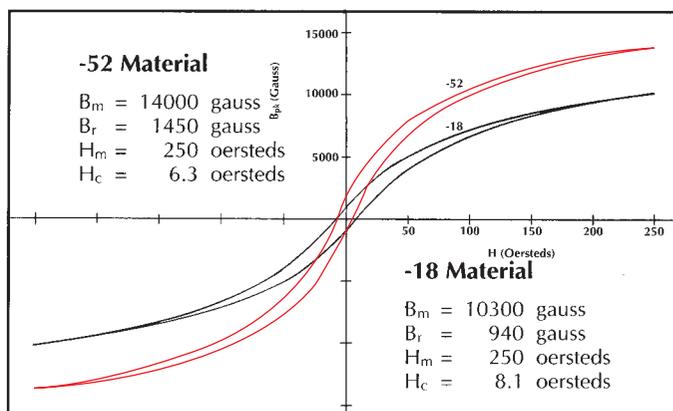
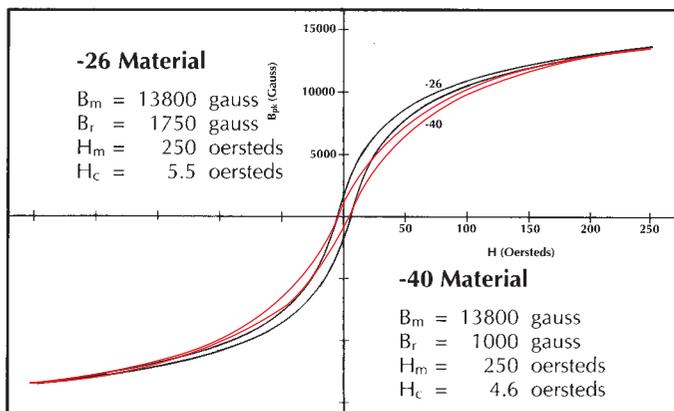
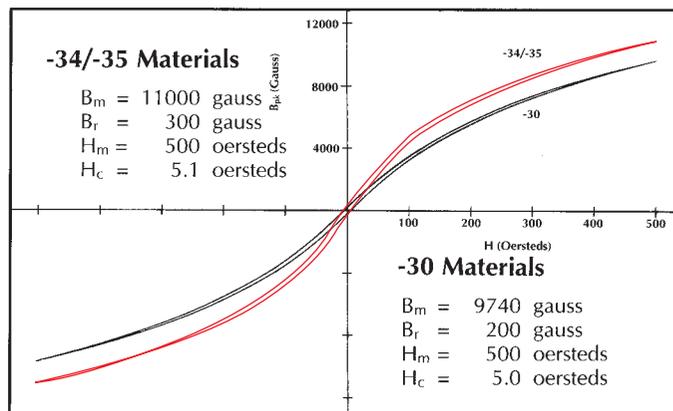
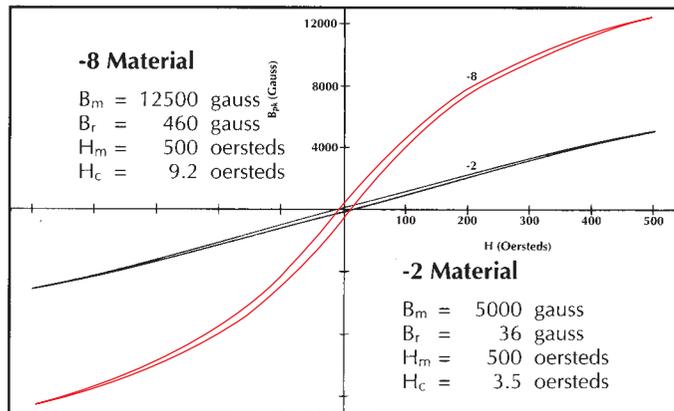
The formula in the body of the graph is used to calculate the peak AC flux density in gauss. The Cross-Sectional Area (A) for each core is included in the part number listing.

The A_L values listed are based on a peak AC flux density of 10 gauss (1 mT). Testing cores at a higher flux density can have a significant effect on measured results.

Frequency Response: The curves at the bottom of page 27 show how the permeability of each material is affected by frequency.

A typical coil wound with multiple turns will have a measurable amount of interwinding capacitance which acts in parallel with the coil. This interwinding capacitance will cause the coil to become self-resonant. In order to avoid this effect, the data at the highest frequencies was taken with a single turn.

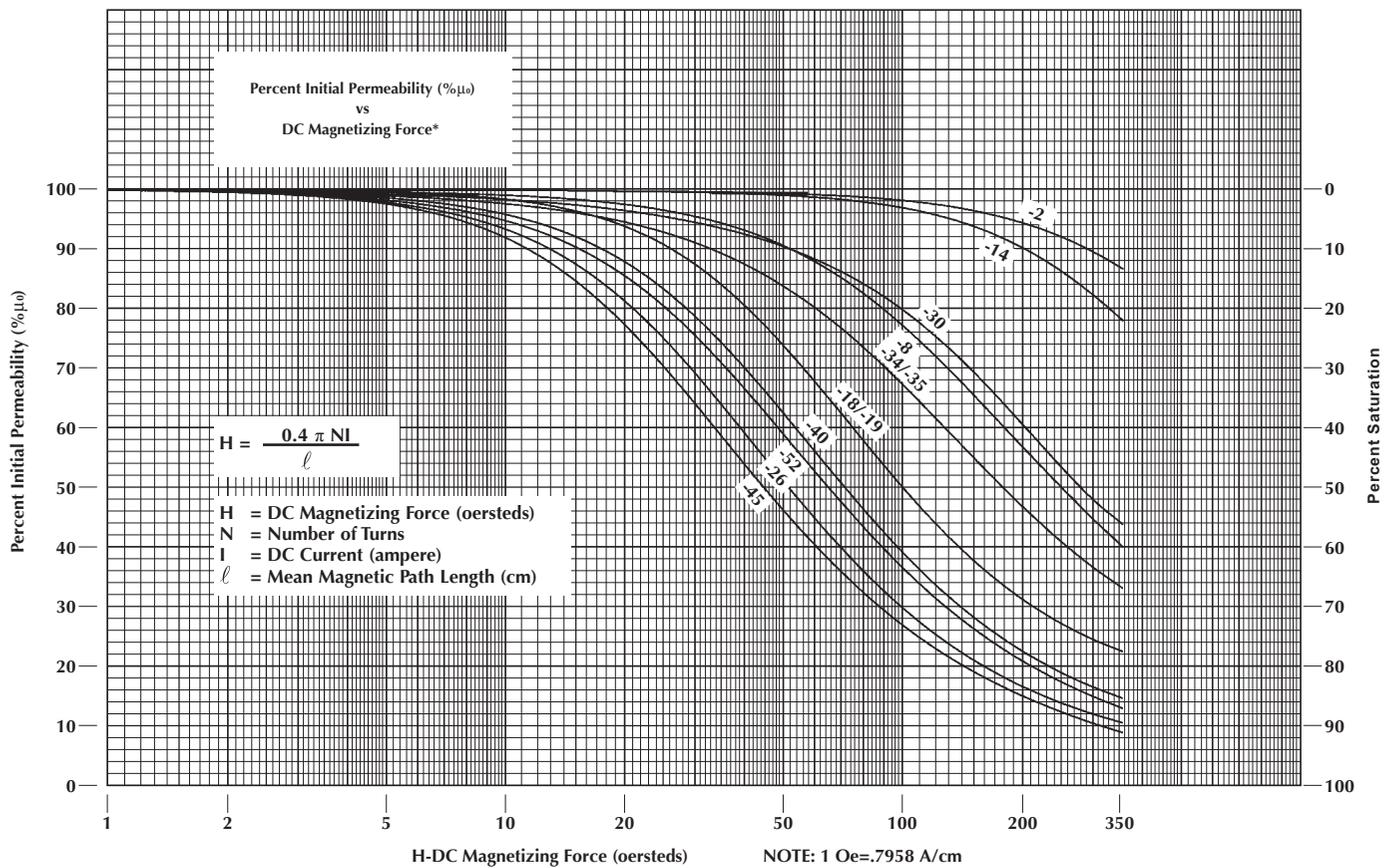
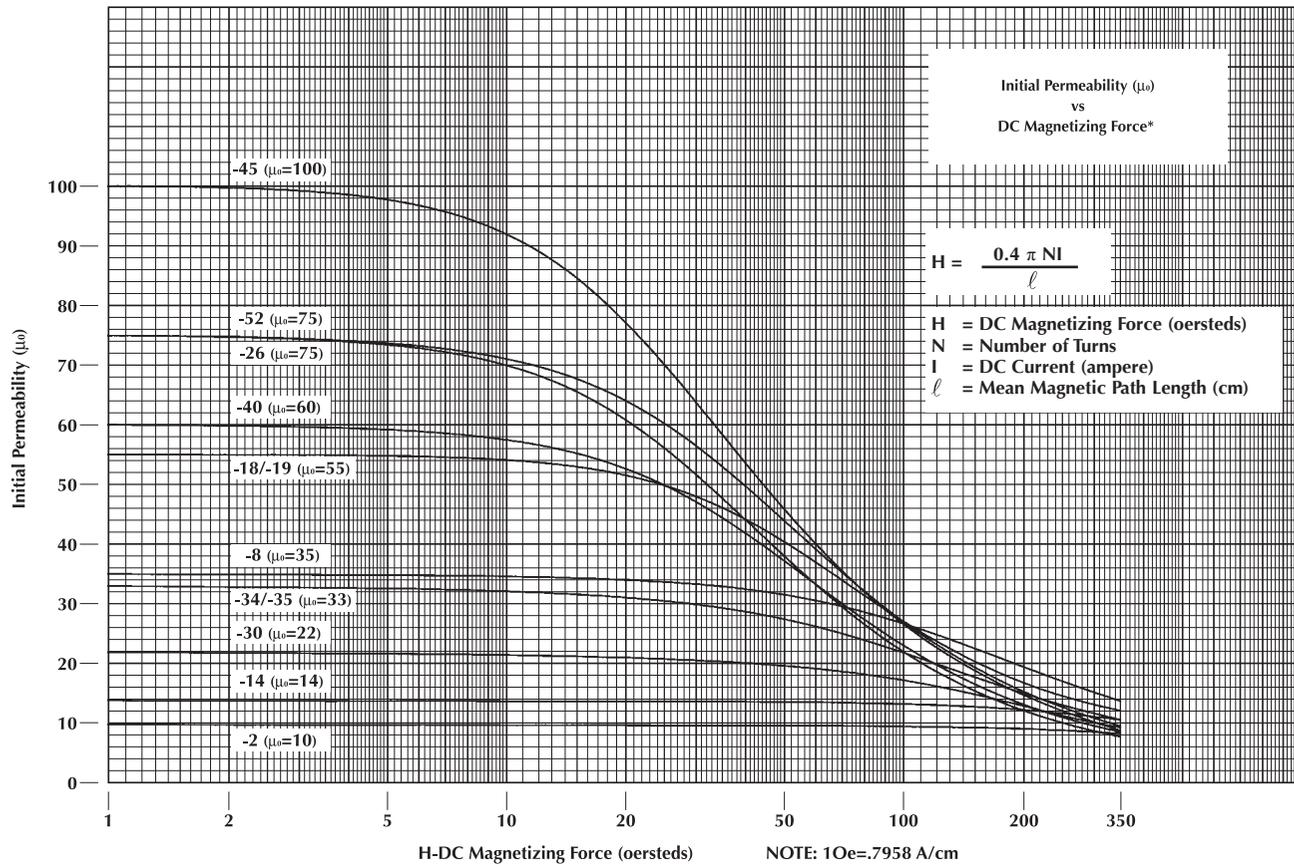
BH CURVES



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MICROMETALS

MAGNETIC CHARACTERISTICS

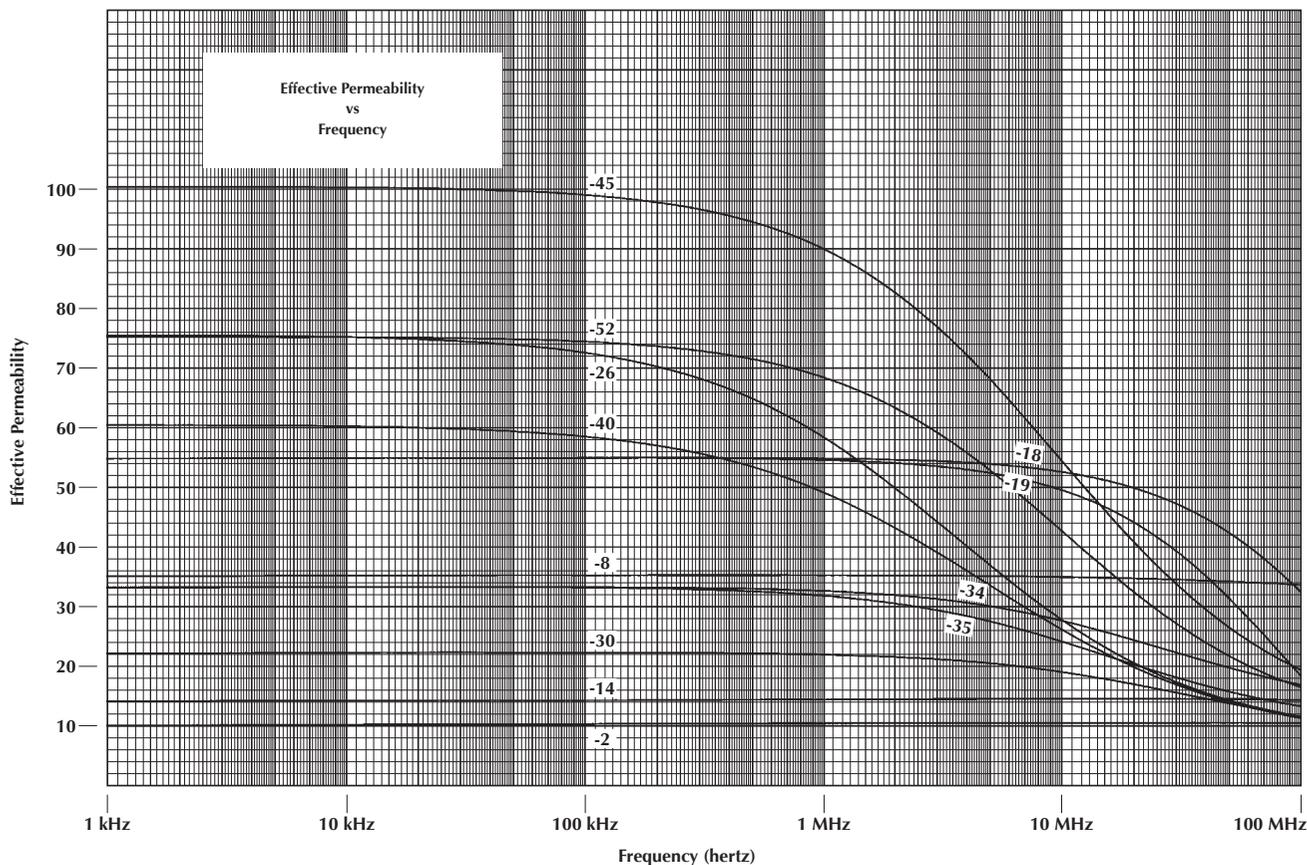
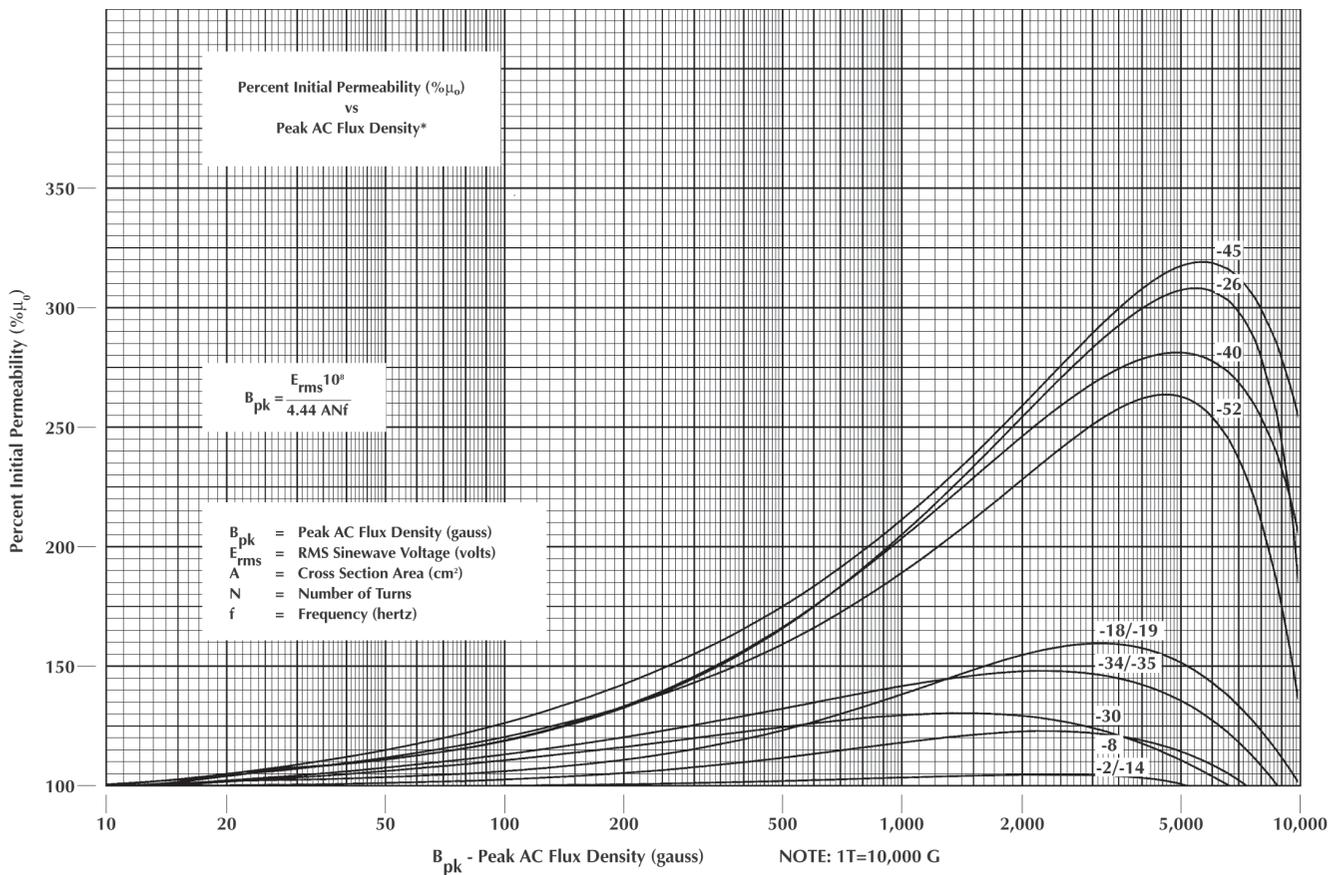


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MICROMETALS

* Curve fit formula provided on page 28

MAGNETIC CHARACTERISTICS



* Curve fit formula provided on page 28

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MICROMETALS

MAGNETIC CHARACTERISTICS

PERCENT PERMEABILITY vs DC MAGNETIZING FORCE* - See page 26

FORMULA: $\% \mu_0 = ((a+cH+eH^2)/(1+bH+dH^2))^{1/2}$

Where: $\% \mu_0$ = Percentage (ie: 90%=90)
H = DC Magnetizing Force (oersteds)

| Material | a | b | c | d | e |
|----------|-------|-----------------------|-------|-----------------------|-----------------------|
| -2 | 10000 | 6.13x10 ⁻⁴ | 5.22 | 3.51x10 ⁻⁶ | 4.64x10 ⁻³ |
| -14 | 10000 | 5.61x10 ⁻⁴ | 5.05 | 6.86x10 ⁻⁶ | 5.58x10 ⁻³ |
| -8 | 10090 | 4.26x10 ⁻³ | 30.9 | 7.68x10 ⁻⁵ | -.0119 |
| -18/-19 | 9990 | 8.36x10 ⁻⁴ | 14.4 | 3.92x10 ⁻⁴ | .0853 |
| -26 | 10090 | 5.05x10 ⁻³ | 13.1 | 1.17x10 ⁻³ | .0212 |
| -30 | 10140 | 4.68x10 ⁻⁴ | -30.2 | 1.45x10 ⁻⁵ | .0505 |
| -34/-35 | 10200 | 5.12x10 ⁻³ | 7.39 | 9.62x10 ⁻⁵ | .0298 |
| -40 | 10240 | 4.32x10 ⁻³ | 12.8 | 6.26x10 ⁻⁴ | .0267 |
| -45 | 10014 | 6.07x10 ⁻³ | 45.2 | 1.79x10 ⁻³ | -.0578 |
| -52 | 10240 | 6.71x10 ⁻³ | 24.7 | 7.75x10 ⁻⁴ | -.0105 |

PERCENT PERMEABILITY vs PEAK AC FLUX DENSITY* - See page 27

FORMULA: $\% \mu_0 = ((a+cB+eB^2)/(1+bB+dB^2))^{1/2}$

Where: $\% \mu_0$ = Percentage (ie: 90%=90)
B = Peak AC Flux Density (gauss)

| Material | a | b | c | d | e |
|----------|-------|-----------------------|------|------------------------|------------------------|
| -2/-14 | 9970 | 5.77x10 ⁻⁴ | 7.29 | -8.96x10 ⁻⁸ | -1.18x10 ⁻³ |
| -8 | 9990 | 4.52x10 ⁻⁴ | 11.4 | 8.82x10 ⁻⁹ | -8.29x10 ⁻⁴ |
| -18/-19 | 10270 | 1.01x10 ⁻⁴ | 12.3 | 2.70x10 ⁻⁸ | -8.43x10 ⁻⁴ |
| -26 | 10600 | 7.21x10 ⁻⁵ | 37.8 | -7.74x10 ⁻⁹ | -3.56x10 ⁻³ |
| -40 | 10480 | 1.62x10 ⁻⁴ | 40.8 | -6.51x10 ⁻⁹ | -3.35x10 ⁻³ |

FORMULA: $\% \mu_0 = a+bB+cB^{1/2}+dB^2$

Where: $\% \mu_0$ = Percentage (ie: 90%=90)
B = Peak AC Flux Density (gauss)

| Material | a | b | c | d |
|----------|------|------------------------|------|------------------------|
| -30 | 93.4 | -2.99x10 ⁻² | 2.08 | 8.30x10 ⁻⁷ |
| -34/-35 | 92.6 | -2.51x10 ⁻² | 2.36 | 1.07x10 ⁻⁷ |
| -45 | 88.3 | 6.78x10 ⁻³ | 3.80 | -2.72x10 ⁻⁶ |
| -52 | 92.0 | 1.34x10 ⁻² | 2.77 | -3.66x10 ⁻⁶ |

CORE LOSS vs PEAK AC FLUX DENSITY - See page 31-36

FORMULA: $CL(mW/cm^3) = \frac{f}{\frac{a}{B^3} + \frac{b}{B^{2.3}} + \frac{c}{B^{1.65}}} + (d f^2 B^2)$

| Material | a | b | c | d |
|----------|---------------------|---------------------|---------------------|-----------------------|
| -2 | 4.0x10 ⁹ | 3.0x10 ⁸ | 2.7x10 ⁶ | 8.0x10 ⁻¹⁵ |
| -8 ** | 1.9x10 ⁹ | 2.0x10 ⁸ | 9.0x10 ⁵ | 5.0x10 ⁻¹⁵ |
| -14 | 4.0x10 ⁹ | 3.0x10 ⁸ | 2.7x10 ⁶ | 1.6x10 ⁻¹⁴ |
| -18 | 8.0x10 ⁸ | 1.7x10 ⁸ | 9.0x10 ⁵ | 3.1x10 ⁻¹⁴ |
| -19 | 1.9x10 ⁹ | 8.4x10 ⁷ | 2.1x10 ⁶ | 5.0x10 ⁻¹⁴ |
| -26 | 1.0x10 ⁹ | 1.1x10 ⁸ | 1.9x10 ⁶ | 1.9x10 ⁻¹³ |
| -30 | 3.3x10 ⁸ | 2.0x10 ⁷ | 2.0x10 ⁶ | 1.1x10 ⁻¹³ |
| -34 | 1.1x10 ⁹ | 3.3x10 ⁷ | 2.5x10 ⁶ | 7.7x10 ⁻¹⁴ |
| -35 | 3.7x10 ⁸ | 2.2x10 ⁷ | 2.2x10 ⁶ | 1.1x10 ⁻¹³ |
| -40 | 1.1x10 ⁹ | 3.3x10 ⁷ | 2.5x10 ⁶ | 3.1x10 ⁻¹³ |
| -45 | 1.2x10 ⁹ | 1.3x10 ⁸ | 2.4x10 ⁶ | 1.2x10 ⁻¹³ |
| -52 | 1.0x10 ⁹ | 1.1x10 ⁸ | 2.1x10 ⁶ | 6.9x10 ⁻¹⁴ |

* Curve fit formula valid only for ranges shown on graph. ** Revised since last issue.

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MICROMETALS

CORE LOSS

Core losses are a result of an alternating magnetic field in a core material. The loss generated for a given material is a function of operating frequency and total flux swing (ΔB). The core losses are due to hysteresis, eddy current and residual losses in the core material.

Core loss curves for each material are shown on pages 31- 36. This information results from sinewave core loss measurement made on a Clarke-Hesse V-A-W Meter. These curves have a typical tolerance of $\pm 15\%$. The core loss in milliwatts per cubic centimeter (mW/cm^3) as a function of peak AC flux density in gauss is shown for various frequencies.

A Core Loss Comparison Table is shown on page 1. This table provides a quick comparison of core loss in mW/cm^3 at various frequencies for a given AC flux density for each material. The relative core loss comparison between materials at other AC flux densities will differ according to each materials response to operating AC flux density.

The formula to calculate the peak AC flux density for an alternating signal based on the average voltage per half-cycle in SI units is:

$$B_{pk} = \frac{E_{avg}}{4 A N f}$$

Where: B_{pk} Peak AC flux density (tesla)
 E_{avg} Average AC voltage per half-cycle (volts)
 A Cross-sectional area (m^2)
 N Number of turns
 f frequency (hertz)

In cgs units, the following formula is commonly used for a sinewave signal with voltage in rms:

$$B_{pk} = \frac{E_{rms} 10^8}{4.44 A N f}$$

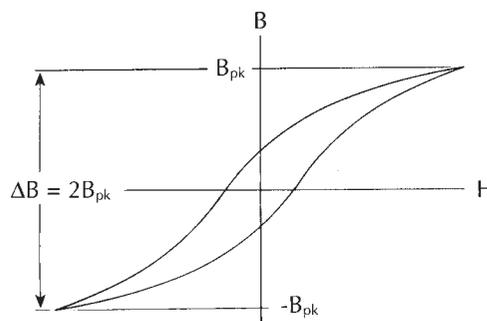
Where: B_{pk} Peak AC flux density (gauss)
 E_{rms} RMS AC voltage (volts)
 A Cross-sectional area (cm^2)
 N Number of turns
 f frequency (hertz)

The factor of 10^8 is due to the B_{pk} conversion from tesla to gauss (1 tesla = 10^4 gauss) and the cross-sectional area (A) conversion from m^2 to cm^2 ($\text{m}^2 = 10^4 \text{cm}^2$). The change in constant from 4 to 4.44 is due to the form factor of a sinewave. Since the form factor is equal to the rms value divided by the average value for a half-cycle, the form factor for a sinewave is 1.11 ($\pi/(2\sqrt{2})$). The form

factor for a square wave is 1.00.

This formula is useful in determining the peak AC flux density (B_{pk}) to be used with the core loss curves for sinewave applications such as 60 Hz differential-mode line filter inductors, resonant inductors in power supplies, and for the fundamental line frequency signal in power factor correction chokes.

Under this condition, the core experiences a total peak to peak AC flux density swing (ΔB) that is twice the value of peak AC flux density (B_{pk}) calculated with the above formulas as illustrated:



In inductor applications where the total losses are dominated by core loss rather than copper loss, an overall improvement in performance can be achieved by using a lower permeability core material. This is typically the case in high frequency resonant inductors.

By utilizing a lower permeability core material (such as -2 Material $\mu = 10$), additional turns will be needed to achieve the required inductance. While additional turns will increase the winding losses, it will reduce the operating AC flux density which will result in lower core loss.

It is possible to introduce a discrete air gap into ferrite structures to lower their effective permeability and, thus lower the operating flux density. However, a discrete air gap can cause severe localized gap loss problems. This is particularly true at frequencies above 100 kHz. In many cases the gap loss will exceed the core loss. Since iron powder cores have a distributed air gap, these localized gap losses are essentially eliminated.

To illustrate the core loss benefit of a lower permeability material, consider that an inductor of a given value on -2 Material ($\mu_0 = 10$) will require about 87% more turns than an inductor on -8 Material ($\mu_0 = 35$). The greater number of turns on the -2 Material will result in an AC flux density which is about 53% of the -8 Material flux density. Consequently, the inductor on the -2 Material will exhibit about $1/4$ the core loss of the inductor on the -8 Material. In general, the -2 and -14 Material is recommended for resonant inductor applications.

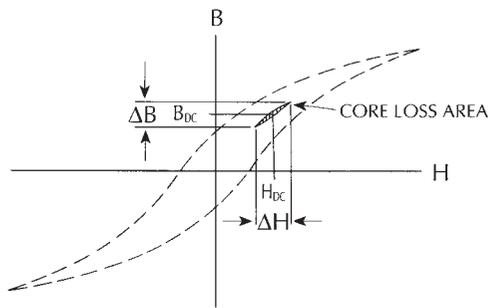
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MICROMETALS

CORE LOSS

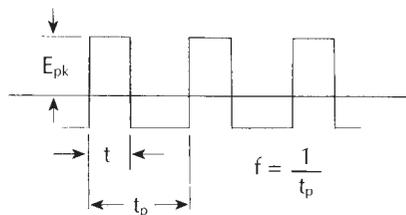
One of the most common applications for iron powder cores in switching power supplies is DC output chokes. In this application, the coil is biased with DC current along with a smaller percentage of ripple current which results from a squarewave voltage. The DC current generates a DC flux density and the squarewave voltage produces an alternating (AC) flux density.

Biasing a magnetic material with DC current will shift the minor alternating BH loop but will not have a noticeable effect on the core loss. It is only the alternating flux density (ΔB) that generates core loss. This condition is illustrated:



Core loss measurements made at the same frequency and total flux density swing (ΔB) produce only slightly higher core loss for squarewaves than for sinewaves.

The following diagram describes a typical squarewave voltage across an inductor in a switching power supply:



Since the volt-seconds (Et) during the "on" and "off" portion of a period must be equal in the steady state, the peak to peak flux density for a squarewave (which is not necessarily symmetric) is described by the following formula in cgs units:

$$\Delta B = \frac{E_{pk} t 10^8}{A N}$$

Where: ΔB Peak to Peak flux density (gauss)
 E_{pk} Peak voltage across coil during "t" (volts)
 t Time of applied voltage (seconds)
 A Cross-sectional area (cm^2)
 N Number of turns

Another representation of this formula which can also be useful for these applications in cgs units is:

$$\Delta B = \frac{L \Delta I 10^8}{A N}$$

Where: ΔB Peak to Peak flux density (gauss)
 L Inductance (Henries)
 ΔI Peak to Peak ripple current (amps)
 A Cross-sectional area (cm^2)
 N Number of turns

In unipolar applications such as flybacks, the preceding formulas which describe the total peak to peak flux density need to be used to verify operation within the maximum flux density limit of the core material to avoid magnetic saturation.

However, since it is industry practice to show core loss as a function of peak AC flux density with symmetrical operation about zero, the core loss curves provided assume $B_{pk} = \Delta B/2$. Therefore, core loss is determined from the graphs by using one-half of the peak to peak flux density at the frequency of the total period where $f = 1/t_p$.

The following formulas should be used to calculate the value of peak AC flux density to be used with the core loss graphs on pages 31-36 to determine the high frequency core loss in iron powder cores for a variety of DC biased inductor applications:

In cgs units:

$$B_{pk} = \frac{E_{pk} t 10^8}{2 A N} = \frac{L \Delta I 10^8}{2 A N}$$

Where: B_{pk} Peak AC flux density (gauss)
 E_{pk} Peak voltage across coil during "t" (volts)
 t Time of applied voltage (seconds)
 L Inductance (Henries)
 ΔI Peak to peak ripple current (amps)
 A Cross-sectional area (cm^2)
 N Number of turns

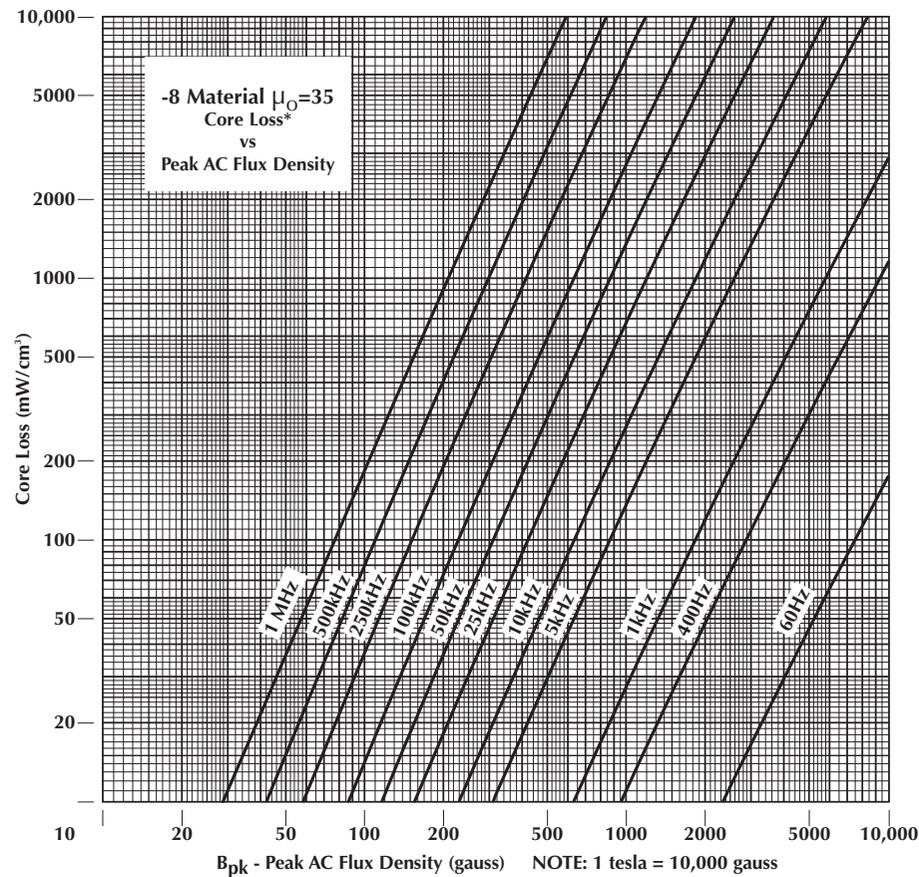
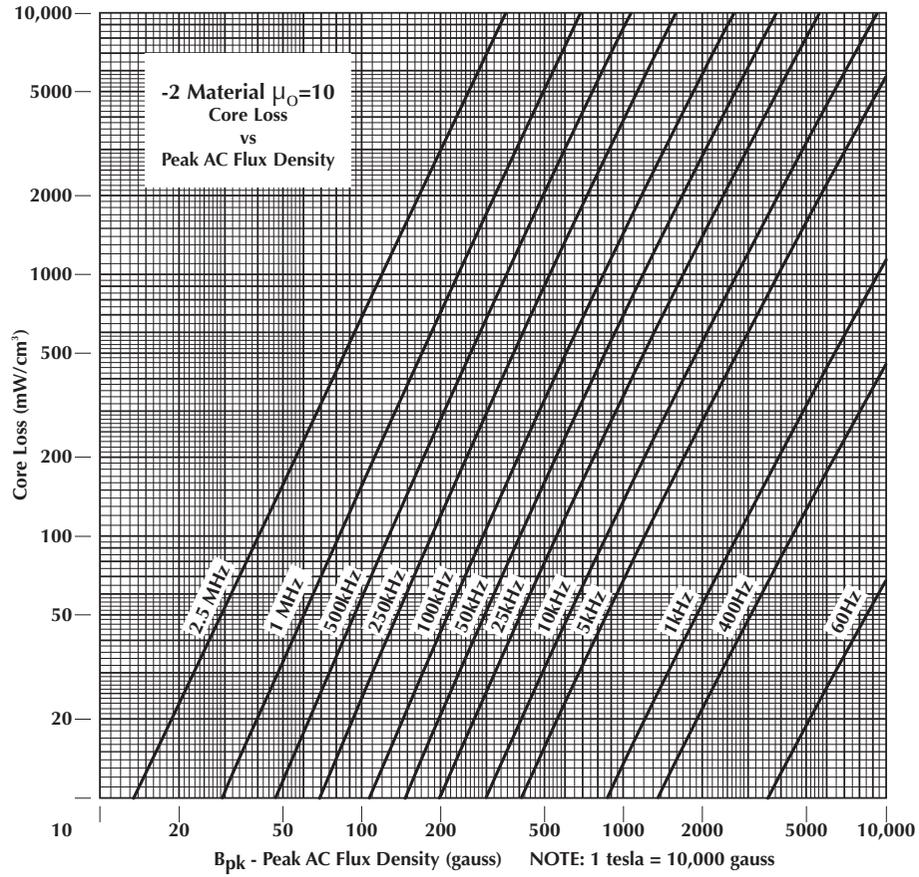
Inductors in active power factor correction boost topologies do not have the simple steady state waveform presented before. Rather, the high frequency signal (typically 100 kHz) is such that both the peak voltage across the inductor (E) and the "on" time (t) are constantly changing throughout the period of the fundamental line frequency (50 or 60 Hz). The core loss in this case will be the time-averaged core loss of the individual pulses for the period of the line frequency.

Please refer to pages 58 and 59 for information on the interpretation of core loss in active PFC inductors.

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CORE LOSS

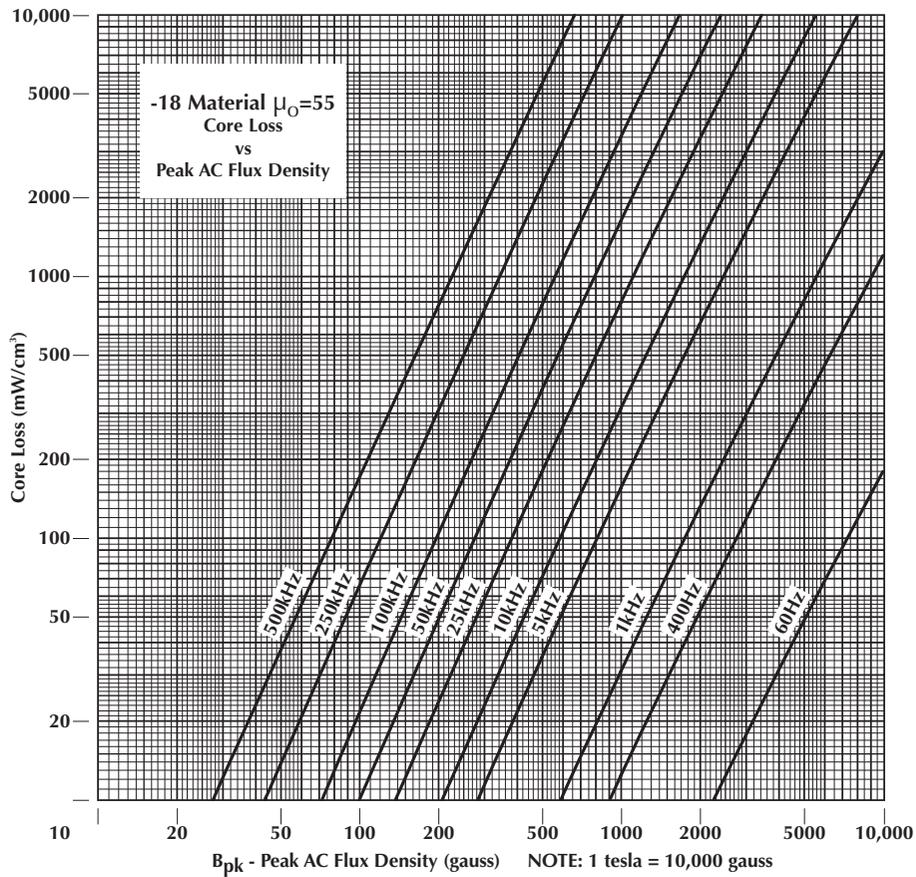
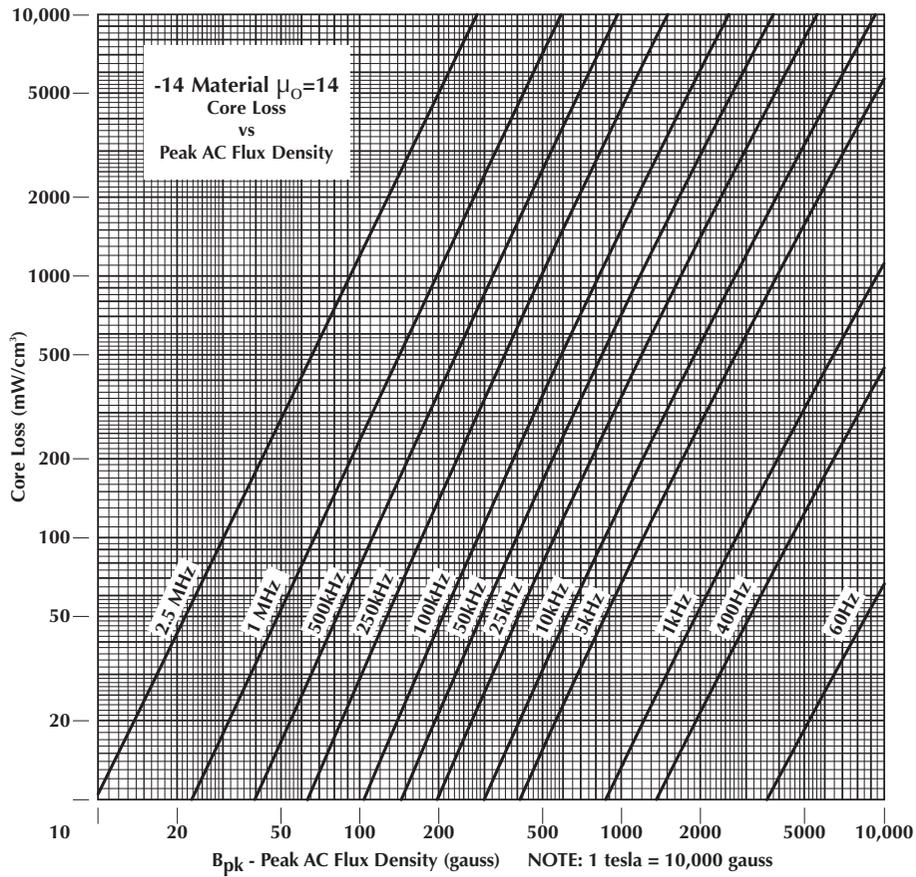


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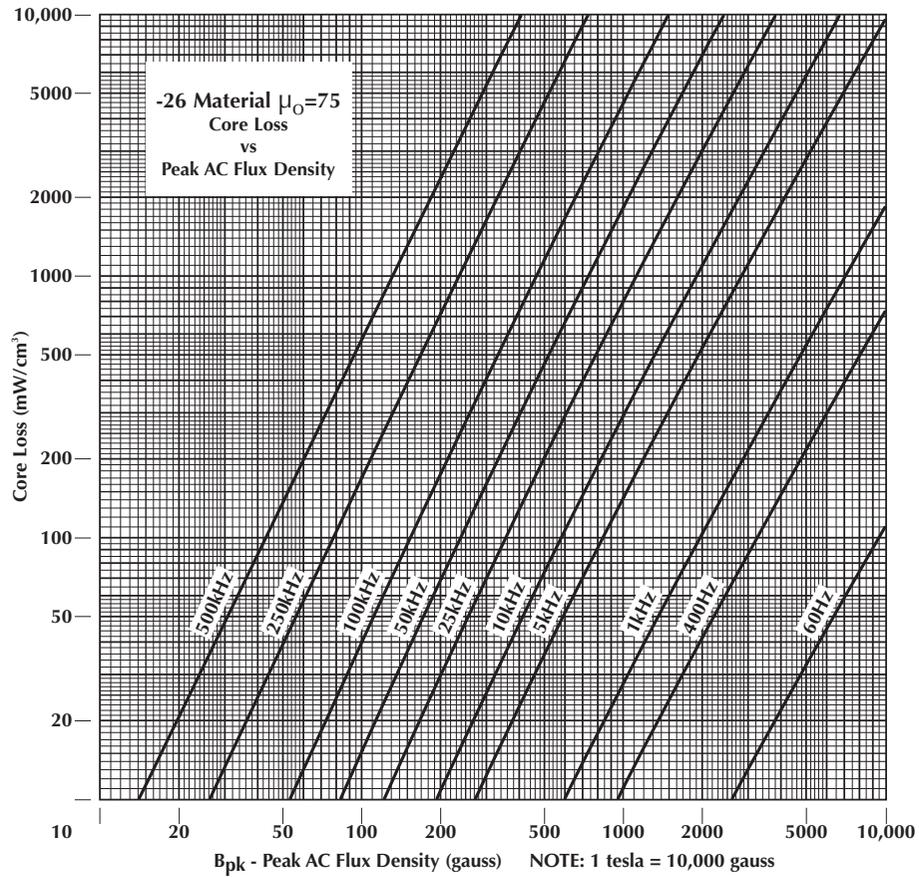
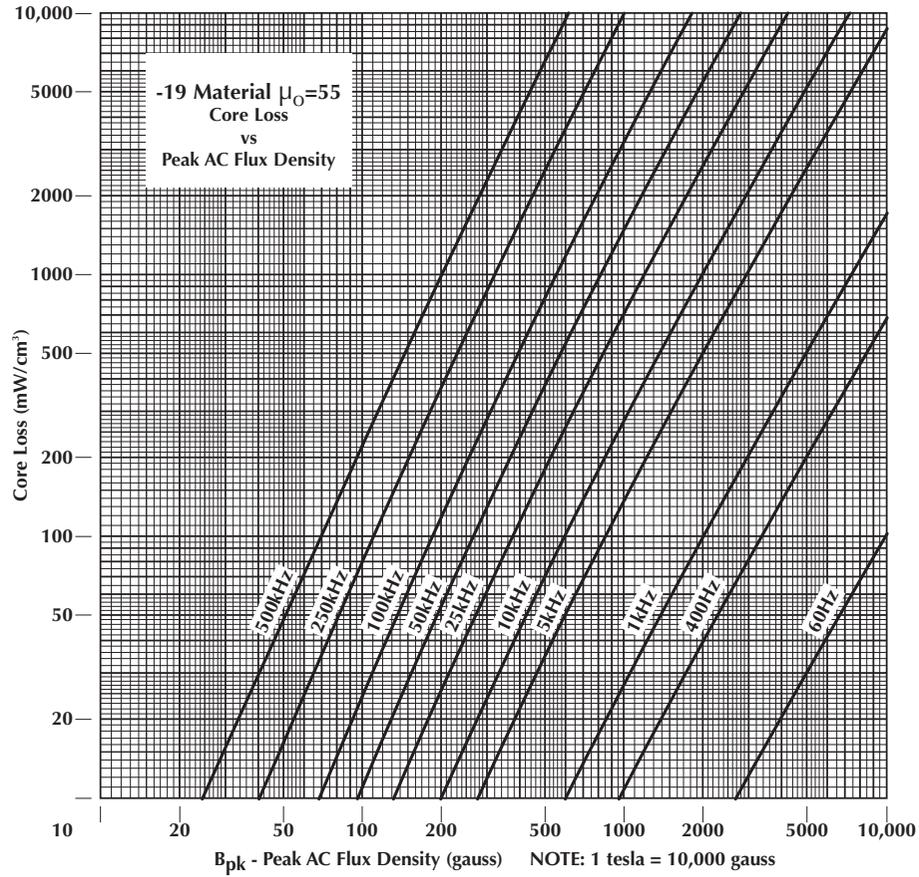
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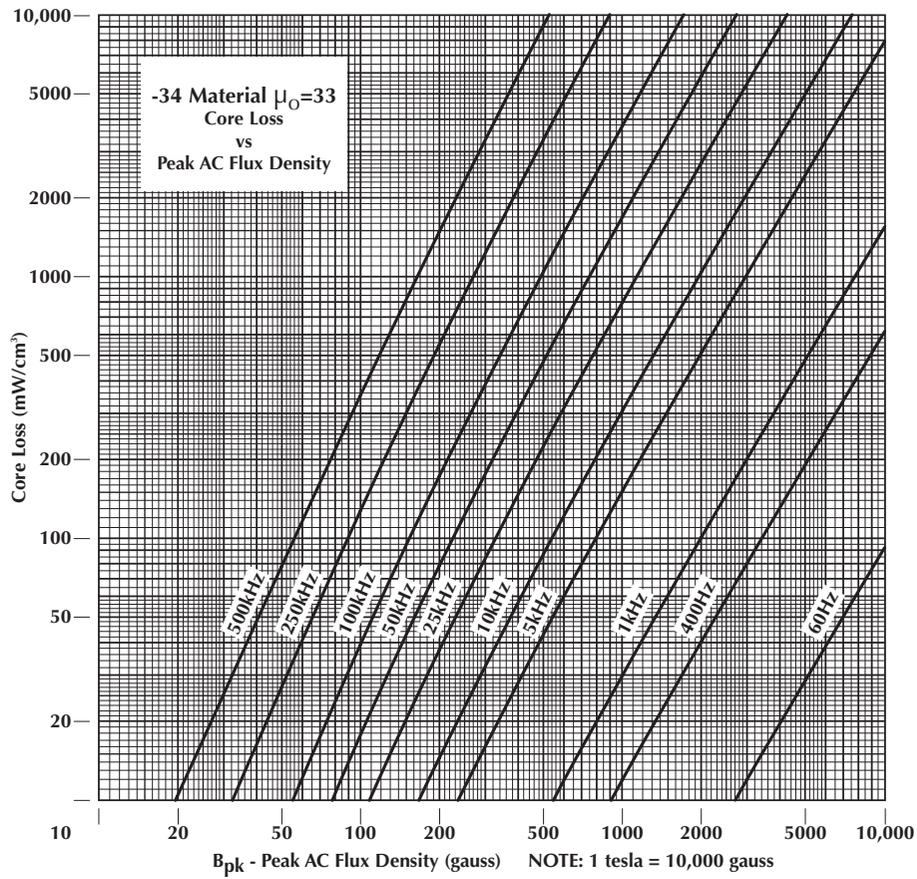
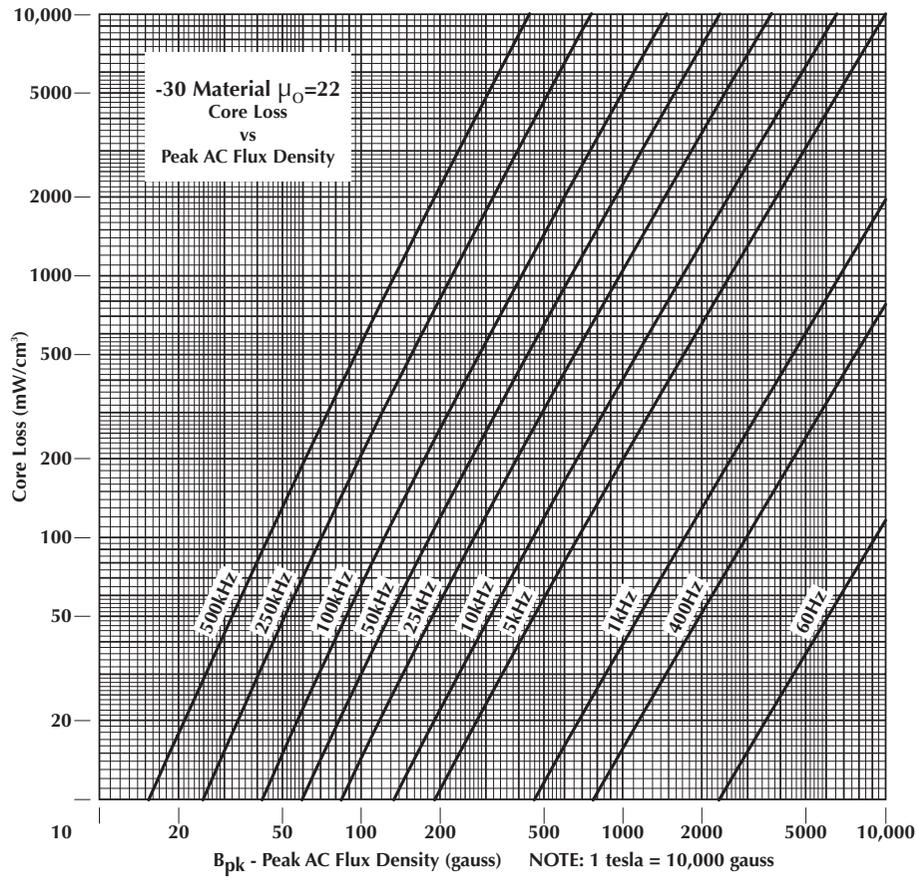
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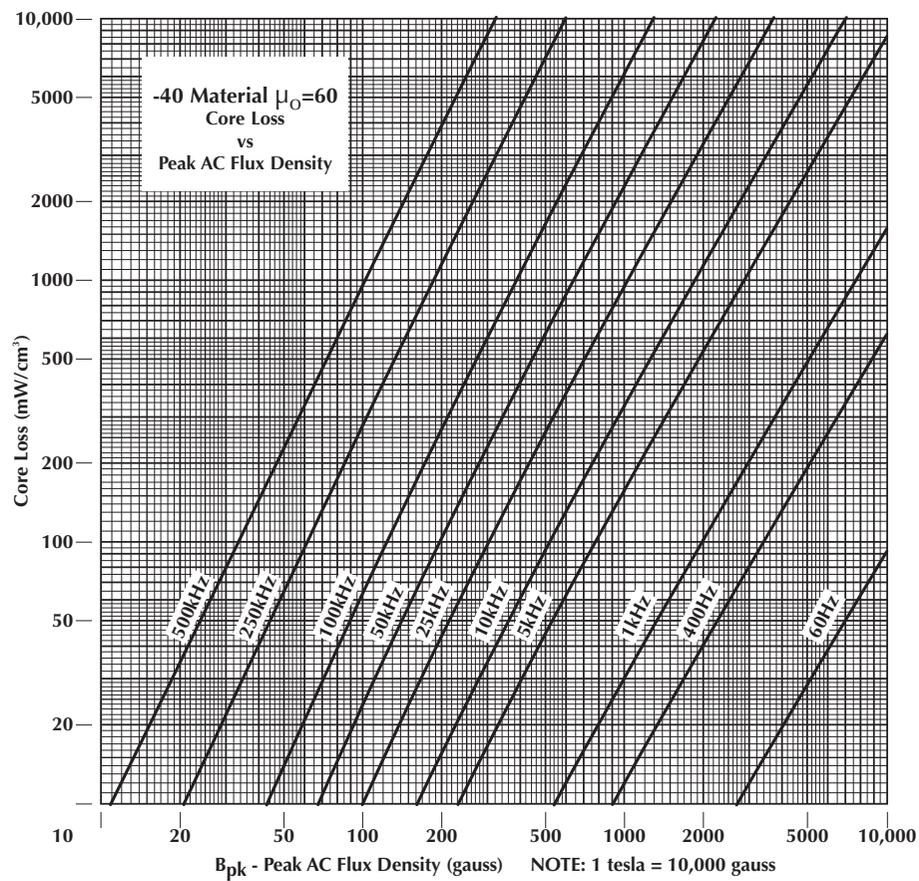
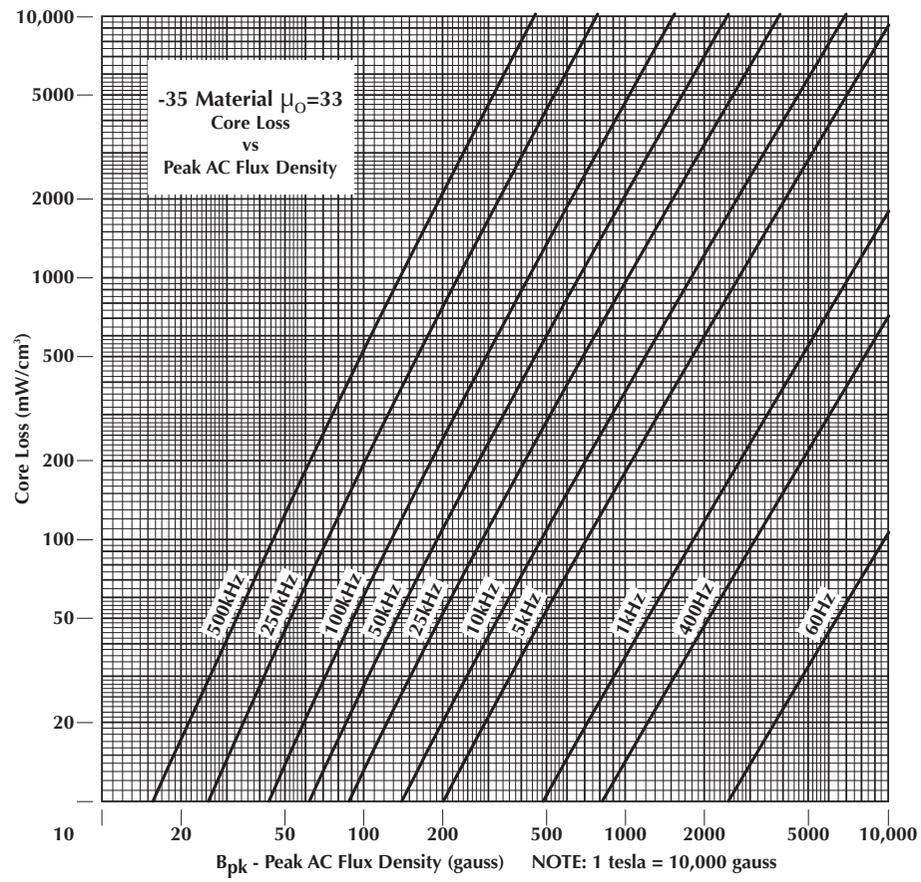
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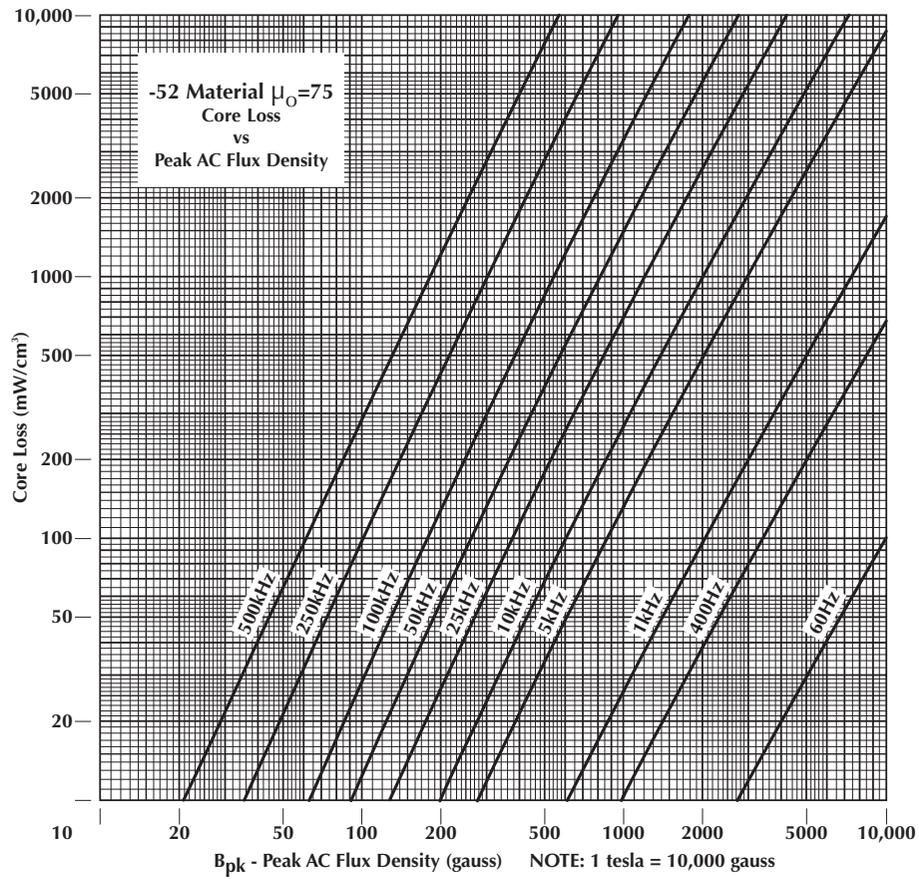
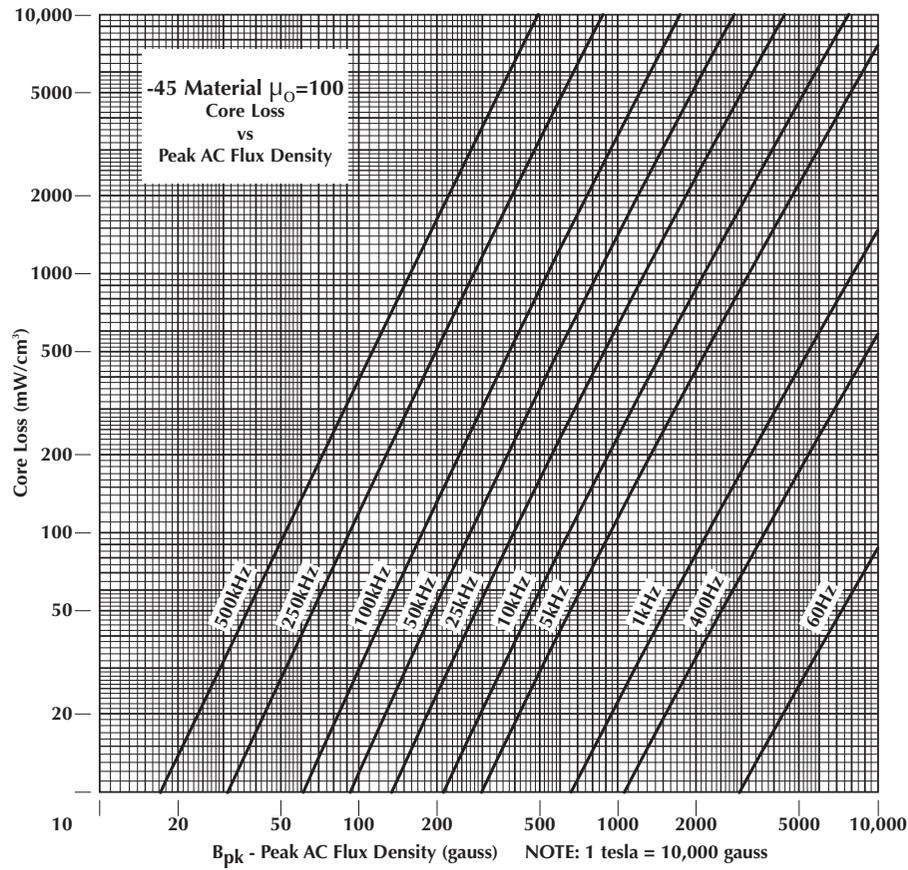
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MICROMETALS

IRON POWDER CORE INDUCTOR DESIGN SOFTWARE

Micrometals Inductor Design Software is a flexible user-friendly tool designed to supplement this catalog in the selection of iron powder cores for a variety of power conversion and line filter applications. The software is a DOS based program with a file size of 320 kB and is available at no charge. Copies of the disk can be obtained from the factory or through any of our sales representatives. The software can also be down loaded from the Micrometals website at www.micrometals.com.

The main menu for the YEAR 2000 revision contains the following selections:

- 1) DC Biased Inductors Design where the inductor must meet a given inductance at a DC current level with ripple conditions defined by voltage and frequency.
- 2) Design of Controlled Swing inductors where the inductance does not exceed a maximum value at reduced current, but is otherwise similar to 1.)
- 3) Design of Wide Swing inductors where the inductance at low current is typically 5 to 20 times higher than the inductance at maximum DC current. This application utilizes a ferrite/iron powder composite core as described on page 14
- 4) Design of Active Power Factor Boost or buck inductors, commonly referred to as PFC chokes.
- 5) Design of Power Line Frequency Inductors for differential-mode filtering using toroidal cores.
- 6) Design of a Resonant Converter Inductor where the current is sinusoidal with no DC bias.
- 7) Analyze a design of an inductor based on user defined parameters.
- 8) Display Micrometals Catalog
- 9) Wire Table

The design portion of the software accepts typical inputs such as required inductance, dc resistance, dc bias current, peak voltage, output voltage, and frequency. A single-layer or full winding can be specified. The user can select the preferred core geometry (i.e., Toroid, E-Core or Ferrite/Iron Powder Composite) and select specific core materials or all materials.

There are pre-set Design Constants and Limits which can be changed by the user. These parameters and their pre-set values follow:

| | |
|-----------------------------------|---------------------|
| Measurement Units System | Mixed English |
| Wire Gage Standard | American AWG |
| Ambient Temperature | 25 °C |
| Maximum Temperature Rise | 40 C° |
| Minimum Copper Density | 150 cir-mils/Amp |
| Maximum Window Fill Factor | 40 percent |
| Minimum % Perm Under DC Bias | 40 percent |
| Wire Resistivity Adjust Factor | 1.000 dimensionless |
| Temp Rise Factor | 1.000 C° mW/sq-cm |
| Temp Rise Characteristic Exponent | 0.833 dimensionless |
| Lead Length Allowance | 2.5 inches each |

The program will automatically calculate the smallest core size possible that will meet the specified needs and will display; 1) Micrometals Part Number, 2) Approximate unit price, 3) Core AL Value, 4) Required Number of Turns, 5) Wire Size, 6) Percent Window Fill, 7) DC Winding Resistance, 8) DC Magnetizing Force, 9) Percent Initial Permeability, 10) Core Loss, 11) Copper Loss, and 12) Temperature Rise. The wound dimensions and weight of the copper wire can also be displayed.

The software allows the design engineer to quickly work up multiple design solutions based on user specified electrical requirements and be easily printed for hard copies. The use of pop-up menus and the ability to scroll backwards through the design solutions greatly enhances this revision.

An important new feature of the YEAR 2000 revision is that predicted changes in core temperature versus time and temperature can be graphically displayed for the designs. This feature will allow the design engineer to see if the design is capable of meeting a minimum life expectancy. The graph will display projected core temperature change out 100,000 hours.

The following are definitions of the units utilized by the design software:

| Unit | Description | Defined |
|----------------|-------------------|-------------------|
| A _L | Inductance Rating | nH/N ² |
| Price | US Dollars | Approx.Value* |
| RDC | DC Resistance | ohms |
| HDC | Magnetizing Force | oersteds |
| P FE | Core Loss | watts |
| P CU | Copper Loss | watts |
| T Rise | Temperature Rise | celsius degrees |

*Approximate value at 5,000 piece quantity

Please contact the factory for technical support. Micrometals will gladly provide sample cores to assist in your evaluation.

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MICROMETALS

CORE LOSS

CORE LOSS INCREASE DUE TO THERMAL AGING

The following discussion and examples illustrate the phenomenon of thermal aging and detail the variables and conditions that effect a change in core loss characteristics. All iron powder cores, regardless of the manufacturer, are susceptible to permanent increases in core loss when exposed to elevated temperatures for extended periods of time. It is important for the design engineer to understand the conditions under which thermal aging can occur and incorporate this knowledge into their standard design process.

Thermal aging is an irreversible increase in core loss as a result of prolonged exposure to elevated temperatures. The extent of these changes and realized effect on the wound core are a function of the following variables; time, ambient temperature and air flow, core volume and shape, operating frequency, peak ac flux density, material type and core manufacturer. Eddy current loss will be the dominant loss at higher frequencies while hysteresis loss will be the dominate loss at lower frequencies. The contribution of each form of loss to the total is also affected by the operating flux density. It is the eddy current portion of the core loss which is affected by high temperature thermal aging.

The first example will illustrate what happens in a design that is dominated by core loss and uses an undersized core. This design utilizes a core that can not safely dissipate the high level of core loss even with the benefit of forced air.

The first design example is for a buck inductor operating at 80 kHz. The parameters are as follows:

$L = 11.5 \mu\text{H}$
 $I_{dc} = 18 \text{ A}$
 $E_{pk} = 45 \text{ V}$
 $E_{dc} = 12.3 \text{ V}$

The maximum ambient temperature is 60°C with forced air cooling supplied by a variable speed fan that provides less air flow at lower power levels.

The core selected is part number T106-52 wound with 14 turns of AWG-14 resulting in 1.72 W of copper loss. The peak AC flux density is 670 G at 80 kHz produces a core loss of 4.9 W. The combined loss is 6.62 W which calculates to a temperature rise of approximately 83°C in free standing air. Since the maximum ambient temperature specified for this part is 60°C the inductor can easily reach 140°C without the benefit of forced air. It should be noted that the core loss tolerances for Micrometals cores are +/-15%. Under worst case core loss conditions, the 4.9 W nominal can be 5.64 W resulting in a total loss of 7.36 W for a

temperature rise of 95°C in free standing air. These temperatures are much too hot for a core operating under these conditions where eddy current losses are a significant portion of the total loss. The T106 size core can safely dissipate a total of 2.59 W for a 40°C temperature rise.

Caution, a warning flag should go up on a design that is *core loss dominated* and depends on the use of air flow to reduce the temperature particularly if it uses a variable speed fan. While the copper loss will decrease at lower power levels, this is generally not the case with core loss. Variable speed fans should not be used with core loss dominated designs. *It is much easier to remove heat from a copper loss dominated design than a core loss dominated design.* The copper winding radiates the heat while the core material has a thermal impedance barrier that must first be overcome. Additionally, the inductor can be several degrees hotter on the inside of the core and in the "shadow of the air flow".

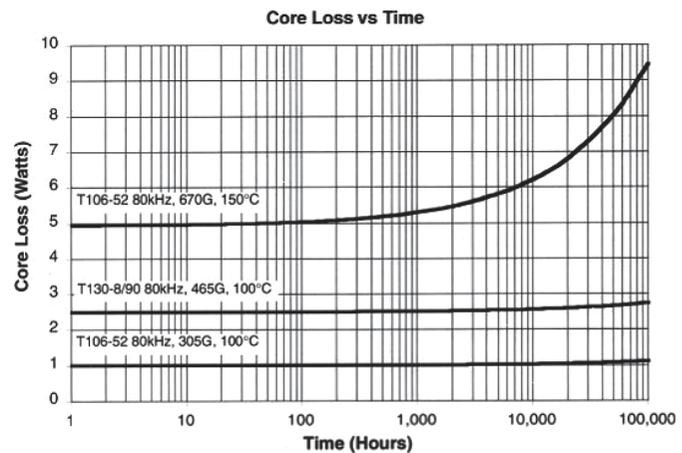


Figure 1

The upper curve in Figure 1 illustrates how quickly the projected core loss increases due to the excessive operating temperature. It should be obvious the surface area of this design is much too small to safely dissipate the excessive core loss in spite of air flow. Pages 64 and 65 show the "Total Power Dissipation (W) Vs Temperature Rise" for various sized Micrometals cores. These tables are useful to quickly determine if the design is capable of meeting a 40°C or less temperature rise.

The middle curve in Figure 1 illustrates the smallest physical core size that meets the design requirements and has a temperature rise of less than 40°C. This core is part

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CORE LOSS

number T130-8/90 wound with 19 turns of AWG-10 for a copper loss of about 1.0 W. The peak AC flux density has been reduced to 465 G at 80 kHz decreasing the core loss to 2.5 W. The graph predicts this design will safely operate at 100°C total temperature well past 100,000 hours.

The lower curve of Figure 1 shows part number T106-52 used under similar conditions to the first design except now the dc output voltage is 5 V instead of 12.3 V. With 14 turns of AWG-12 wire, the peak AC flux density has decreased to 305 G and core loss to 1.0 W. The combined core and copper losses are 2.04 W for a temperature rise of 33°C. This design will safely operate at 100°C total temperature for more than 100,000 hours.

The next design examples will illustrate differences using a much larger core size, operating at two differing frequencies and peak AC flux densities.

The first design is operating at 60Hz, 10 kG on Micrometals part number T300-26D. The calculated core loss is about 7.35 W and assuming a copper loss of 7.35 W, the combined loss of 14.7 W results in a 33°C temperature rise. The lower curve in Figure 2 predicts that the core loss does not change even after 100,000 hours at 125°C. Almost all of the core loss at this frequency is hysteresis loss and is unaffected at this temperature.

The upper curve in Figure 2 shows how quickly the core loss increases in a design operating at 40 kHz with a peak AC flux density of 283 G. While the total core loss of 7.35 W is the same as the 60 Hz example, the eddy current losses are now dominant and increase with constant exposure to 125°C.

Assuming the copper loss is 7.35 W, the total loss of this design is 14.7 W resulting in a temperature rise of 33°C at time zero. After 20,000 hours the core loss has increased to 9.5 W and the temperature rise now reaches 37°C. After 100,000 hours at 125°C, the core loss has increased to 12.5 W, pushing the temperature rise to 42°C. This design example is not an extreme case but illustrates how the temperature rise of the inductor continues to increase as a function of time and temperature.

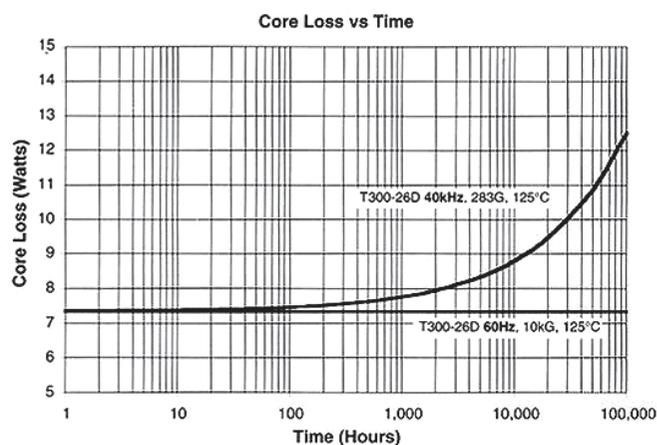


Figure 2

Another popular application for iron powder cores is power factor correction boost chokes. This can be a very demanding application where core loss calculation is more complex and often misunderstood. This can lead to poor designs that will have reliability problems. For a detailed discussion of proper core loss analysis for PFC boost chokes refer to page 58 of this catalog. Also, the latest version of Micrometals design software includes a PFC core loss application.

| | Solution #1 | Solution #2 | Solution #3 |
|---------------------------------------|-------------|-------------|-------------|
| Part Number | E168-52 | E168-52 | E168-2 |
| A_L (nH/N ²) | 179 | 179 | 44 |
| Turns | 45 | 90 | 76 |
| AWG# | 14 | 17 | 16 |
| Bpk @ 100 kHz (G) | 389 | 195 | 230 |
| Core Loss (mW/cm ³) | 495.9 | 120.0 | 61.5 |
| Core Volume (cm ³) | 18.5 | 18.5 | 18.5 |
| Core Loss (mW) | 9,174 | 2,220 | 1,137 |
| Copper Loss (mW) | 866 | 3,480 | 2,324 |
| Total Loss (mW) | 10,040 | 5,700 | 3,461 |
| Wound Surface Area (cm ²) | 66.7 | 66.7 | 66.7 |
| Maximum Size (in) | 1.7 x 1.7 | 1.7 x 1.7 | 1.7 x 1.7 |
| T (C°) | 65 | 41 | 27 |
| Approx. Core Cost (per piece) | \$0.23 | \$0.23 | \$0.55 |
| Thermal Life (Hours) | <12,000 | ~1,000,000 | >10,000,000 |

Table 1

CORE LOSS

The third design example is a PFC boost choke operating at 100 kHz with the following requirements:

$L_{min} = 250 \mu H$

$I_{dc} = 7 A$

$E_{pk In} = 120V$

$E_{dc Out} = 400V$

Referring to Table 1, you can see that design Solution #1 is a design that is dominated by 9.17 watts of core loss with only 0.87 watts of copper loss. This results in a temperature rise of 65°C. Figure 3 indicates that with an ambient of 55°C, this part will have thermal runaway in less than 2 years.

Solution #2 demonstrates that with the same core, by simply increasing the number of turns with the required smaller wire size, the core and copper losses will become more balanced. This results in improved efficiency (saving 4.3 watts), a lower operating temperature ($\Delta T=41^\circ C$), and a dramatic improvement in thermal life (almost 2 orders of magnitude). While it may seem obvious that solution #1 is a poor design, this is a fairly common mistake.

If the higher inductance produced by adding turns in solution #2 is unacceptable in the circuit, the core and copper losses can also be better balance by selecting a lower permeability material. Solution #3 illustrates how the Micrometals 10 μ_o (-2 Material) performs. This choke will be the most efficient and reliable, but this material type is more expensive than the -52 Material option.

Another important thermal aging consideration is the source of the iron powder cores, in other words, beware of “equivalent” iron powder cores. As demonstrated above, different materials will thermally age at different rates. This is also true with different manufacturers of core materials. In many cases, the term “equivalent core” is solely based on dimensional and permeability characteristics.

Figure 4 illustrates the thermal aging characteristic of Micrometals T90-26 at 75kHz with 633G as well as the same winding on an “equivalent” competitor. The Micrometals core will safely operate for 300,000 hours whereas the competitor will runaway in less than 30,000 hours. Clearly, both cores are thermally aging at different rates.

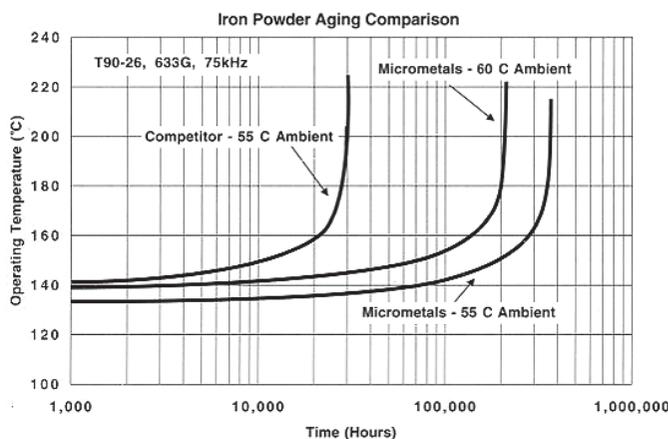


Figure 4

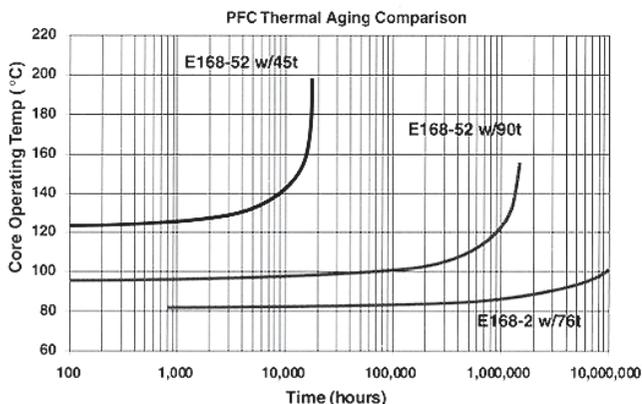


Figure 3

Less obvious is the variation of initial core operating temperatures between the Micrometals and competitor cores. The competitors increased initial core temperature is a result of higher core losses. In another example, the ambient temperature for the Micrometals winding was increased to 60 °C to match the initial core operating temperature of the competitor. Again, the predicted difference in thermal life is dramatic.

As the example above demonstrate, evaluating one manufacturers core and substituting another at a later time can be a critical error. It is also very important to regulate the supply chain and monitor that sub-suppliers are not making any unknown core substitutions.

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DESIGN SOFTWARE

The design software described on the previous page is an extremely useful tool for selecting Micrometals iron powder cores for DC applications and compliments the energy storage curves provided here.

DC energy storage inductors are an ideal application for Micrometals iron powder cores. In this application the core must support a significant DC current while maintaining an inductance adequate to filter high frequency signals. The amount of energy stored is a function of inductance and current. Specifically, energy storage for an inductor is described:

$$\text{Energy} = 1/2 LI^2$$

Microjoules
(μJ)
Microhenries
(μH)
Amperes
(a)

Energy storage is proportional to the flux density squared divided by the effective permeability of the structure.

$$\text{Energy} \sim \frac{B^2}{\mu_{\text{effective}}}$$

The introduction of a discrete air gap significantly lowers the effective permeability of core structures made from ferrites and iron alloys. This increases the energy storage capabilities of the core by allowing additional energy to be stored in the gap.

DC inductors, most commonly, fall into one of 3 basic categories:

1. Those specifically designed to maintain a relatively constant inductance from zero to full-rated load.
2. Those specifically designed to have greater inductance, under minimum load conditions (swing).
3. Those simply requiring a minimum inductance.

Micrometals Energy Storage Curves are presented for a number of core sizes in each material (except -2 Material due to its low permeability) to assist in the design of such inductors. These curves are shown both in terms of ampere-turns (NI) at the top portion of each page, and percent saturation (100% -% initial permeability) at the bottom portion of each page.

The curves shown on pages 42-51 are based on a peak AC flux density of 10 gauss (1 mT). This will typically represent a ripple current of less than 1%. Under this condition, the only heat generated results from the resistive winding (copper) losses. The energy storage limits for 10 C°, 25 C°, and 40 C° temperature rise (in free-standing air) resulting from winding losses are shown on each graph.

When significantly greater AC or ripple flux density

is present, the cores will produce higher inductance due to the AC magnetization characteristics shown at the top of page 27. Under this condition, the high frequency core losses must also be taken into account as described on pages 29 - 36. Refer to pages 56 - 57 for additional information.

The -8, -18 and -52 Materials should be considered for DC shokes operating above 100kHz due to their lower core loss characteristics at high frequency.

The importance of the swing of the inductor must be determined before the appropriate core material can be selected.

1. The -8, -18, -30, -34 and -35 Materials (or a gapped E Core, see pages 54-55) should be considered if the inductor must maintain a relatively constant inductance from minimum to full-rated current. These materials are able to store high energy with a minimum of saturation.
2. The -26, -40, -45 and -52 materials should be considered if the inductor should "swing" (increase in inductance as current decreases) a moderate amount. These materials have higher permeability and can produce a 2:1 swing (50% saturation point).
3. The -26, -40 and -52 Materials are generally recommended for designs concerned with minimum inductance because they are the most cost effective.

The temperature rise of the wound unit, aside from saturation, is the primary limiting factor in inductor design. In the case of DC inductors with very low level AC ripple, this temperature rise is a result of copper loss in the winding. (DC flux does not have a noticeable effect on core loss.)

For single-layer windings on toroidal cores, the current handling capability of a wire size as a function of temperature rise is relatively independent of core size. Making use of this, a single-layer winding table has been developed giving current ratings for temperature rises of 0 C°, 25 C°, and 40 C° temperature rise in free-standing air. (page 64)

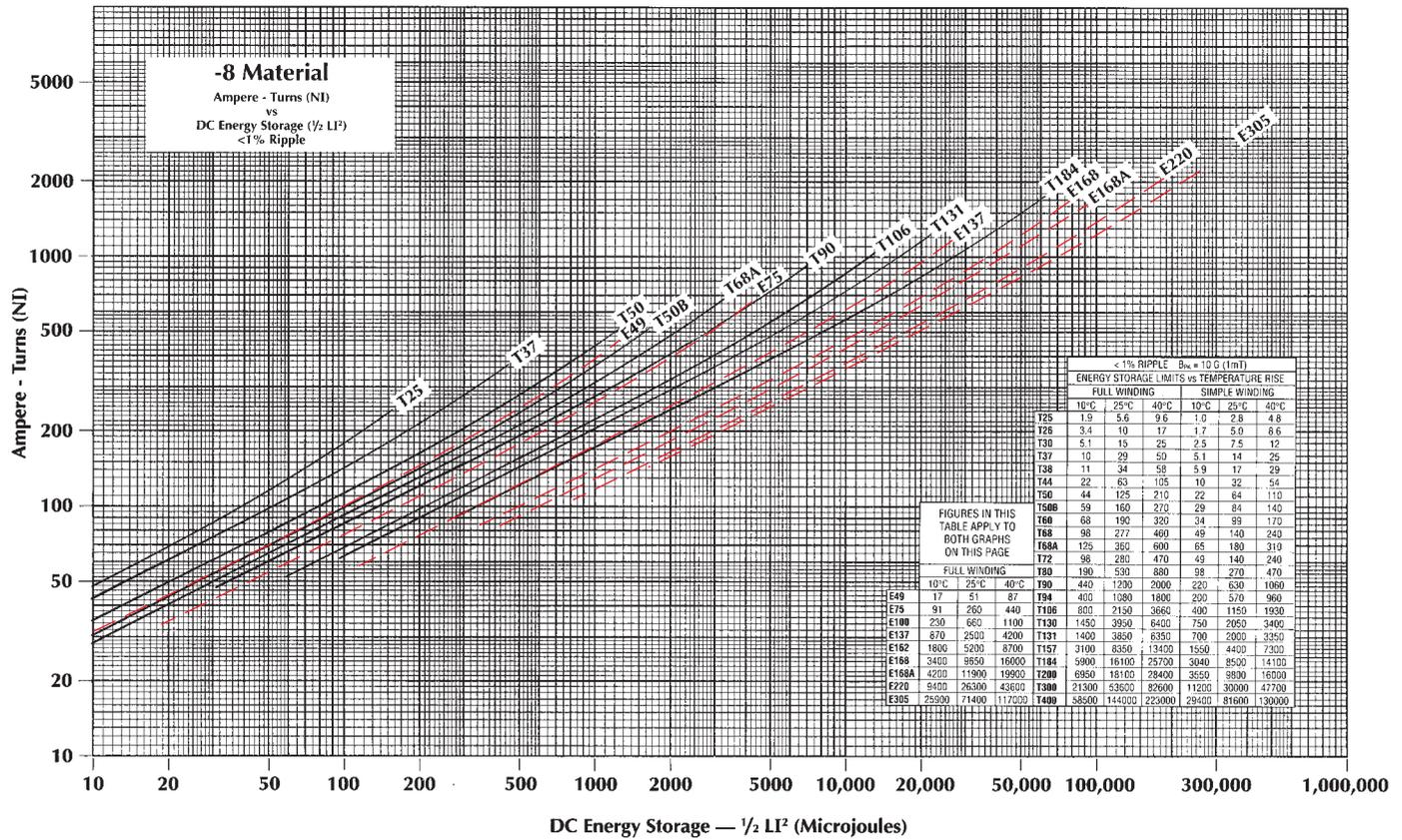
For full windings (45% toroid inside diameter remaining) a similar table has been developed. (page 65) In the case of full windings, the current handling capability of a given wire size is no longer independent of core size. However, for any particular core size, an ampere-turn rating for a given temperature rise does become a constant. These ampere-turn constants are included in the full windig table.

Refer to page 57 for design examples using the Energy Storage Curves.

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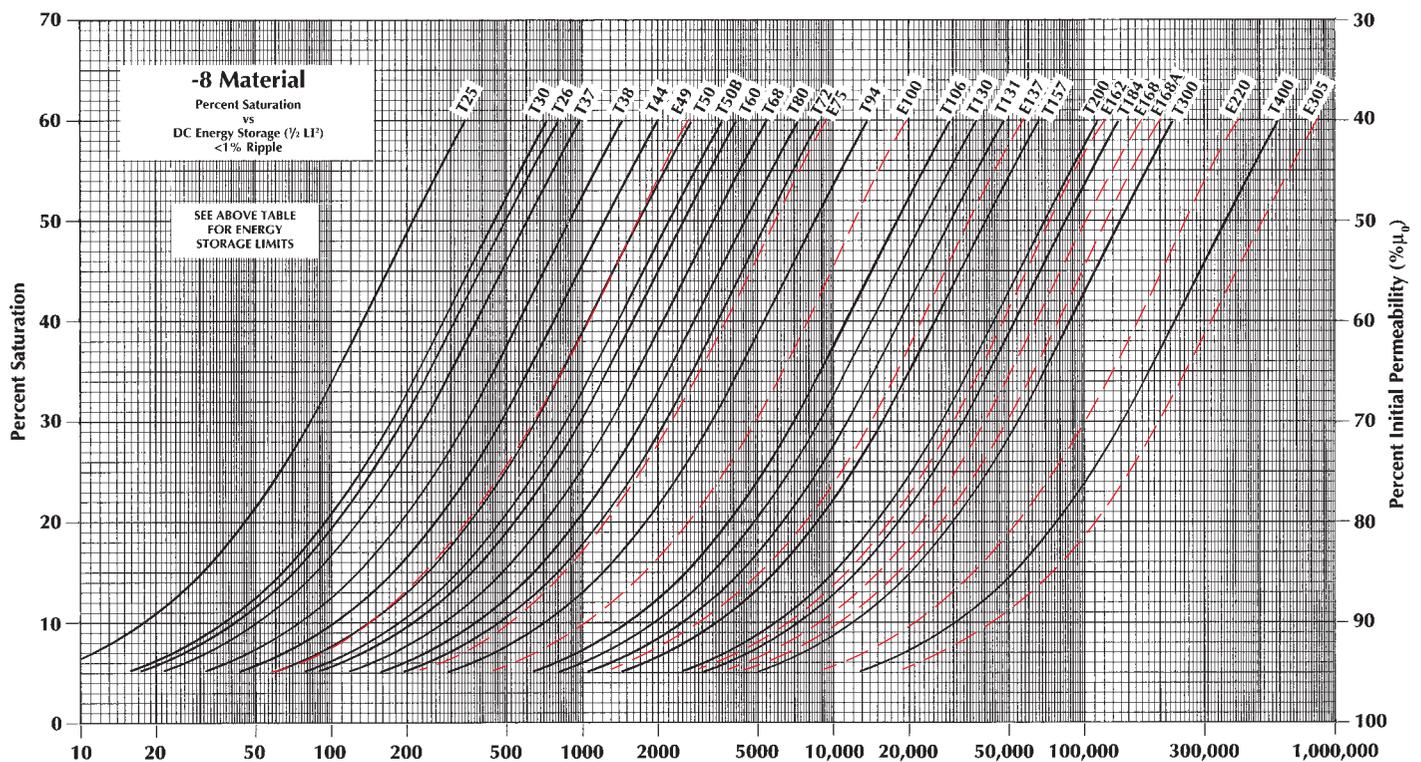
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QUICK REFERENCE A_L VALUES FOR -8 MATERIAL

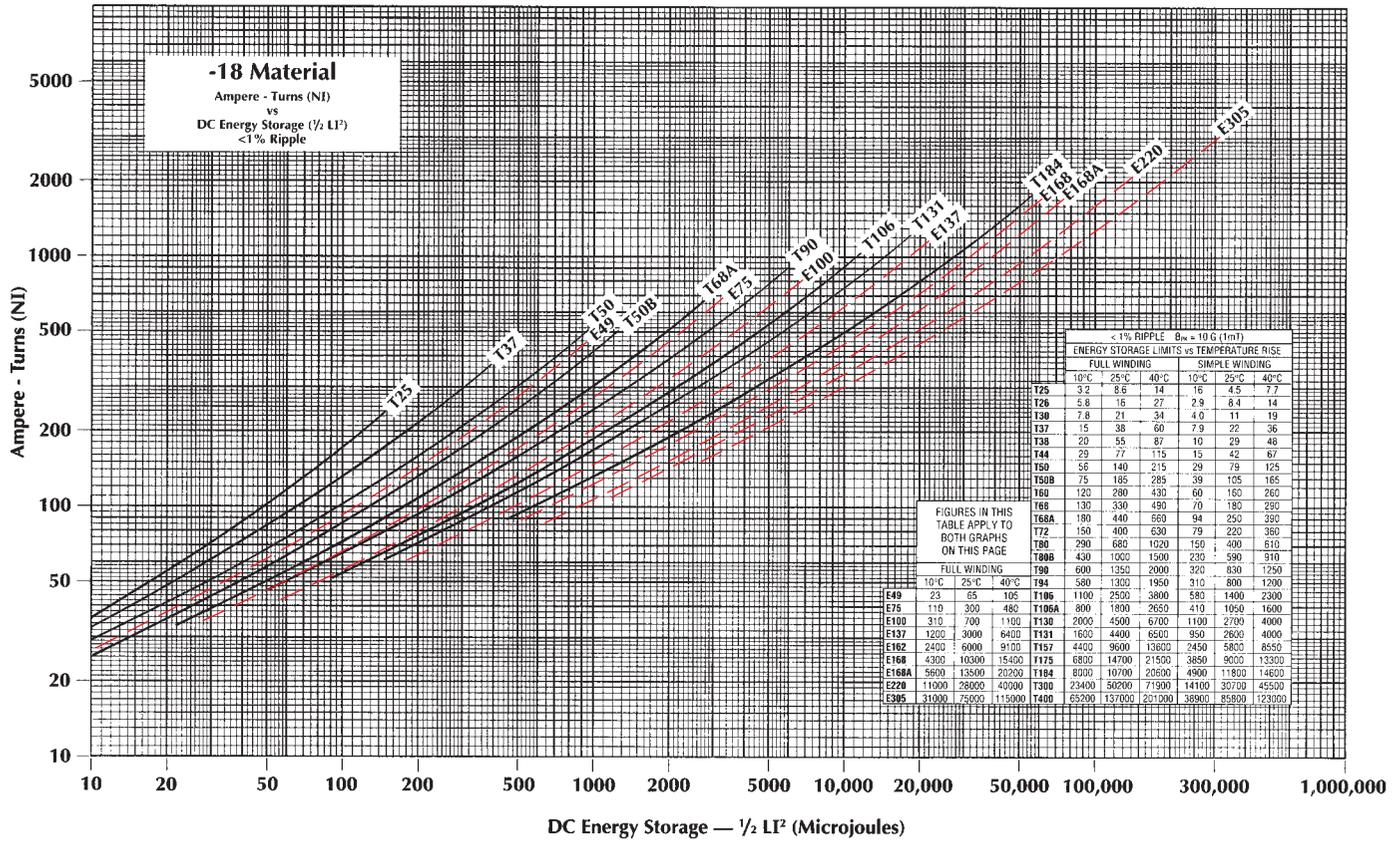
| | | | | | | | | | | | | | | | | | | | | |
|-------------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| PART NO. | T25 | T26 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T72 | T80 | T94 | T106 | T130 | T131 | T157 | T184 | T200 | T300 |
| A_L VALUE | 10.0 | 24.0 | 14.0 | 12.0 | 20.0 | 18.0 | 17.5 | 23.0 | 19.0 | 19.5 | 36.0 | 18.0 | 25.0 | 45.0 | 35.0 | 52.5 | 42.0 | 72.0 | 42.5 | 37.0 |
| PART NO. | T400 | E49 | E75 | E100 | E137 | E162 | E168 | E168A | E220 | E305 | | | | | | | | | | |
| A_L VALUE | 60.0 | 20.5 | 33.5 | 48.0 | 67.0 | 105 | 97.0 | 116 | 143 | 156 | | | | | | | | | | |



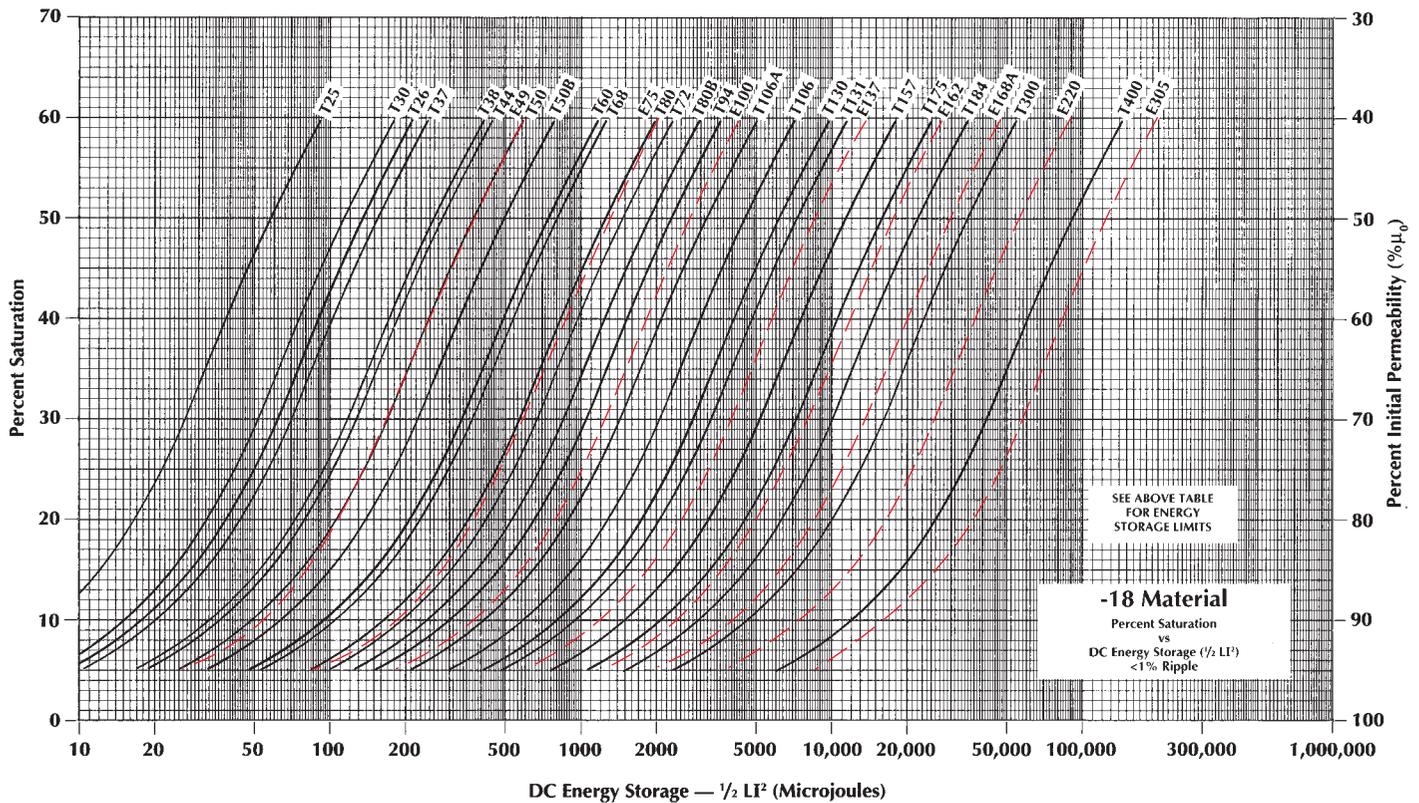
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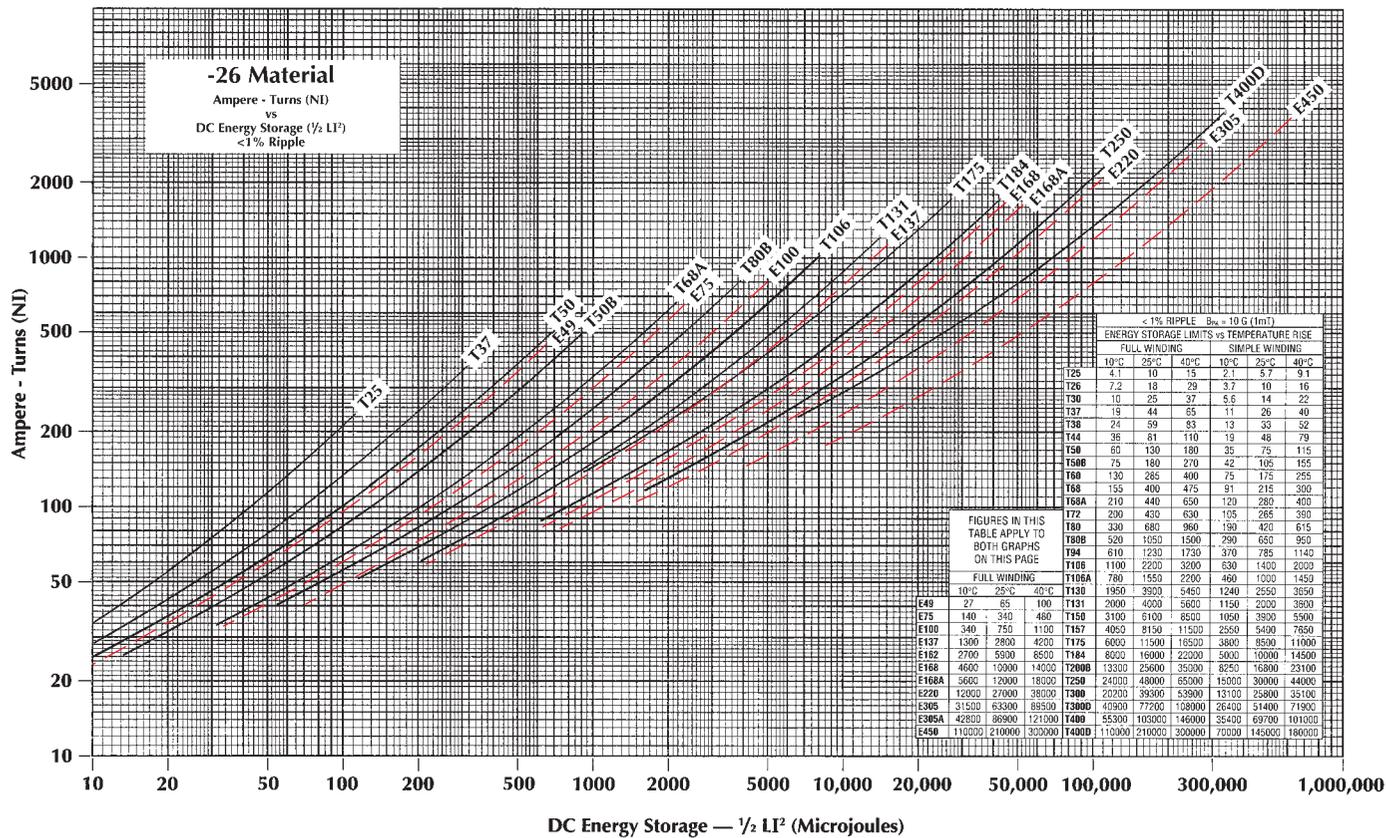


| QUICK REFERENCE A_L VALUES FOR -18 MATERIAL | | | | | | | | | | | | | | | | | | | | |
|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|-------|------|------|------|------|
| PART NO. | T25 | T26 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T72 | T80 | T80B | T94 | T106 | T106A | T130 | T131 | T157 | T175 |
| A_L VALUE | 17.0 | 41.5 | 22.0 | 19.0 | 36.0 | 25.5 | 24.0 | 32.0 | 34.5 | 29.0 | 60.0 | 31.0 | 46.5 | 42.0 | 70.0 | 49.0 | 58.0 | 79.0 | 73.0 | 82.0 |
| PART NO. | T184 | T300 | T400 | | E49 | E75 | E100 | E137 | E162 | E168A | E220 | E305 | | | | | | | | |
| A_L VALUE | 116 | 58.0 | 96.0 | | 29.0 | 45.5 | 65.0 | 100 | 149 | 170 | 196 | 222 | | | | | | | | |



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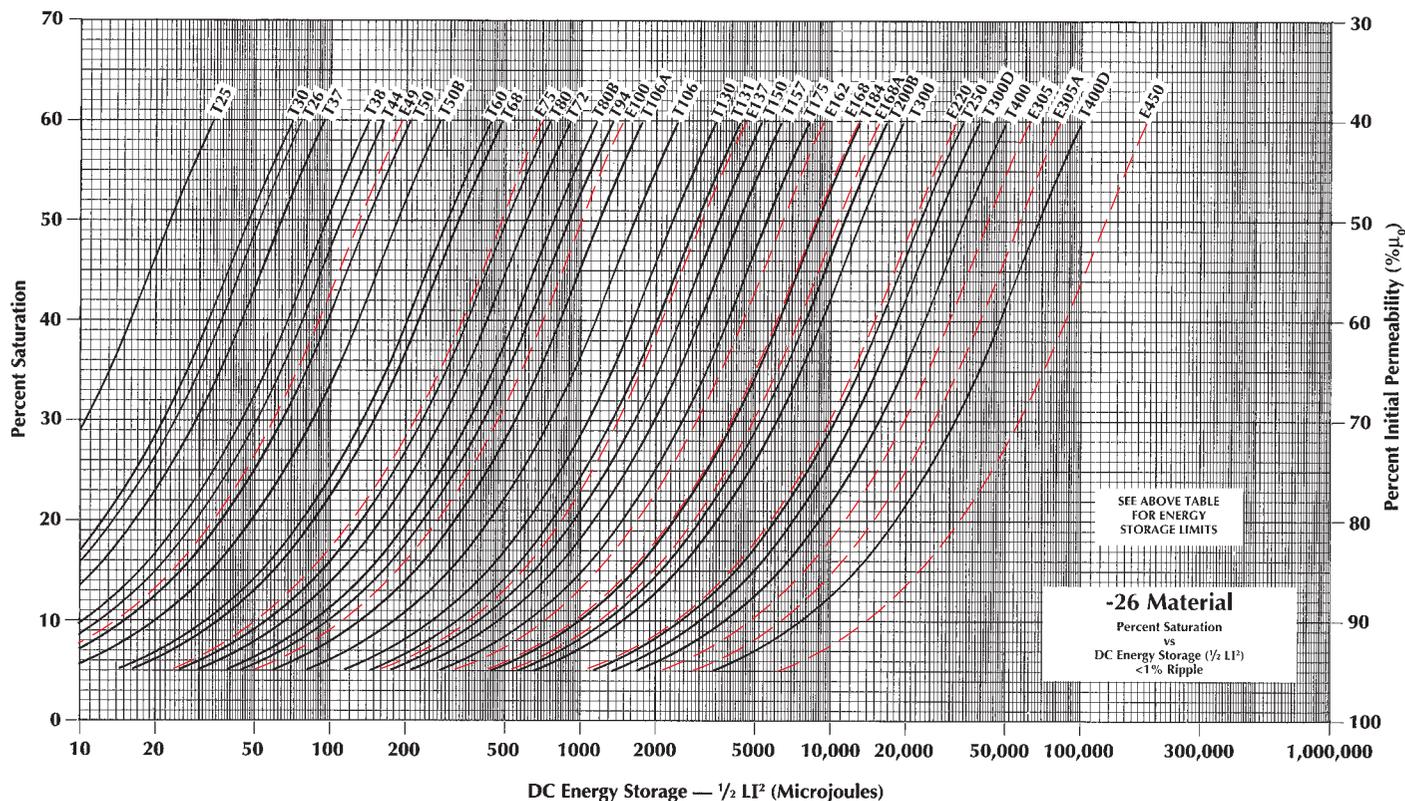
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QUICK REFERENCE A_L VALUES FOR -26 MATERIAL

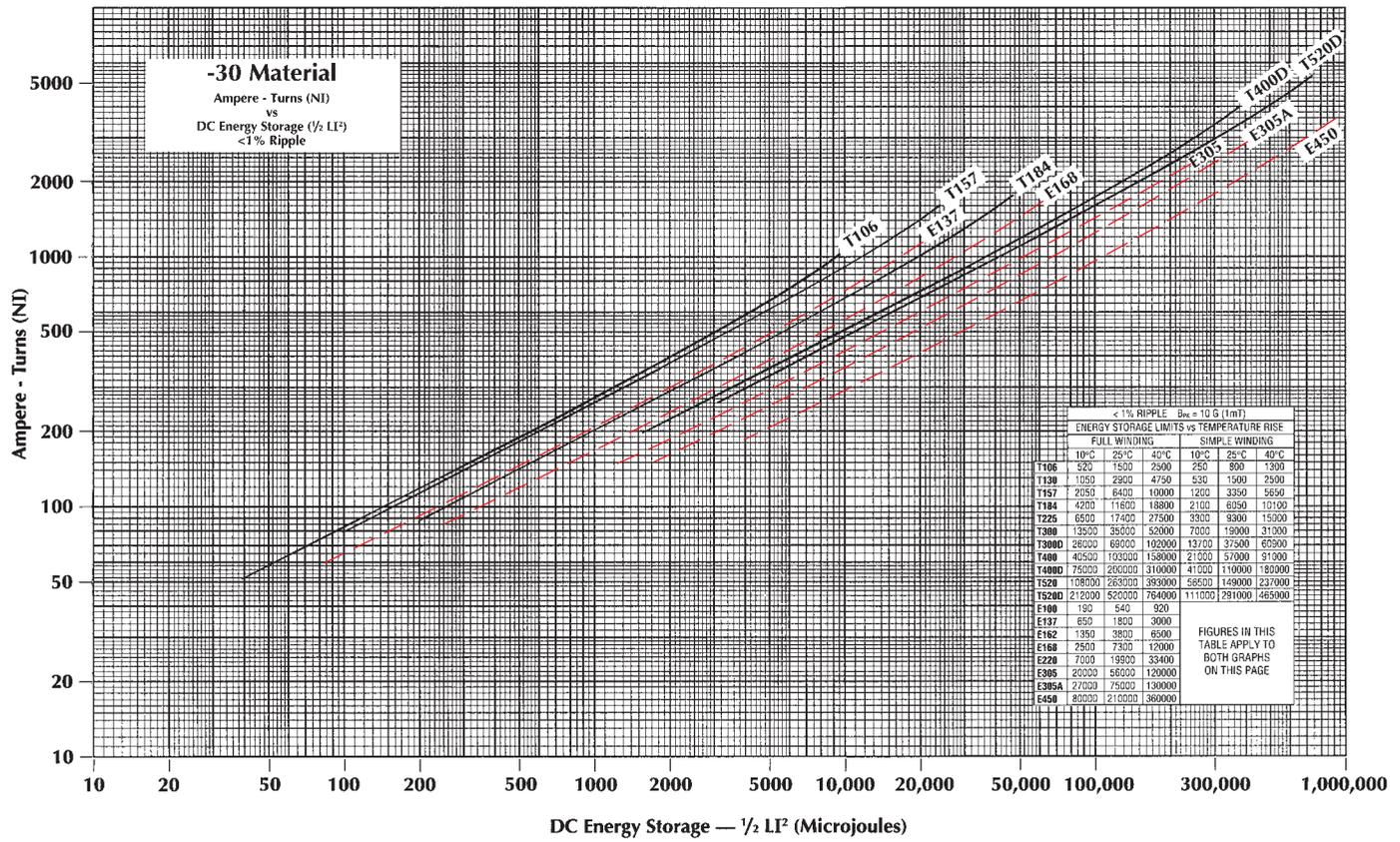
| PART NO. | T25 | T26 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T72 | T80 | T80B | T94 | T106 | T106A | T130 | T131 | T150 | T157 |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|
| A_L VALUE | 24.5 | 57.0 | 33.5 | 28.5 | 49.0 | 37.0 | 33.0 | 43.5 | 50.0 | 43.5 | 90.0 | 46.0 | 71.0 | 60.0 | 93.0 | 67.0 | 81.0 | 116 | 96.0 | 100 |

| PART NO. | T175 | T184 | T200B | T250 | T300 | T300D | T400 | T400D | E49 | E75 | E100 | E137 | E162 | E168 | E168A | E220 | E305 | E305A | E450 |
|-------------|------|------|-------|------|------|-------|------|-------|------|------|------|------|------|------|-------|------|------|-------|------|
| A_L VALUE | 105 | 169 | 160 | 242 | 80 | 160 | 131 | 262 | 38.0 | 64.0 | 92.0 | 134 | 210 | 195 | 232 | 275 | 287 | 382 | 540 |

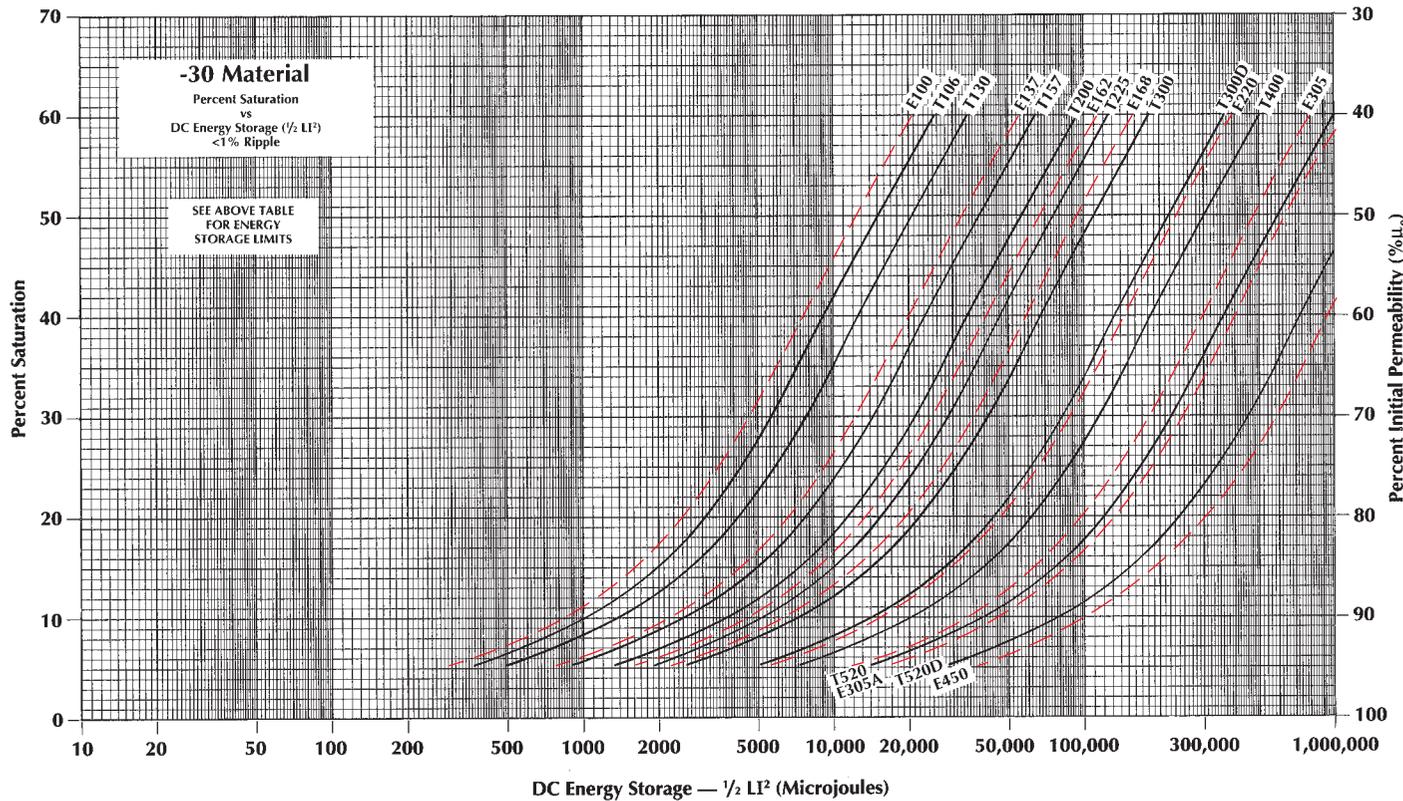


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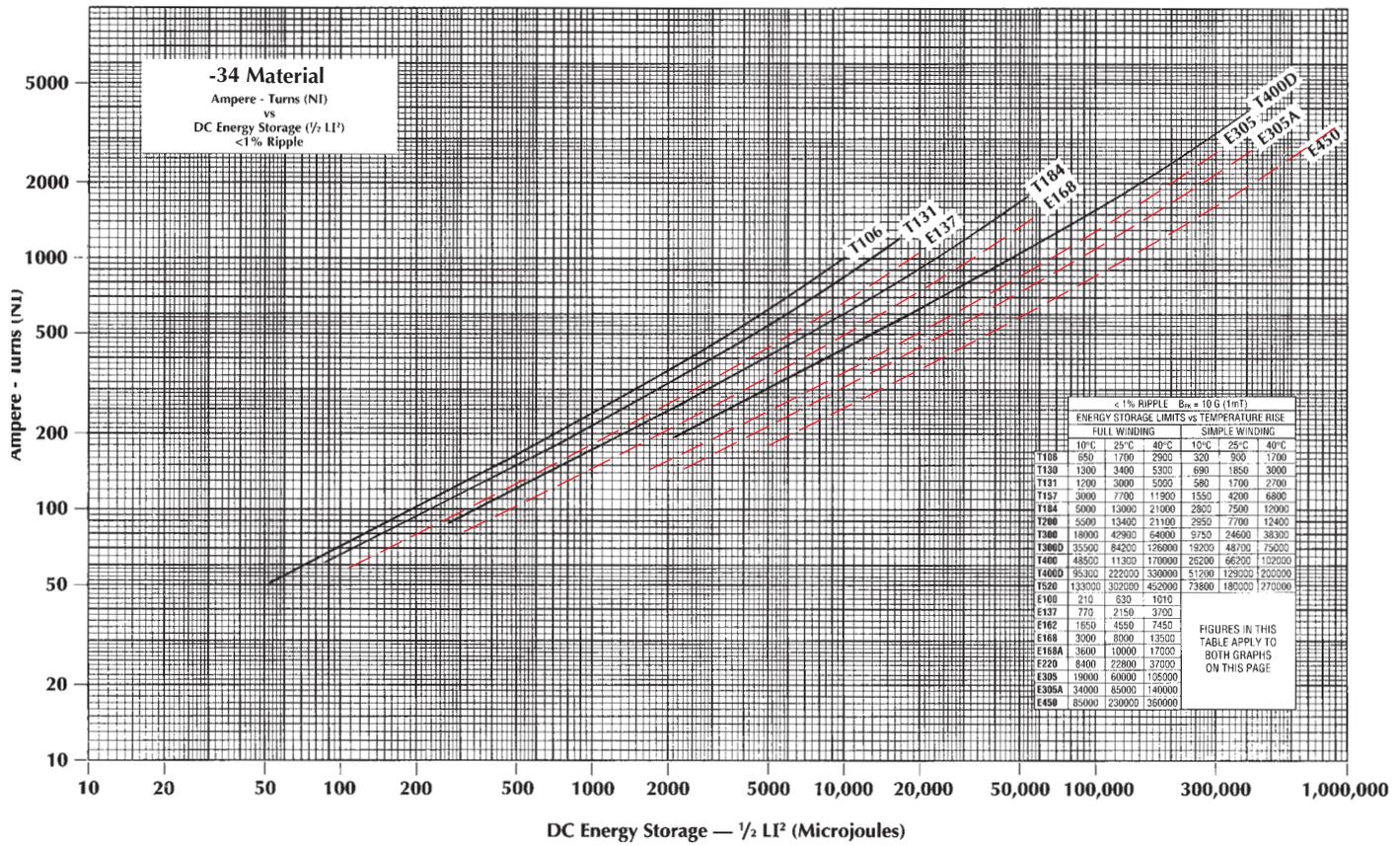
| QUICK REFERENCE A_L VALUES FOR -30 MATERIAL | | | | | | | | | | |
|---|------|------|-------|------|------|-------|------|------|-------|--|
| PART NO. | T106 | T130 | T157 | T225 | T300 | T300D | T400 | T520 | T520D | |
| A_L VALUE | 30.0 | 25.0 | 31.5 | 28.0 | 23.0 | 46.0 | 40.5 | 45.0 | 90.0 | |
| PART NO. | E220 | E305 | E305A | E450 | | | | | | |
| A_L VALUE | 107 | 124 | 165 | 235 | | | | | | |



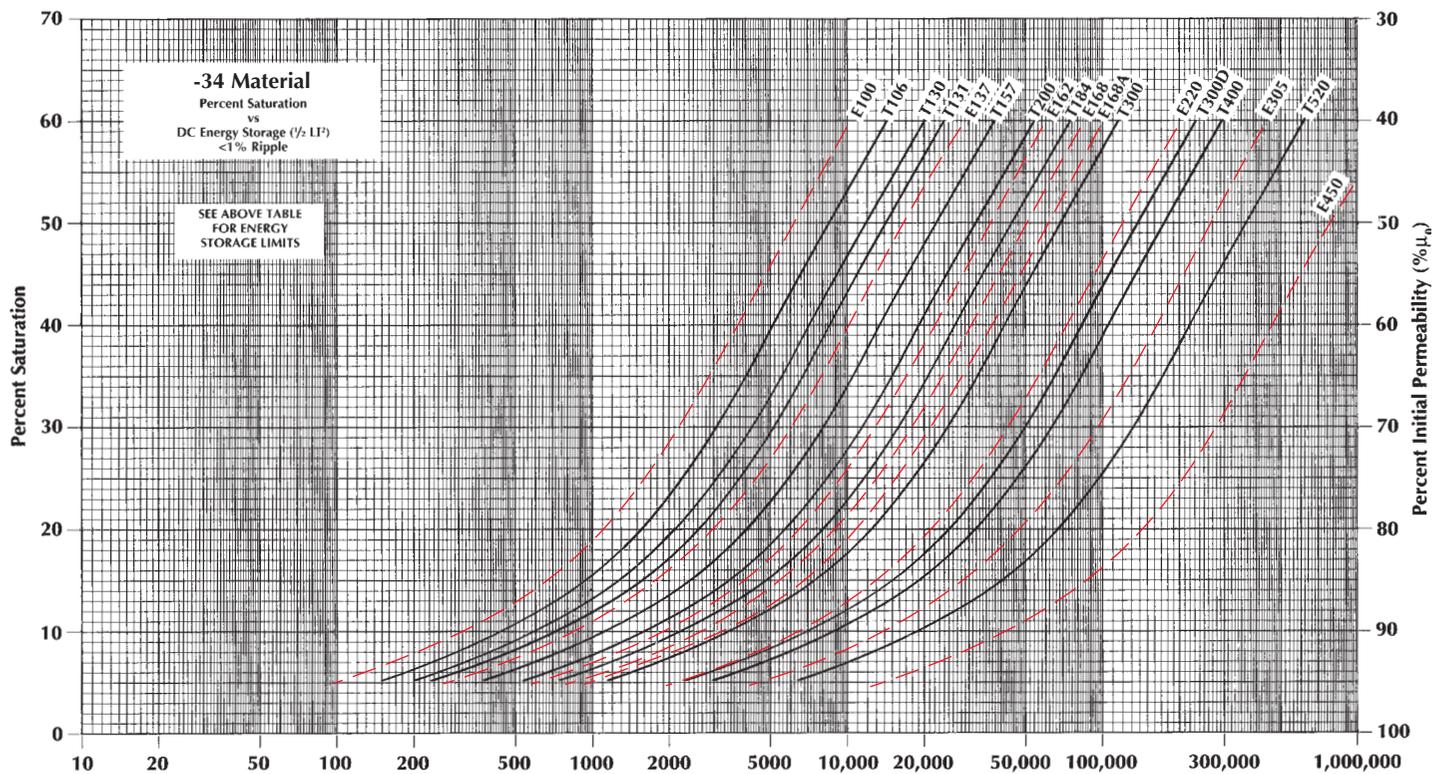
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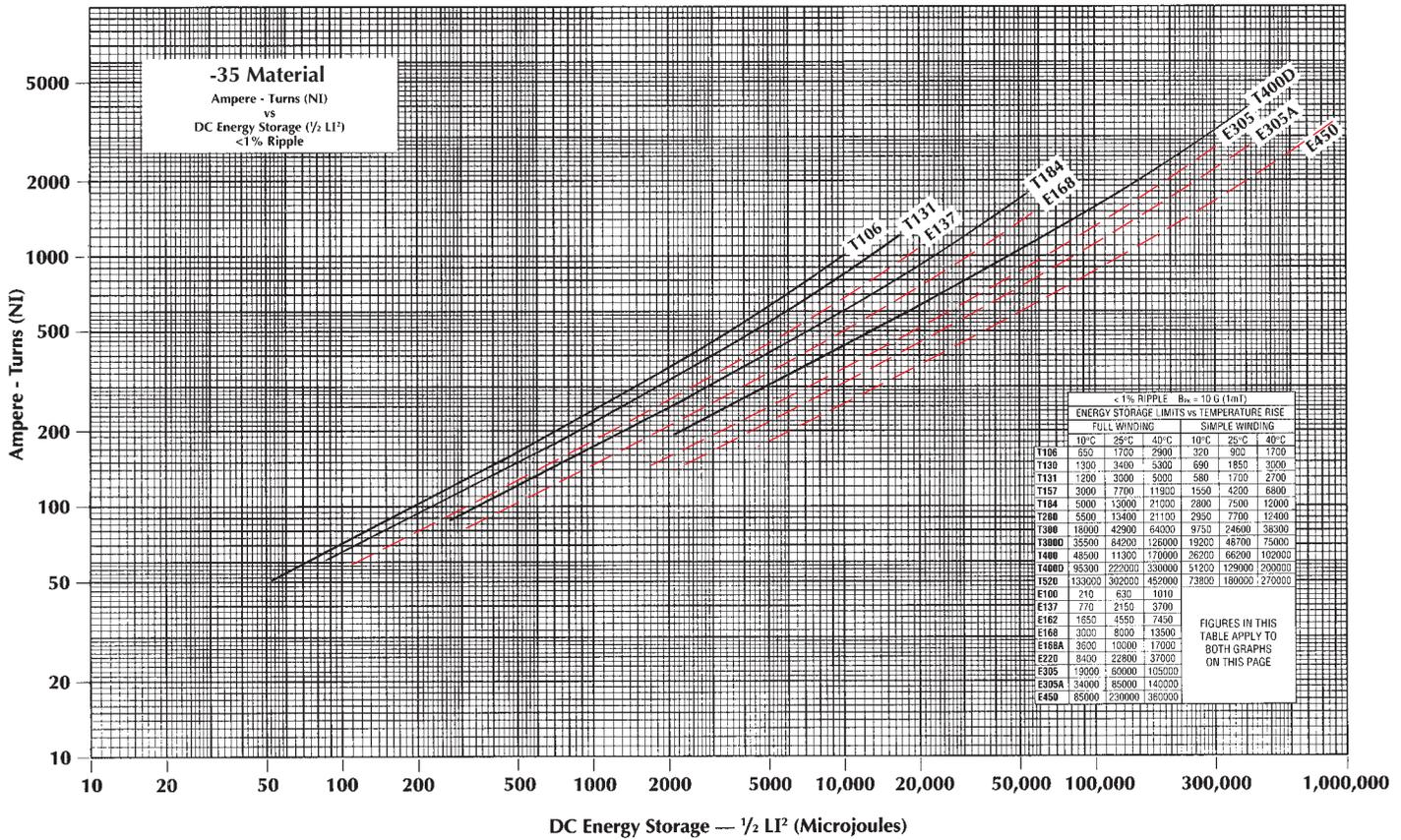
| QUICK REFERENCE A_L VALUES FOR -34 MATERIAL | | | | | | | | | | |
|---|------|------|------|------|------|------|------|-------|------|------|
| PART NO. | T106 | T130 | T131 | T157 | T184 | T200 | T300 | T300D | T400 | T520 |
| A_L VALUE | 40.0 | 33.5 | 46.5 | 43.5 | 70.0 | 37.0 | 34.5 | 69.0 | 55.0 | 65.0 |
| PART NO. | E220 | E305 | E450 | | | | | | | |
| A_L VALUE | 136 | 150 | 300 | | | | | | | |



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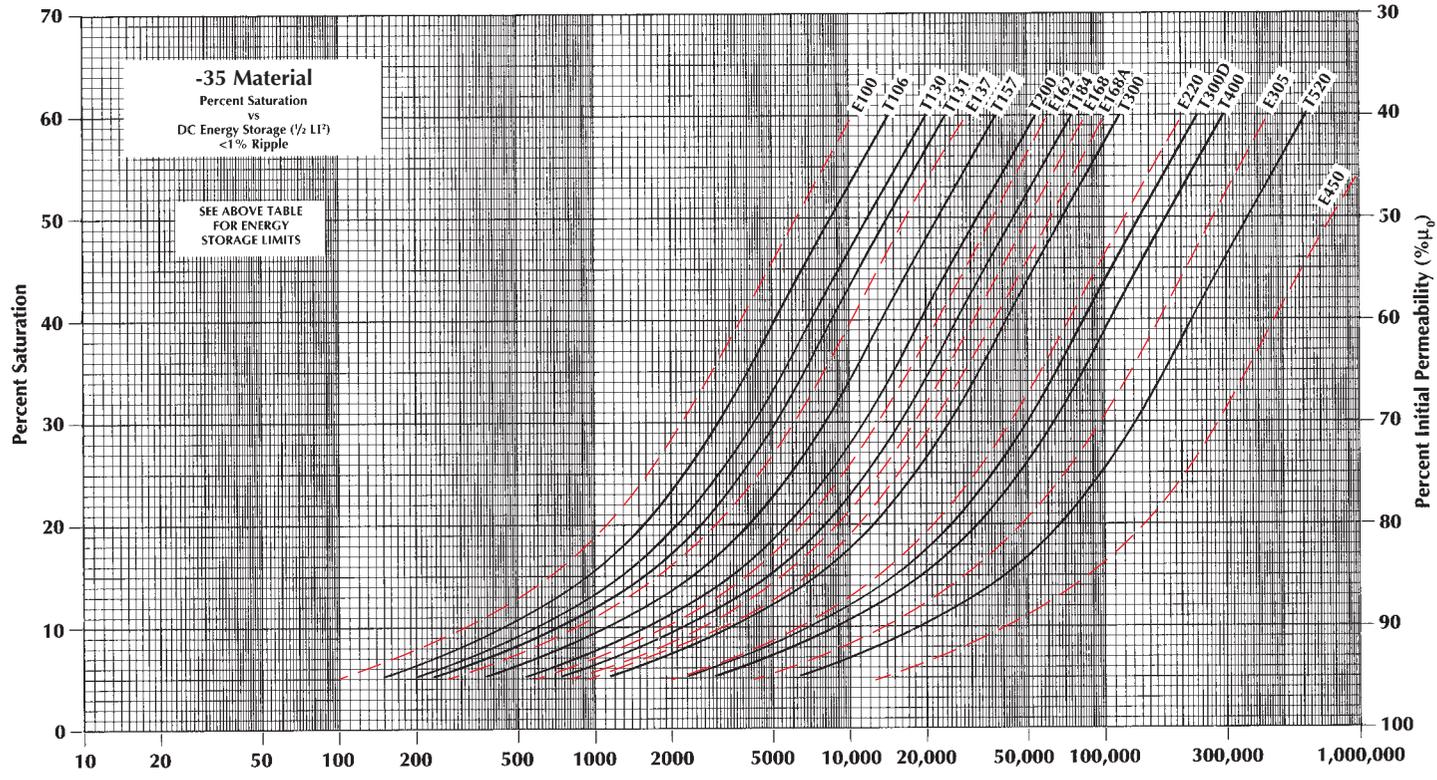
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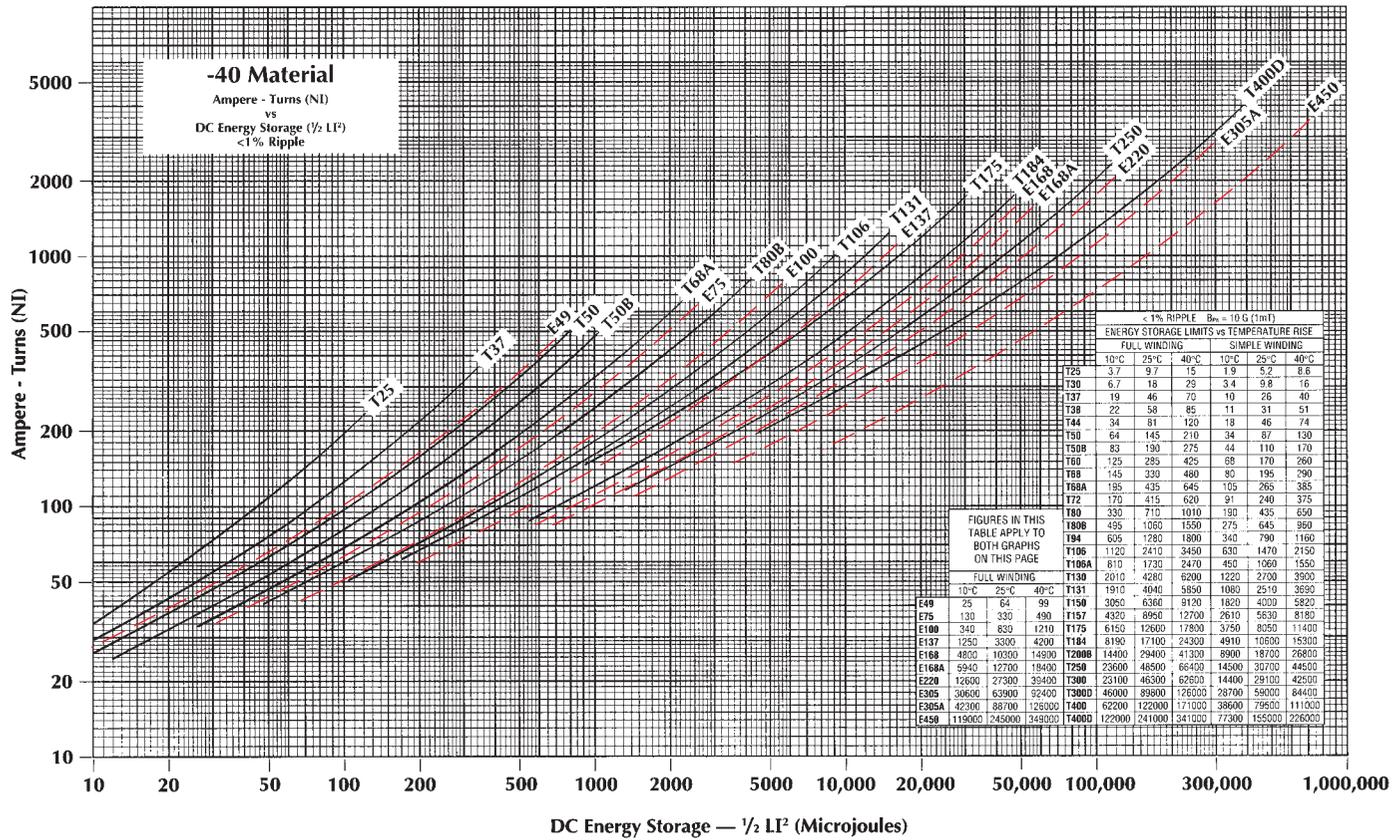
QUICK REFERENCE A_L VALUES FOR -35 MATERIAL

| | | | | | | | | | | |
|-------------|------|------|------|------|------|------|------|-------|------|------|
| PART NO. | T106 | T130 | T131 | T157 | T184 | T200 | T300 | T300D | T400 | T520 |
| A_L VALUE | 40.0 | 33.5 | 46.5 | 43.5 | 70.0 | 37.0 | 34.5 | 69.0 | 55.0 | 65.0 |
| PART NO. | E220 | E305 | E450 | | | | | | | |
| A_L VALUE | 136 | 150 | 300 | | | | | | | |

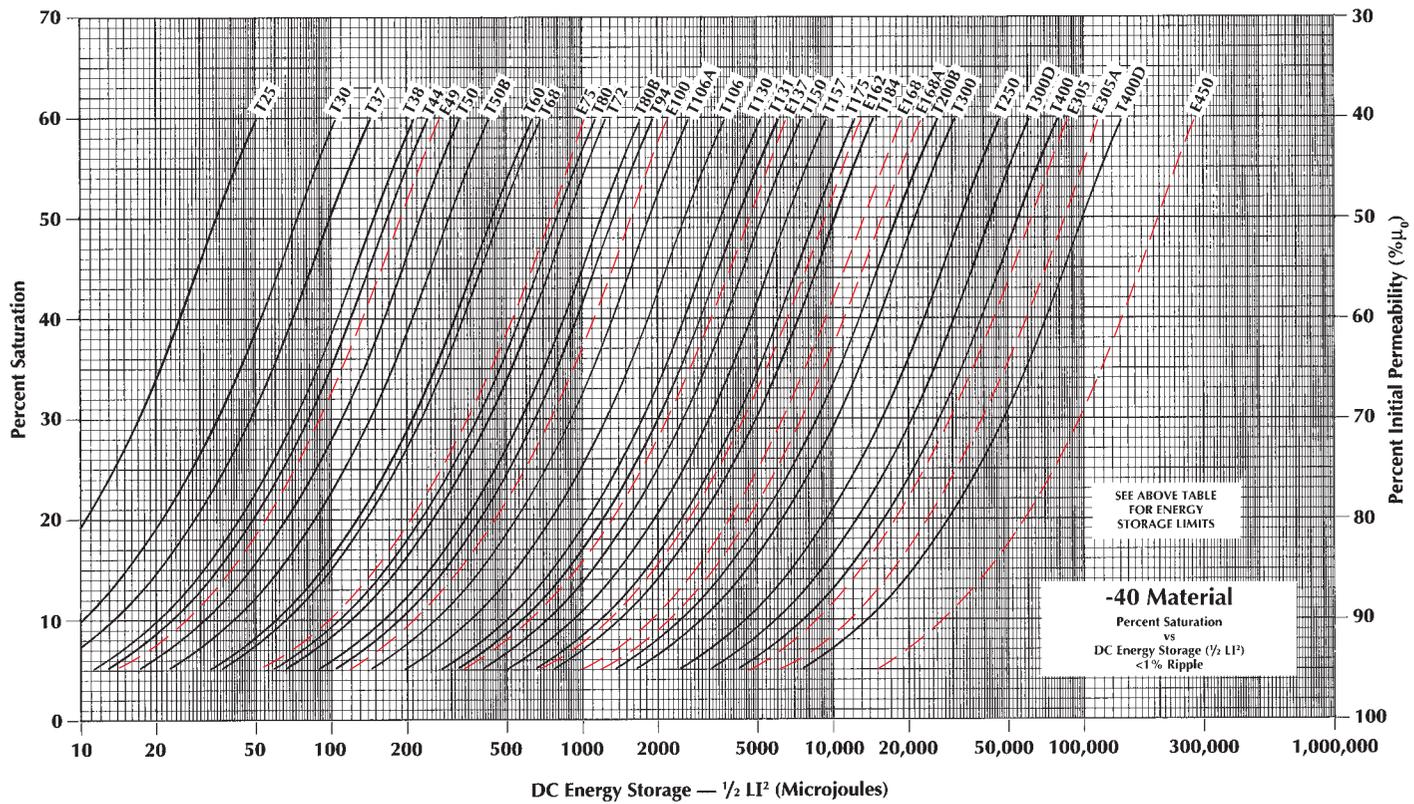


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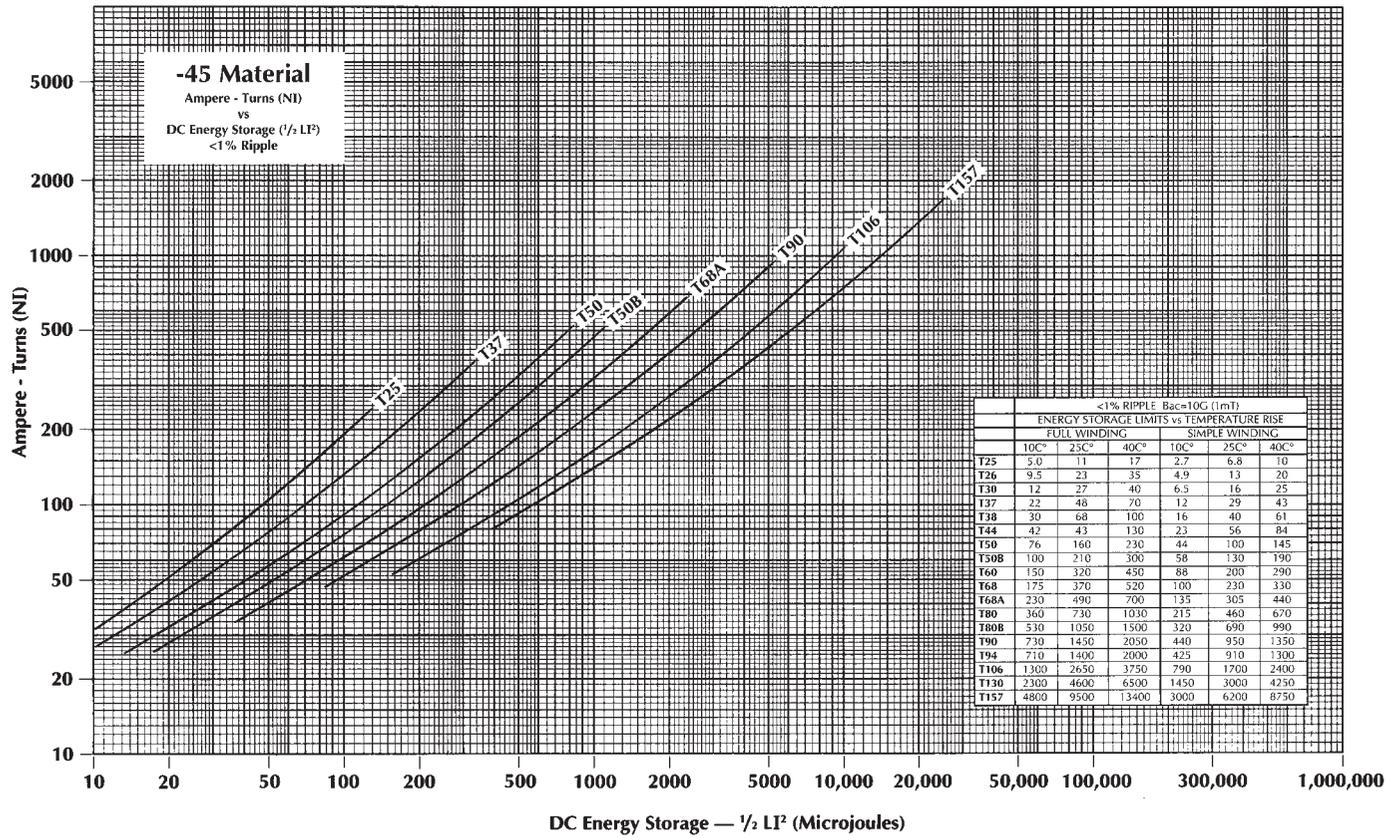
| QUICK REFERENCE A_L VALUES FOR -40 MATERIAL | | | | | | | | | | | | | | | | | | | | |
|---|------|-------|------|------|-------|------|-------|------|------|------|------|------|------|-------|-------|-------|------|------|------|------|
| PART NO. | T25 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T72 | T80 | T80B | T94 | T106 | T106A | T130 | T131 | T150 | T157 | T175 |
| A_L VALUE | 20.5 | 28.0 | 24.5 | 41.5 | 31.0 | 29.5 | 38.5 | 41.5 | 35.0 | 71.0 | 39.5 | 59.0 | 49.0 | 81.0 | 58.0 | 69.0 | 93.0 | 78.0 | 86.0 | 90.0 |
| PART NO. | T184 | T200B | T250 | T300 | T300D | T400 | T400D | E49 | E75 | E100 | E137 | E162 | E168 | E168A | E305 | E305A | E450 | | | |
| A_L VALUE | 143 | 142 | 194 | 71.0 | 142 | 115 | 230 | | 31.5 | 55.0 | 81.0 | 113 | 175 | 163 | 196 | 255 | 339 | 480 | | |



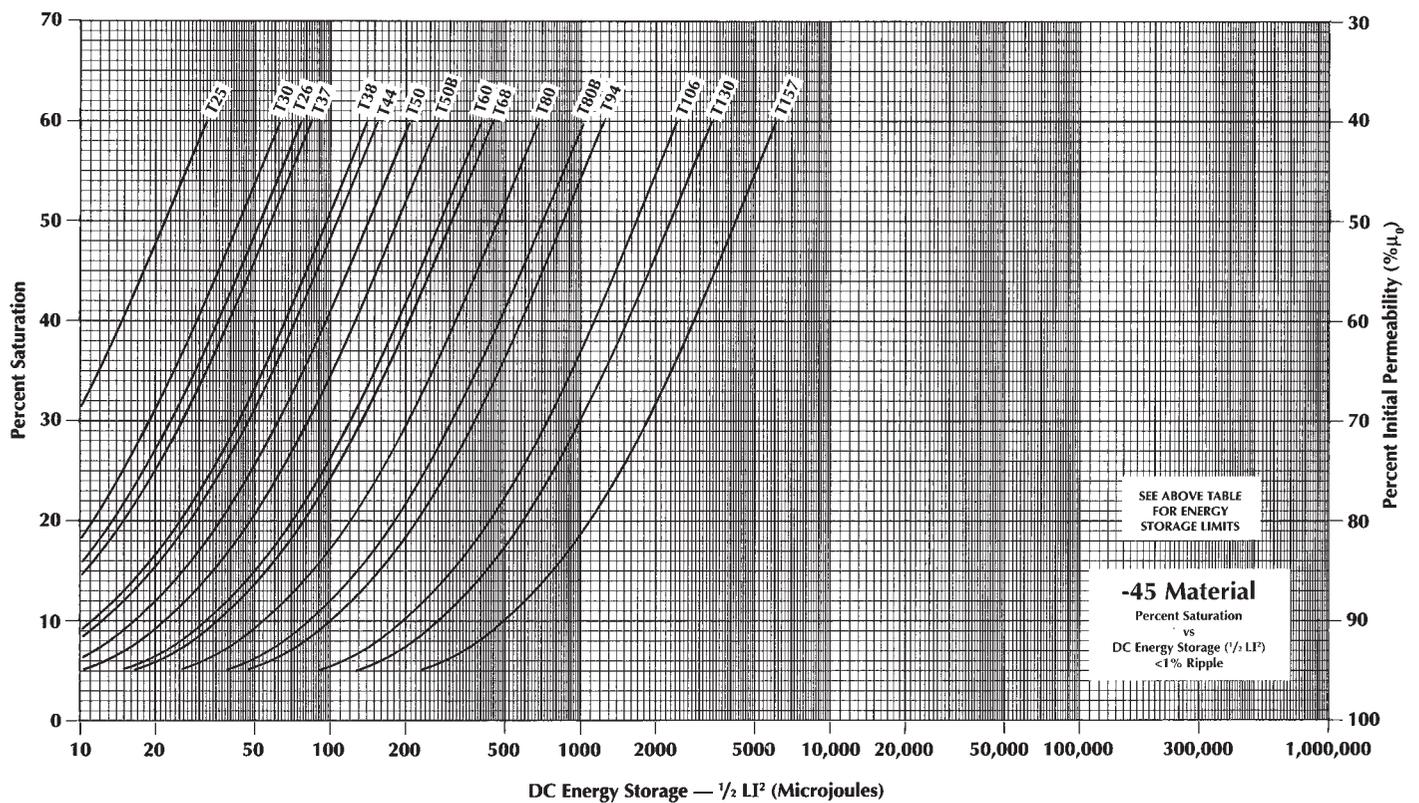
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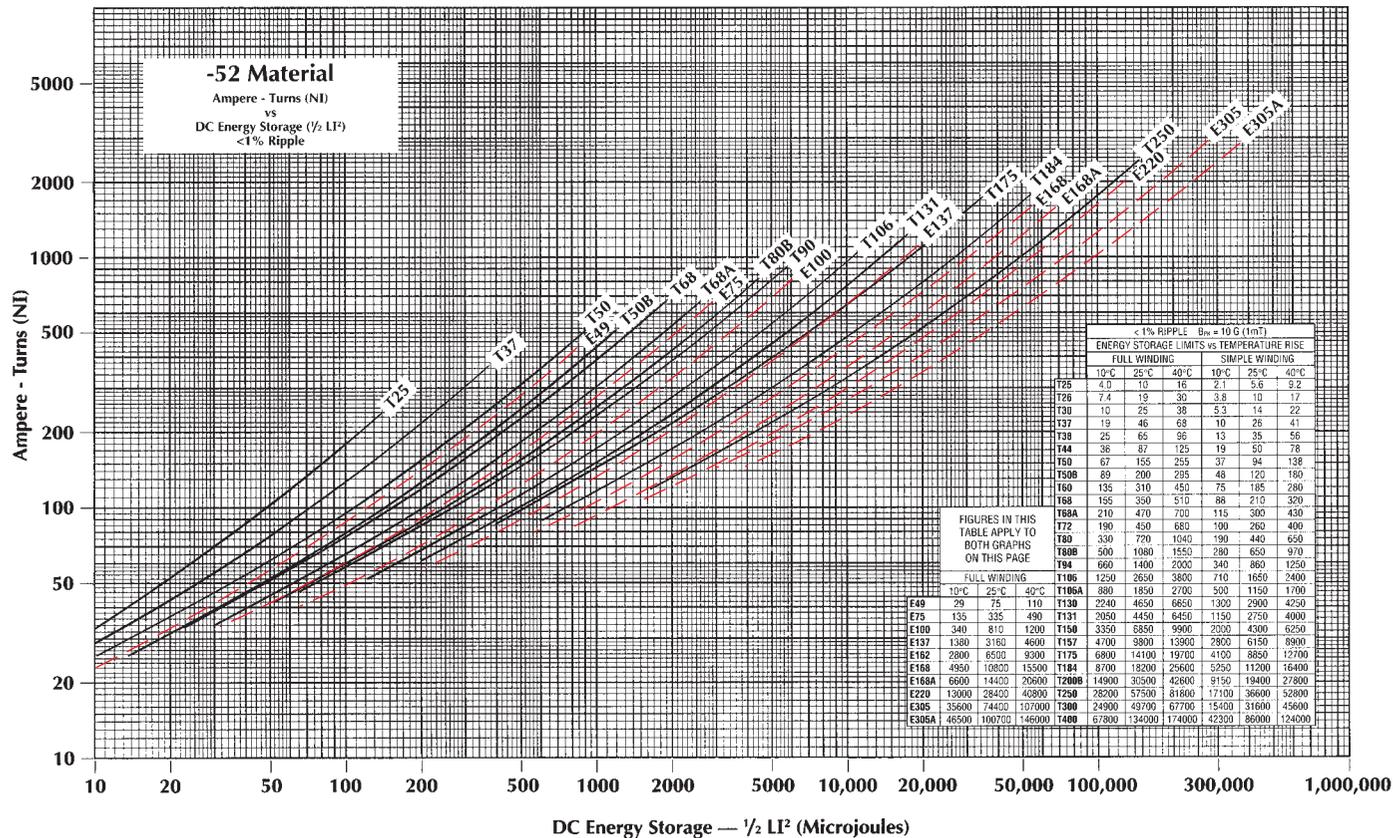


| QUICK REFERENCE A_L VALUES FOR -45 MATERIAL | | | | | | | | | | | | | | | | | | |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|-------|
| PART NO. | T25 | T26 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T68A | T80 | T80B | T90 | T94 | T106 | T130 | T157 |
| A_L VALUE | 31.0 | 77.0 | 40.5 | 34.0 | 65.0 | 46.5 | 44.0 | 58.0 | 62.0 | 53.0 | 71.0 | 56.0 | 84.0 | 85.0 | 76.0 | 125.0 | 105.0 | 130.0 |



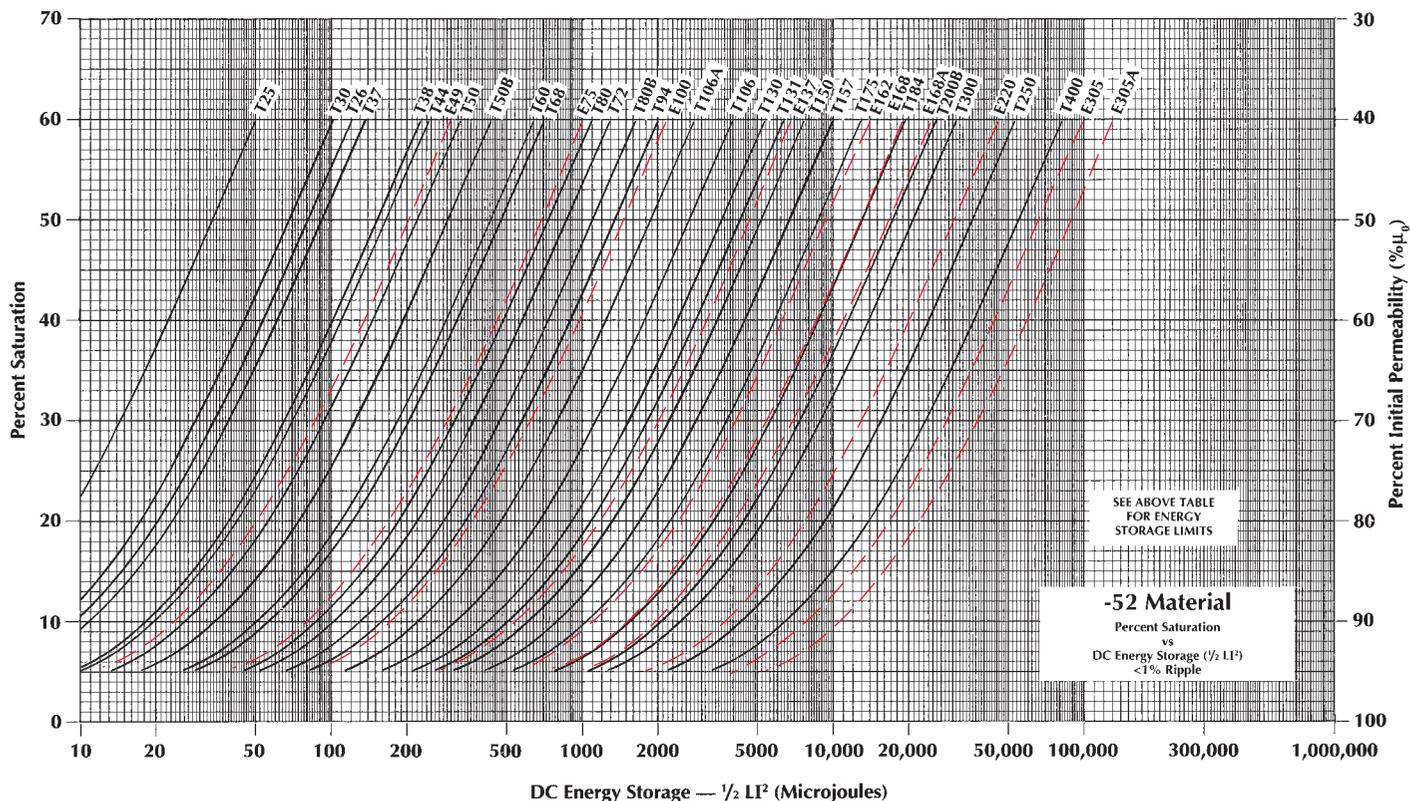
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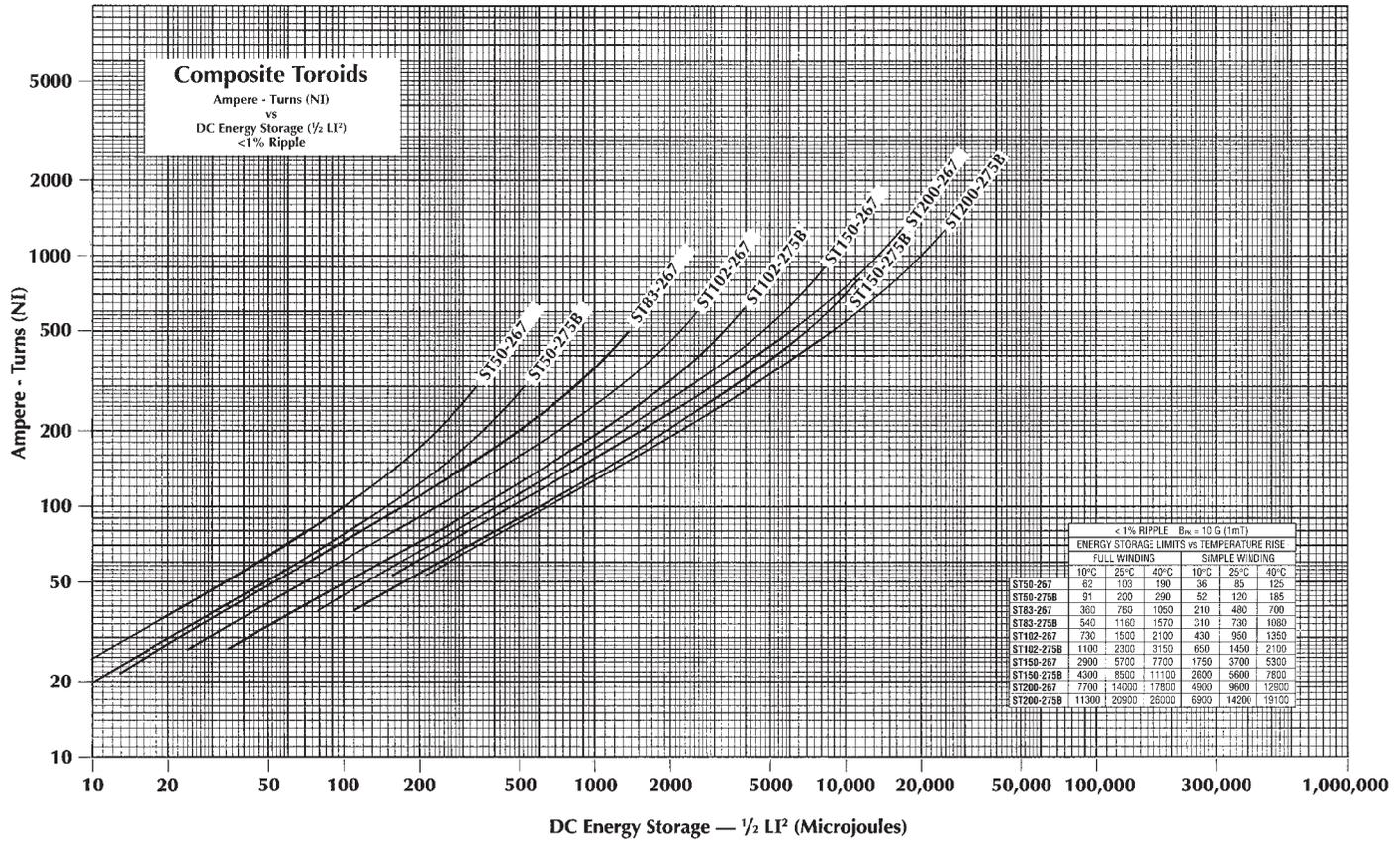
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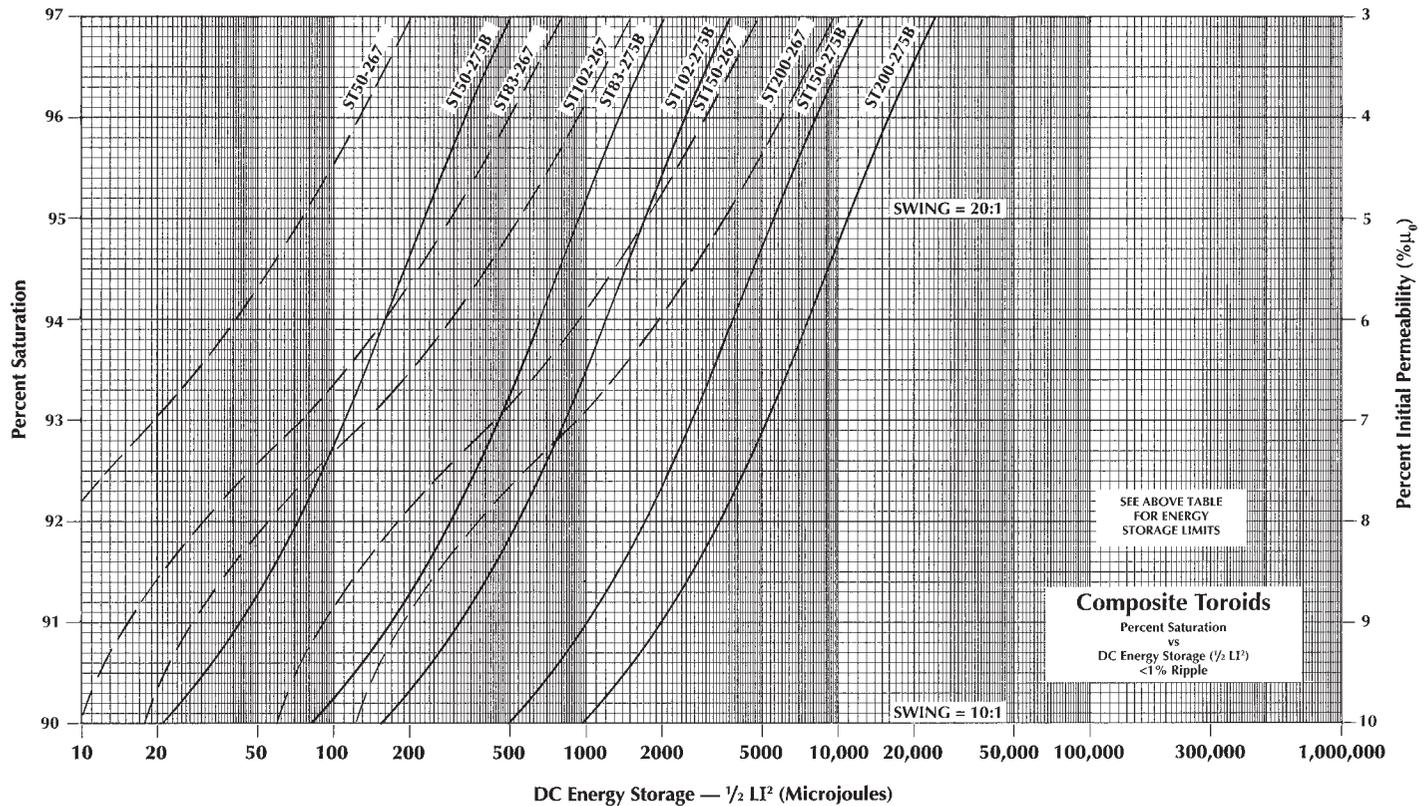
| PART NO. | T25 | T26 | T30 | T37 | T38 | T44 | T50 | T50B | T60 | T68 | T72 | T80 | T80B | T94 | T106 | T106A | T130 | T131 | T150 | T157 |
|-------------|------|------|-------|------|------|------|------|------|------|------|------|------|------|-------|------|-------|-------|------|------|------|
| A_L VALUE | 23.0 | 56.0 | 30.5 | 26.0 | 49.0 | 35.0 | 33.0 | 43.5 | 47.0 | 40.0 | 82.0 | 42.0 | 63.0 | 57.0 | 95.0 | 67.0 | 79.0 | 108 | 89.0 | 99.0 |
| PART NO. | T175 | T184 | T200B | T250 | T300 | T400 | | E49 | E75 | E100 | E137 | E162 | E168 | E168A | E220 | E305 | E305A | | | |
| A_L VALUE | 105 | 159 | 155 | 242 | 80.0 | 131 | | | 38.0 | 59.0 | 85.0 | 131 | 199 | 179 | 230 | 262 | 287 | 382 | | |

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| QUICK REFERENCE A_L VALUES FOR COMPOSITE TOROIDS | | | | | | | | | | |
|--|----------|-----------|----------|-----------|-----------|------------|-----------|------------|-----------|------------|
| PART NO. | ST50-267 | ST50-275B | ST83-267 | ST83-275B | ST102-267 | ST102-275B | ST150-267 | ST150-275B | ST200-267 | ST200-275B |
| A_L VALUE | 450 | 475 | 625 | 650 | 800 | 825 | 1250 | 1300 | 1275 | 1325 |



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DC APPLICATIONS

DC INDUCTOR DESIGN EXAMPLES

EXAMPLE #1

Requirements: 45 μH at 7.75 amps DC
($< 1\%$ ripple current)

EXAMPLE #2

Requirements: 45 μH at 7.75 amps DC
60 μH max at 0 amps DC
(25% saturation max)
($< 1\%$ ripple current)

Determine importance of the following design considerations: component size, temperature rise and cost.

Example #1: Design Priorities
cost
temperature rise
component size

Example #2: Design Priorities
component size
temperature rise
cost

Select appropriate materials to be considered.

-26, -52 and -40 Materials should be considered since the inductor requirements do not limit swing and these materials are the most cost effective.

-8, -18, -28 and -33 Materials should be considered because of the limited swing requirements.

Calculate the required Energy Storage ($1/2 LI^2$)

$$1/2 LI^2 = (1/2) (45) (7.5)^2 = 1266 \mu\text{J}$$

$$1/2 LI^2 = (1/2) (45) (7.5)^2 = 1266 \mu\text{J}$$

Select core size and shape

-26 Material will be used in this example. Refer to the Energy Storage Table on page 40. The T106 size toroid will be selected in order to keep the winding "simple" and the temperature rise around 25C° . The E137 is an attractive choice if bobbin winding is preferred.

The -8 Material is the best choice since component size is the primary concern. The Energy Storage Table on page 38 indicates that the T94 size toroid is the smallest core able to meet the energy storage requirements at $< 40\text{C}^\circ$ temperature rise. We must also check the % saturation curves (page 38 bottom) to verify that this core will be operating at less than 25% saturation.

Determine number of turns

The curve at the top of page 40 indicates the T106 will require 217 ampere-turns to produce 1266 μJ .

The curves at the bottom of page 38 indicate that the T94 will be operating at 84.5% of initial permeability (15.5% saturation) to produce 1266 μJ . Use the following formula to calculate turns:

Therefore,
 $NI = 162 / 7.5 = 29$ turns

In the case of the E137 core, the curves indicate that 162 ampere-turns will be required to provide 1266 μJ .

Therefore,
 $NI = 162 / 7.5 = 22$ turns

$$N = \left[\frac{\text{desired } L \text{ (nH)}}{(A_L) (\% \mu_o)} \right]^{1/2}$$

$$N = \left[\frac{45,000}{(25.0) (.85)} \right]^{1/2} = 46 \text{ turns}$$

Determine wire size

In the case of the T106 toroidal core, the "simple" winding limits are close estimates of typical single layer windings, refer to the Single Layer Winding Table on page 60. This table shows that #7 wire will fit in a single layer and result in a 25C° temperature rise from the wire. In the case of the E137, referring to the Full Winding Table on page 61 indicates that up to #13 wire can be used.

Since a "full" winding was required to keep the temperature rise of the T94 below 40C° , refer to the winding table on page 60. This table indicates that #16 wire should be used.

This table also contains the information necessary to calculate the DC resistance of a winding.

Solution: T106-26 with 29 turns #17
or E137-26 with 22 turns #14

Solution: Part number T94-8/90
with 46 turns #16

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DC APPLICATIONS

| DC Inductor Examples | | | | | | | | | | |
|--|-----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|--------------------------|--------------------------|--------------------------|--|--|
| TOROIDAL CORES: SINGLE LAYER WINDINGS | | | | | | | | | | |
| DC CURRENT WIRE * SIZE | 1.0 amps #28 AWG | 2.5 amps #24 AWG | 5.0 amps #20 AWG | 7.5 amps #18 AWG | 10 amps #15 AWG | 15 amps #13 AWG | 20 amps #11 AWG | 30 amps #9 AWG | | |
| T50-52 | 94 μ H 59 turns | 30.7 μ H 37 turns | 10.2 μ H 22 turns | 5.0 μ H 16 turns | 2.8 μ H 12 turns | 1.3 μ H 8 turns | 0.7 μ H 6 turns | 0.2 μ H 3 turns | | |
| T68-52A | 250 μ H 74 turns | 81.6 μ H 46 turns | 27.6 μ H 28 turns | 16.7 μ H 21 turns | 8.3 μ H 16 turns | 4.4 μ H 12 turns | 2.1 μ H 8 turns | 0.8 μ H 5 turns | | |
| T90-52 | 680 μ H 115 turns | 224 μ H 72 turns | 74.0 μ H 44 turns | 40.9 μ H 34 turns | 23.6 μ H 26 turns | 13.0 μ H 20 turns | 7.3 μ H 15 turns | 3.7 μ H 11 turns | | |
| T106-52 | 1,080 μ H 118 turns | 362 μ H 74 turns | 124 μ H 46 turns | 69.3 μ H 36 turns | 39.0 μ H 27 turns | 21.3 μ H 21 turns | 11.4 μ H 15 turns | 5.8 μ H 11 turns | | |
| T131-52 | 1,660 μ H 134 turns | 550 μ H 85 turns | 188 μ H 52 turns | 107 μ H 41 turns | 63.0 μ H 32 turns | 33.3 μ H 24 turns | 18.8 μ H 18 turns | 9.2 μ H 13 turns | | |
| T157-52 | 3,320 μ H 204 turns | 1,090 μ H 129 turns | 380 μ H 81 turns | 213 μ H 64 turns | 127 μ H 50 turns | 69.3 μ H 39 turns | 40.1 μ H 30 turns | 21.5 μ H 23 turns | | |
| T184-52 | 5,400 μ H 202 turns | 1,790 μ H 129 turns | 624 μ H 81 turns | 345 μ H 63 turns | 210 μ H 50 turns | 114 μ H 38 turns | 65.0 μ H 29 turns | 34.0 μ H 22 turns | | |
| T250-52 | 14,800 μ H 270 turns | 4,960 μ H 172 turns | 1,720 μ H 108 turns | 978 μ H 86 turns | 591 μ H 67 turns | 332 μ H 59 turns | 195 μ H 41 turns | 102 μ H 31 turns | | |
| T400-52 | 26,100 μ H 494 turns | 8,690 μ H 317 turns | 3,100 μ H 160 turns | 1,760 μ H 157 turns | 1,050 μ H 126 turns | 590 μ H 100 turns | 347 μ H 78 turns | 190 μ H 61 turns | | |
| E CORES: FULL BOBBIN WINDINGS | | | | | | | | | | |
| DC CURRENT WIRE * SIZE | 2.5 amps #20 AWG | 5.0 amps #18 AWG | 10 amps #14 AWG | 15 amps #12 AWG | 20 amps #11 AWG | 30 amps FOIL | 50 amps FOIL | 100 amps FOIL | | |
| E137-52 | 976 μ H 112 turns | 348 μ H 71 turns | 64.0 μ H 29 turns | 25.8 μ H 18 turns | 15.3 μ H 14 turns | 8.7 μ H 11 turns | 3.4 μ H 7 turns | 0.7 μ H 3 turns | | |
| E168-52 | 4,000 μ H 212 turns | 1,420 μ H 136 turns | 260 μ H 55 turns | 105 μ H 34 turns | 64.0 μ H 27 turns | 41.1 μ H 20 turns | 9.2 μ H 10 turns | 3.0 μ H 6 turns | | |
| E220-52 | 11,700 μ H 303 turns | 4,080 194 turns | 760 μ H 78 turns | 311 μ H 49 turns | 190 μ H 39 turns | 88.9 μ H 27 turns | 32.0 μ H 16 turns | 8.0 μ H 8 turns | | |

* Based on max temperature rise of 40C° due to copper and core loss

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DC APPLICATIONS

GAPPING IRON POWDER E CORES

Gapping iron powder E Cores increases energy storage capabilities beyond that inherent in the distributed air gap structure that is characteristic of the material. Gapping of E Cores is advantageous only in the higher permeability -26, -40 and -52 Materials due to ampere-turn temperature rise limitations.

The graphs below and to the right illustrate the typical effect of gapping on the basic magnetic characteristics of -26 Material. The magnetization curves for the E Core geometry vary somewhat from curves for toroidal cores. This difference is due to the variation in leakage between the geometries. Similarly, some variation will exist between particular E Cores sizes. These curves are for reference only.

Similar results occur for -40 and -52 Materials. While -40 Material has an initial permeability approximately 20% lower than -26 and -52 Materials, when the two materials are gapped the resulting effective permeabilities are much closer to one another.

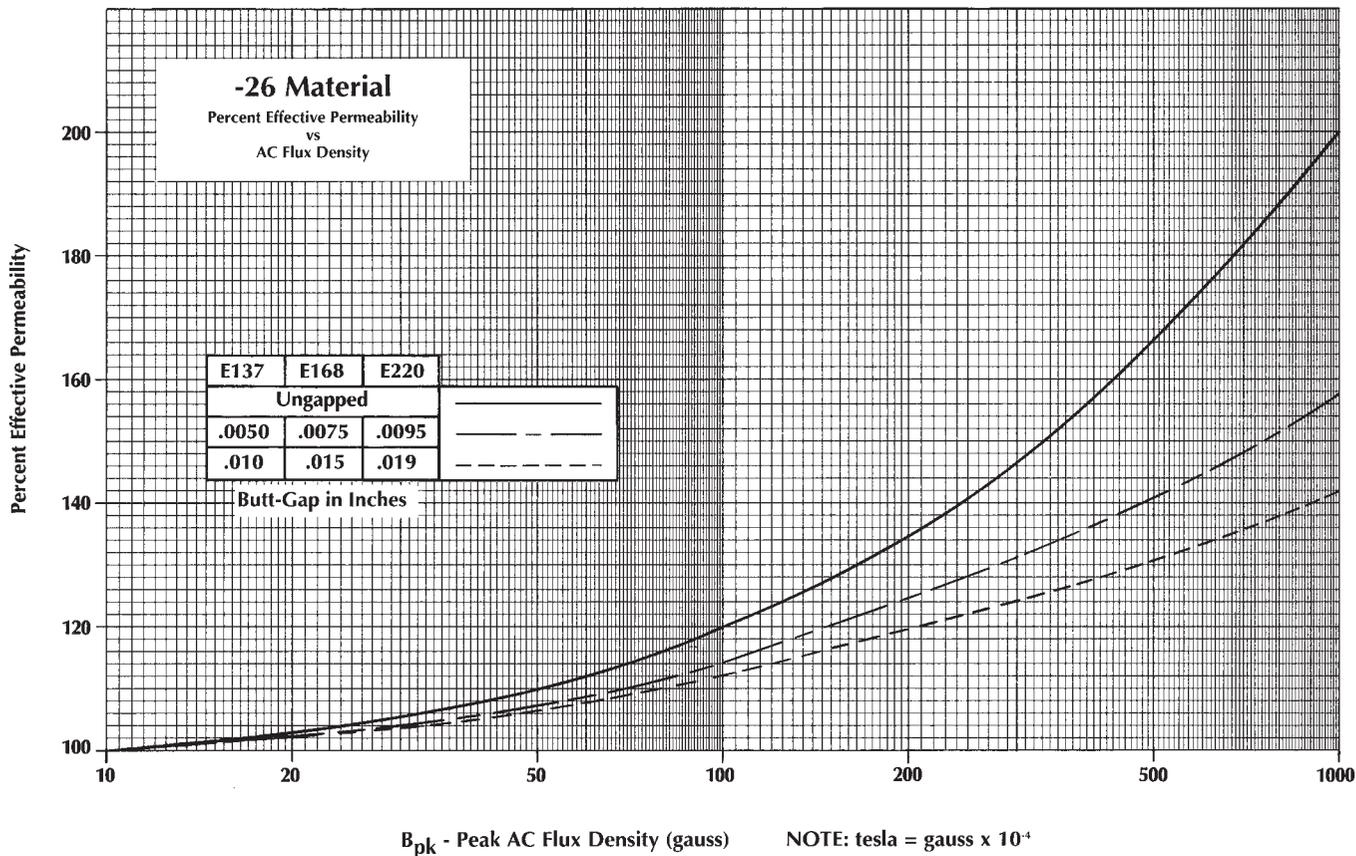
In addition to increasing energy storage, gapping also significantly reduces the swing of these materials with DC bias resulting in performance similar to -8, -18, -30, -34, and -35 Materials without a gap. Since -26, -40, and -52 Materials are less expensive than -8, -18, -30, -34 and -35 Materials this offers an attractive design alternative.

An additional discrete gap in iron powder does not have a dramatic impact on effective permeability as illustrated by the graph to the upper right. As a result, the gapping of iron powder E Cores is relatively non-critical when compared to ferrites and iron alloy laminations.

Energy Storage Curves for optimum butt-gapped E Cores in -26 Material are shown at the bottom of the following page. Similar or slightly higher energy storage will result with -52 Material while slightly lower energy storage will result for -40 Material with the same windings.

The term butt-gap has been used to indicate the physical separation of two standard E Cores (that are butted up against a spacer). By example, a set of cores with all three legs separated by .010 inches has a butt-gap of .010 inches. This creates an effective discrete gap of .020 inches. A butt-gap of .010 inches is equivalent to a total center-leg gap of .020 inches.

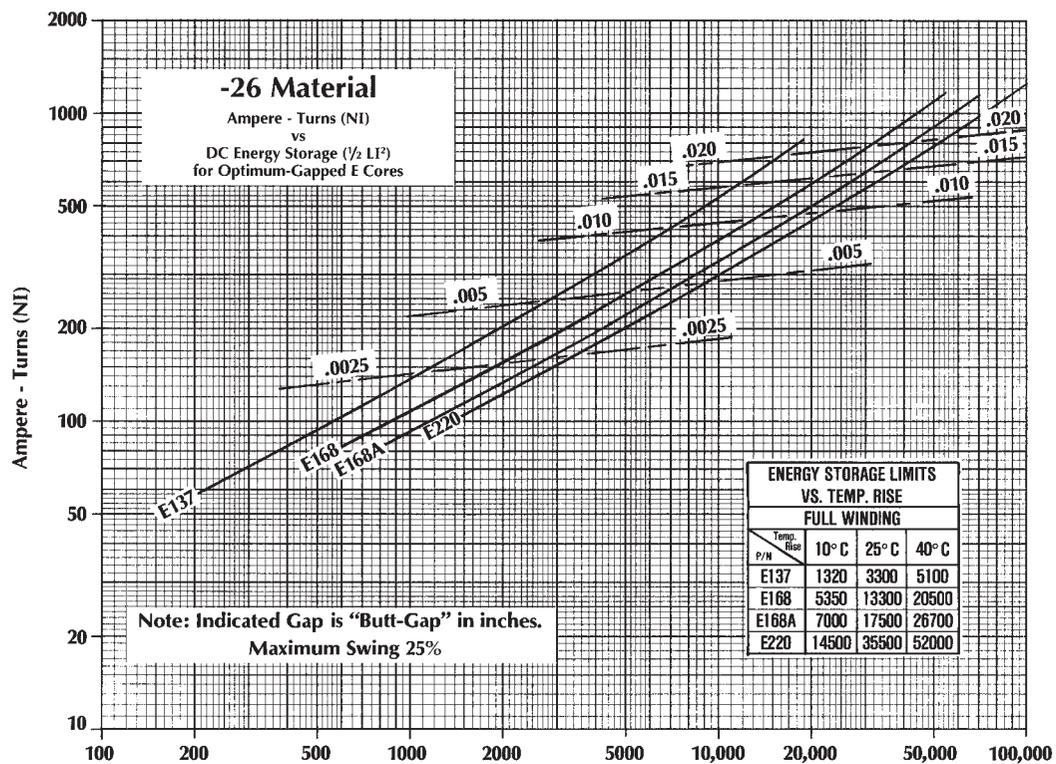
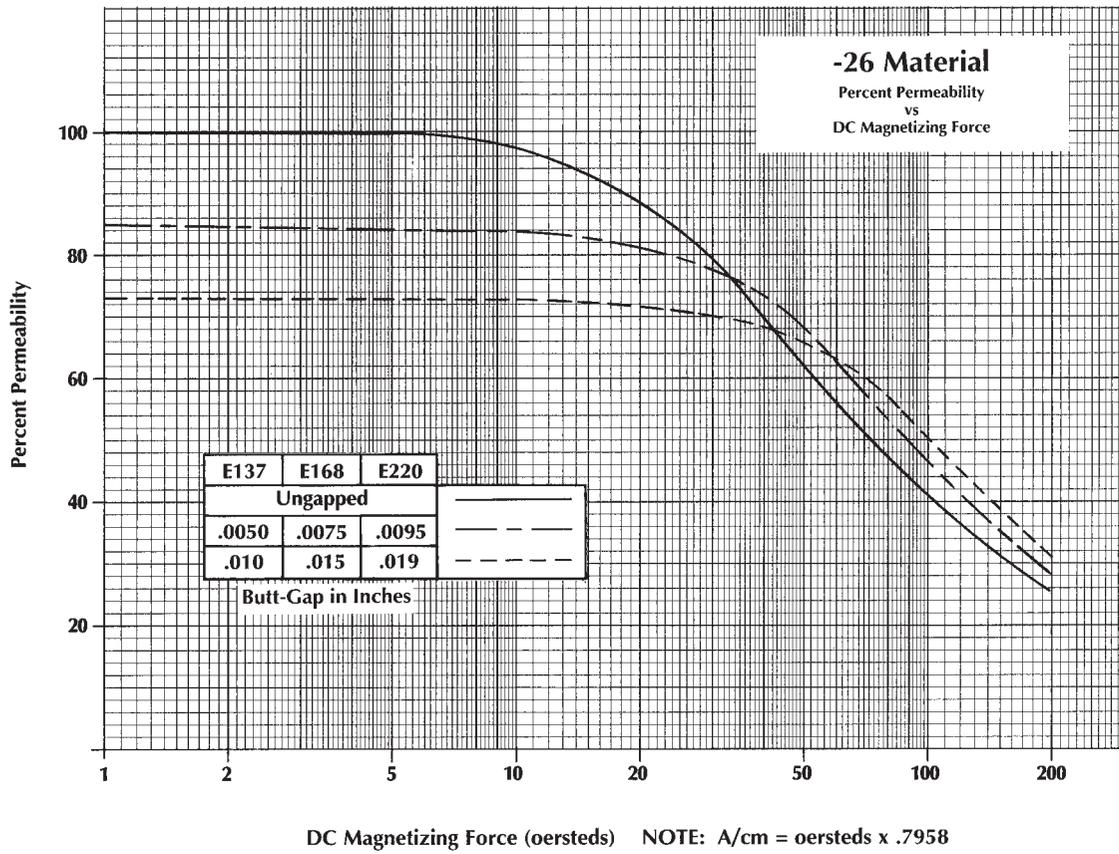
The E168, E168A, E220 and E305 size E Cores are available with standard center-leg gaps as detailed in the E Core listing on pages 15 - 18. The E168 and E168A are available with a center-leg gap of .015 inches per half. A set made up of two of these gapped cores will produce a center-leg gap of .030 inches. The E220 is available with a center-leg gap of .020 inches per half.



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DC APPLICATIONS

THE EFFECT OF AC OR RIPPLE ON DC INDUCTORS

The effect of AC or ripple flux can be significant in many DC inductor applications. The DC energy storage curves provided on pages 42-49 are based on a peak AC flux density of 10 gauss (1 mT) which will typically represent less than 1% ripple current. When significantly greater AC flux density is present, it becomes necessary to consider its effect on both core loss and permeability (inductance).

The interpretation of core loss in DC chokes is covered on pages 29-30. The core loss curves on pages 31-36 also include Et/N (volt-microsecond per turn) ratings for various core sizes at a number of frequencies for a 15C° temperature rise due to core loss.

The -26 Material is a commonly used core material for DC output chokes. However, as switching frequencies increase, the lower core loss characteristics of -8, -18, and -52 Materials also make them good choices. The -8 Material will gain an additional advantage due to its lower permeability.

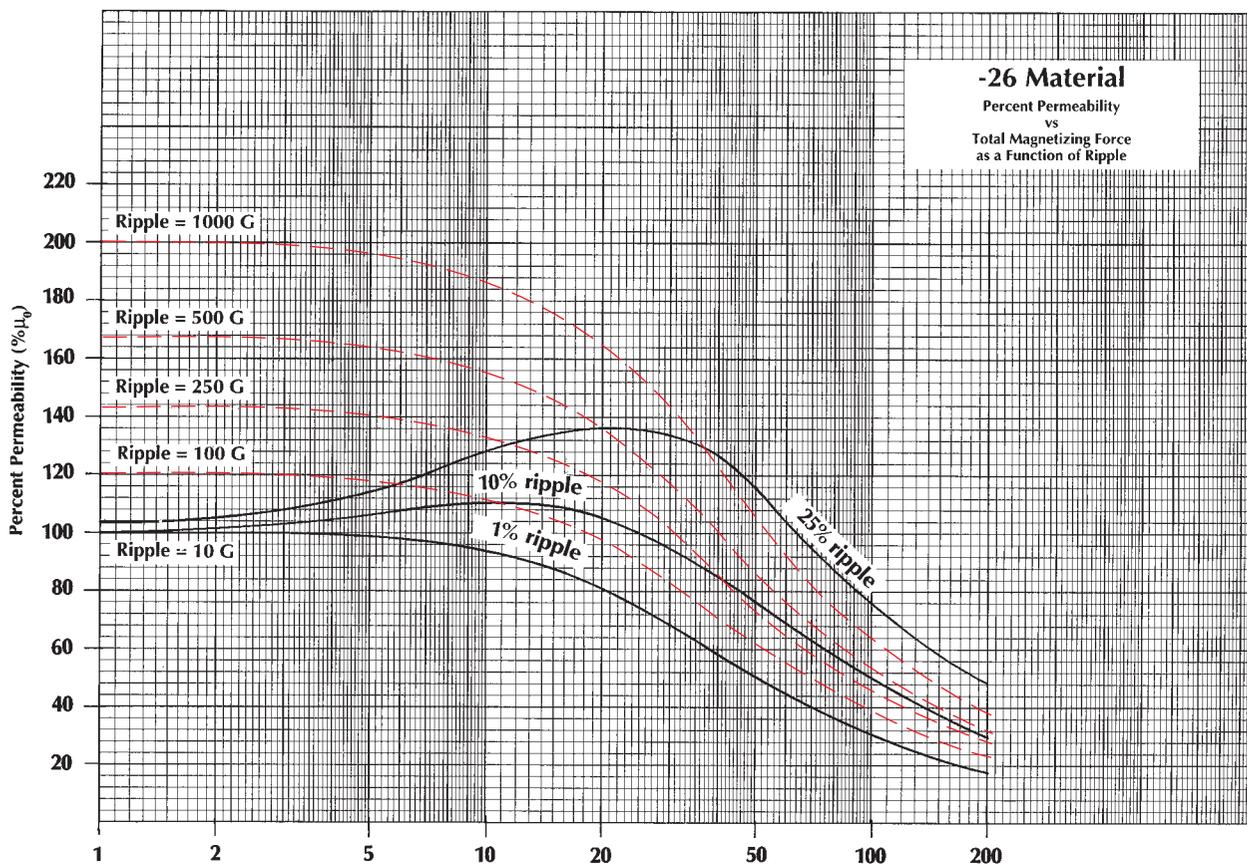
The temperature rise that will result from a given core loss per unit volume (mW/cm^3) is dependent on the core's effective surface area available to dissipate the heat. Since volume is a cubed function and surface area is a squared function, a core's capacity to dissipate heat per unit volume varies inversely with size. Large cores

can dissipate less heat per unit volume than small cores for the same temperature rise. The winding tables on pages 64 and 65 contain information on surface area and power dissipation for temperature rises of 10C°, 25C°, and 40C°.

Most DC output chokes operate with a peak AC flux density of less than 1000 gauss (100 mT); with a level of 200 gauss (20 mT) being more typical. The various iron powder material are affected by peak AC flux density as shown by the graph at the top of page 27. The percent initial permeability increases for all materials as the peak AC flux density is increased from 10 gauss (1 mT) to 1000 gauss (100 mT). The -26, -40, and -52 Materials have the most pronounced response to elevated AC flux density.

The -26 Material responds to the combined effects of AC and DC magnetization as shown by the graph below. The responses of -40 and -52 Materials are very similar.

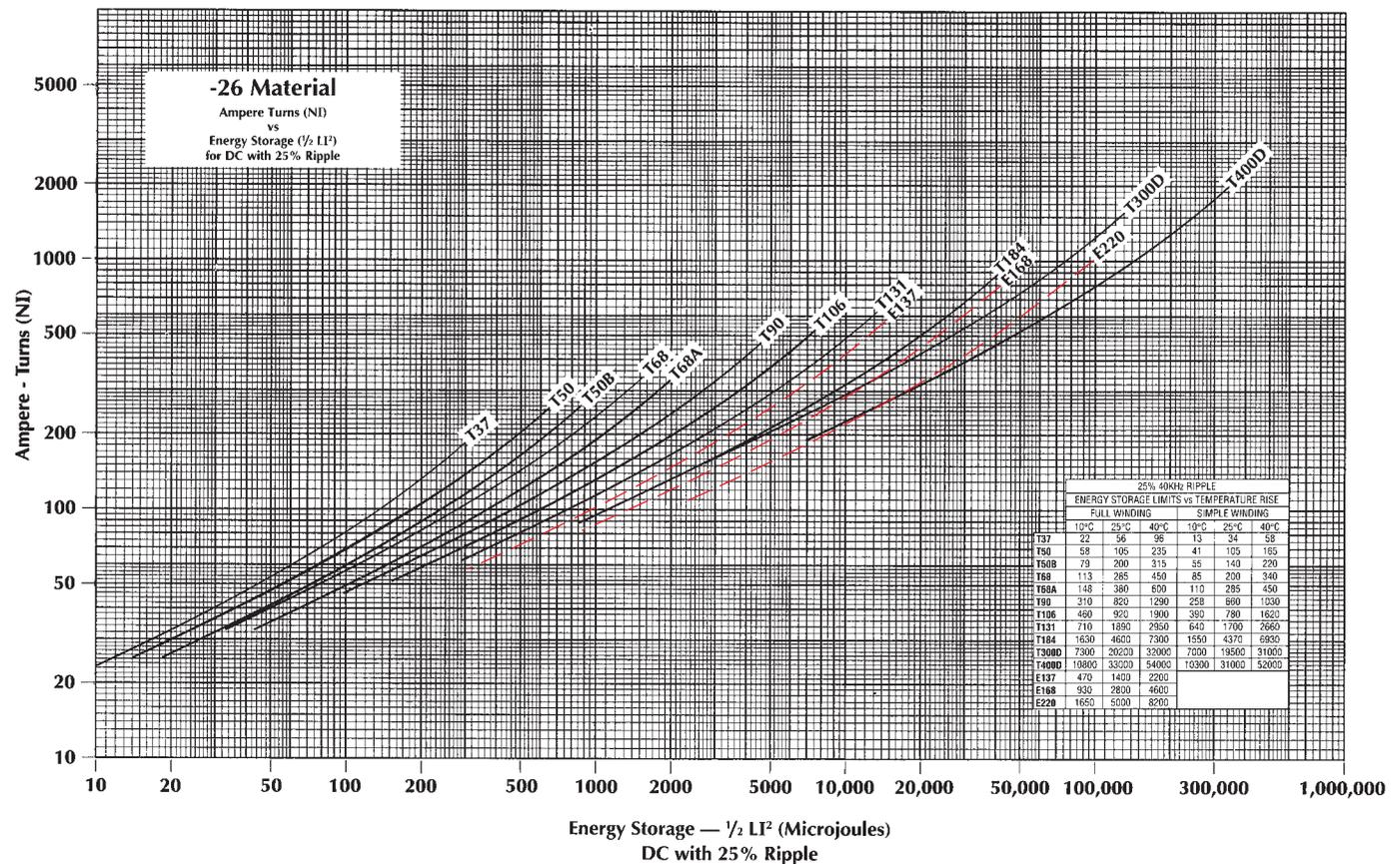
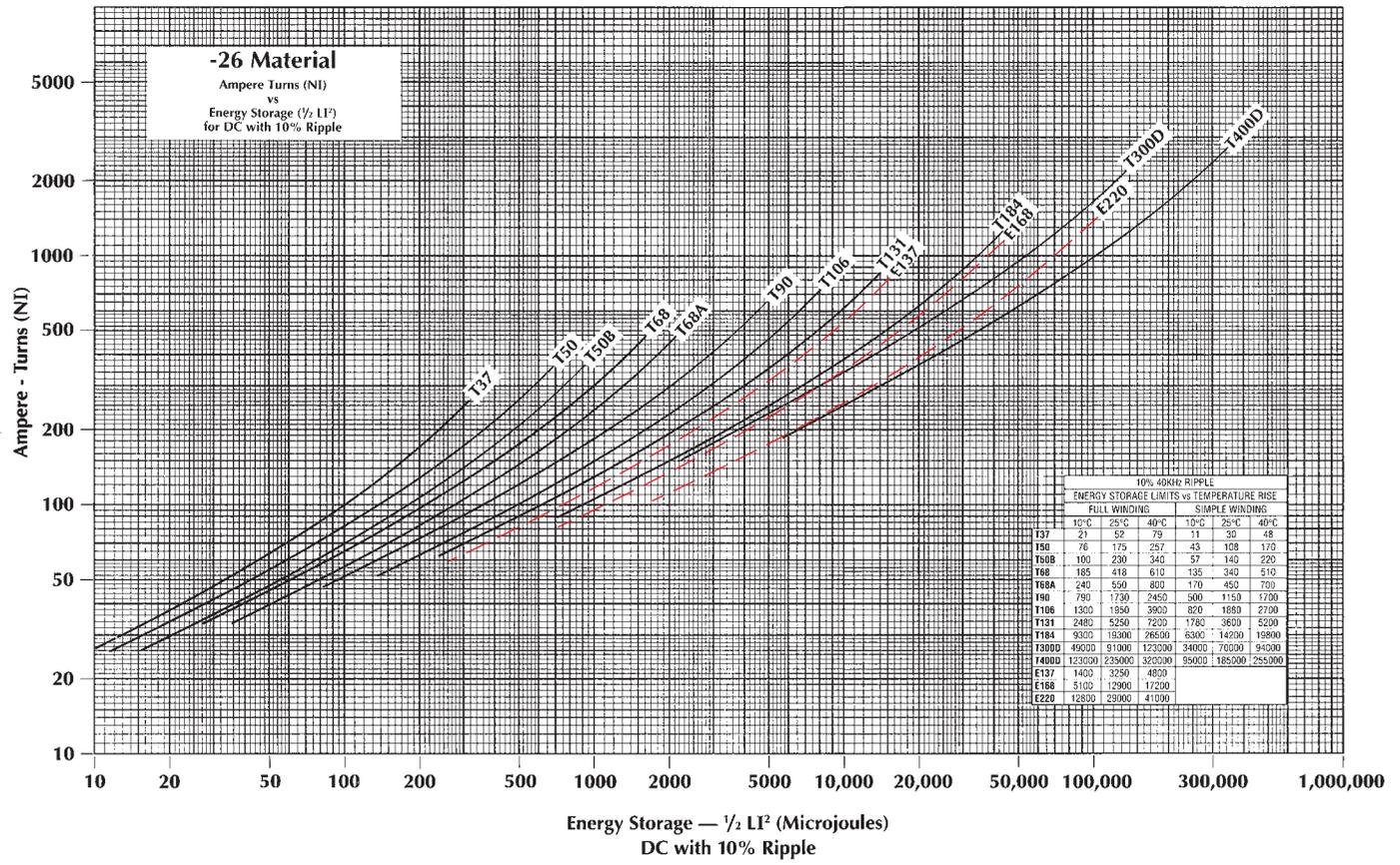
Energy Storage Curves which take into account both the core loss and permeability characteristics for -26 Material with 10% and 25% ripple are provided on page 57. Fewer ampere-turns are required for the same energy storage than when <1% ripple is present. However, with high ripple at high frequency this material will be able to store less energy due to core loss limitations.



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AC APPLICATIONS

POWER FACTOR BOOST PREREGULATOR CORE LOSS CALCULATIONS

The following article is a synopsis of an application note written by Bruce Carsten for Micrometals, Inc. followed by a section on PFC Design Guidelines written by Micrometals. The unabridged original version of the Bruce Carsten application note is available upon request.

The boost preregulator "front end" is increasingly used with AC line inputs to obtain an (essentially) Unity Power Factor, or UPF. Calculation of the core losses in the main inductor is problematic, however, as AC flux in changing continuously in a complex manner even with "fixed" input and output voltages.

The basic AC-DC boost preregulator power circuit is shown in Figure 1. The operation of this circuit is generally well known; the duty cycle of the main switch Q1 is controlled by logic (not shown) to boost the rectified line input voltage "Vi" to the output voltage "Vo", while forcing the short term average input current (=L1 current) to be proportional to the instantaneous AC line voltage. Since the AC line voltage is (ideally) sinusoidal, the line current is also sinusoidal.

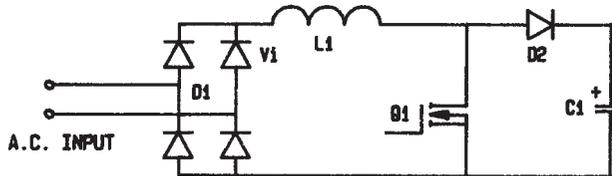


Figure 1

Basic Unity Power Factor boost preregulator power circuit

The actual control technique and circuit used are largely irrelevant to the calculation of losses in UPF boost preregulators. The loss calculation approach used here is generally applicable to constant switching frequency circuits where the boost inductor current is above "critical", or continuous, throughout most of the AC line cycle.

A sinusoidal input voltage, constant output voltage and constant conversion frequency are assumed for calculating the (relative) AC core and HF winding current losses in the main inductor (L1). The peak HF AC flux in the inductor core can be calculated from the switching voltage waveform. A convenient formula for peak AC flux " \hat{B} " in CGS units is:

$$\hat{B} = \frac{10^8 E \Delta T}{2 N A}$$

Where: E = Peak Inductor Voltage
 ΔT = Time Increment
 N = Number of Winding Turns
 A = Core Area (cm²)

The maximum flux " \hat{B}_{max} " occurs when:

$$V_i = V_o/2$$

Where: V_i = "Instantaneous" Input Voltage
 V_o = DC Output Voltage

The actual switching frequency AC flux varies over the AC line voltage half cycle. Curves of \hat{B} / \hat{B}_{max} vs. AC line phase angle θ , for various ratios of V_i/V_o (where V_i = Peak AC Input Voltage) are plotted in figure 2

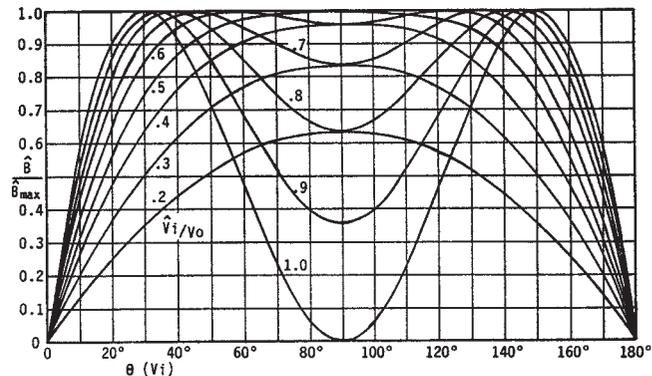


Figure 2

Relative Peak Flux in L1 Core vs. AC Input Voltage and Phase

At a constant switching frequency, the core loss "Pfe" will vary as B^n , where the loss exponent "n" is typically between 1.65 and 3 for most magnetic materials, including powder iron materials. The ratio of average core loss (over an AC line voltage cycle) to the "maximum" loss (at $V_i = V_o/2$), for core loss exponents of 2.0, 2.5 and 3.0 are plotted in Figure 3.

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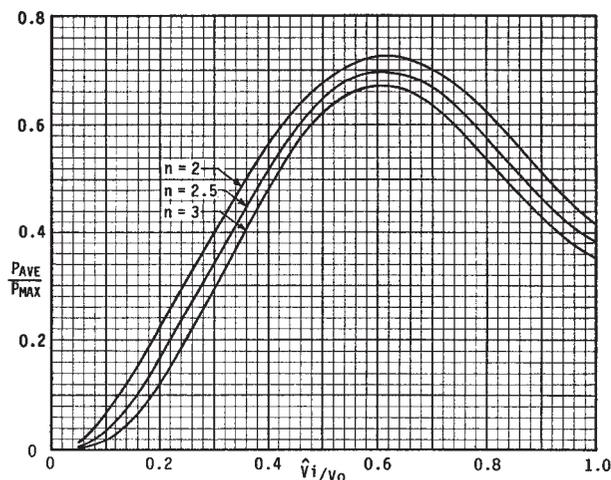


Figure 3

Ratio of Average to Maximum Core Loss vs. V_i/V_o and Loss Exponent "n"

It can be seen that the ratio of average/maximum core loss reaches a maxima when the peak AC line/DC output voltage ratio is near 0.61. The core loss ratio is not very sensitive to the core loss exponent, being somewhat less for higher loss exponents, with the largest average/maximum ratio only ranging from 0.672 for $n = 3$ to 0.725 for $n = 2$.

Since operation at the loss ratio maxima will occur in most UPF boost preregulators, a useful rule-of-thumb is that the "worst case" average core loss will be 70% of the loss calculated for $V_i = V_o/2$, where the Peak flux is:

$$\hat{B} = \frac{10^8 V_o}{8 N A f}$$

Where: f = Boost Switching Frequency

IRON POWDER PFC DESIGN GUIDELINES

Extra care must be taken when designing and specifying iron powder cores for PFC applications due to the AC content and complexity of the core loss calculations. Most present day applications for iron powder cores can have ambient temperatures up to 55°C. Therefore, the increase in temperature rise due to losses must be kept to a minimum.

It is important for a PFC design to be evaluated under the worst case conditions which will be at maximum power and in most designs when the peak input voltage is either at its lowest level or

when the peak input voltage is .61 times the boost or output voltage. The worst case winding losses will occur at the lowest input voltage since this is when the maximum current will flow, but the worst case core losses will occur when the peak input voltage is .61 times the peak output voltage.

It is important to recognize that a PFC design dominated by core loss is not acceptable without first completing a thorough design analysis. It is generally recommended that the loss distribution be no greater than a 50/50% split between core and copper loss. In fact, a 20/80% or 25/75% split between core to copper loss is preferred. It is also important to remember that it is much easier to remove heat from the copper winding than from the core.

PFC applications mean that higher Peak AC Flux density conditions are often present in the core than traditional output choke applications. If an inappropriate core material or undersized core is selected, the core will be subjected to excessive high frequency core loss resulting in a temperature rise that can possibly lead to thermal failure.

Many designs today utilize variable speed fans in order to cool and "quiet down" the power supply. Even at a reduced power load condition, the effective AC flux density and resulting core loss of the PFC inductor can remain fairly constant. Only the copper loss (I^2R) has been reduced. Extreme care should be taken since a reduction in fan speed can result in a higher than expected temperature owing to the reduction of air flow.

The best way to determine the "hot spot" core temperature is to drill a small hole midway into the core and install a thermocouple wire. The soundness of the thermocouple connection to the core is critical for accurate results. Close attention should be paid to the "shadow" areas that do not get the benefit of good air flow. These areas will be at a higher temperature than those directly in the air flow path. It is recommended that the unit is operated continuously under the worst case conditions for a period of 4 to 8 hours or until the inductor reaches thermal equilibrium. The true maximum temperature of the core can then be determined. Iron Powder core materials do have differing thermal conductivities which will effect their temperature gradient. Please refer to the Thermal Conductivity information on page 3.

Selecting a lower permeability core material will reduce the peak operating flux density and associated core loss. This reduction in core loss can be very significant and will, generally, more than offset any increase in winding losses.

The Micrometals Design Software is also available for a rapid solution to your requirements.

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AC APPLICATIONS

IRON POWDER FOR 60Hz FILTER INDUCTORS

The addition of both U.S. and International regulations has increased the need to effectively filter the main power line. In order to accomplish this, both the common-mode and differential-mode (normal-mode) noise must be controlled. Common-mode noise is interference that is common to both the positive and neutral lines in relation to earth ground and is usually a result of capacitive coupling. Differential-mode noise is the interference that is present between the positive and neutral lines and is typically generated by switching devices such as transistors, SCRs and triacs. This type of noise is more readily filtered when the choke is in close proximity to the noise source.

Common-mode filtering requires capacitors to earth ground. Safety regulations limit these capacitors to a relatively low value. This mandated low value of capacitance for common-mode filtering makes a high value of inductance essential for effective filtering. Common-mode inductors typically require a minimum inductance of 1000 mH and are most often wound in a balun configuration on a 5000 or higher permeability ferrite core. The balun winding allows the 60 Hz flux density generated by each line to cancel in the core, thus avoiding saturation. Lower permeability materials like iron powder are useful for common-mode applications involving significant line imbalance. Otherwise, for most common-mode applications, the increased core size necessary to accommodate the number of turns needed to achieve the required inductance makes this alternative less attractive.

Differential-mode chokes usually have a single winding, though it is possible to put more than one differential-mode choke on a core by connecting the windings in the additive configuration rather than in the balun configuration. This type of choke must be able to support significant 60 Hz flux density without saturating and at the same time respond to the high frequency noise. The distributed air-gap of iron powder in addition to its high saturation flux density of greater than 12,000 gauss (1.2 T) make it well-suited for this requirement.

Iron powder experiences magnetostriction. This means that as the material is magnetized it experiences a very slight change in dimensions. In applications above audible frequencies (>20 kHz) this is of no concern. In certain 60 Hz applications, however, core buzzing can be noticeable. This condition will be more noticeable with E Cores than with toroids. It will also be more significant with signals which have been chopped (light dimmers, motor controllers) than with normal sinewaves. It is also dependent on operating AC flux density.

Energy storage inductor design is limited by temperature rise resulting from the combined copper and core loss, and core saturation. While the -8, -18 and -52 Materials have lower core losses at 60 Hz.

Further, the higher core loss characteristics of the -26 and -40 Materials at frequencies above 25 KHz will produce a coil with low Q at high frequency. This characteristic is an additional benefit in helping to suppress the unwanted signals. (see pages 27-33).

The -26 and -40 Materials maintain good permeability versus AC flux density characteristics as illustrated at the top of page 27. The significant increase in percent permeability for these materials can be a considerable advantage. It appears that this increase in permeability is experienced in applications such as light dimmers.

Tests performed with a low-level 10 KHz sinewave superimposed over a 60 Hz signal of increasing level did indicate that the high frequency signal experienced an increase in inductance as the 60 Hz signal was increased. While this may be the case for a continuous time averaged signal, it is not clear if this is the case for instantaneous noise signals.

Energy Storage Curves for 60 Hz filtering applications for -26 and -40 Materials are shown on page 61. These curves take into account the increase in permeability illustrated by the curves at the top of page 27. The AC flux density levels have been referenced. These flux density references can be useful in approximating core loss as well as determining how the inductance will vary with current.

The representation of percent permeability versus peak AC flux density at the top of page 27 shows how the permeability (inductance) will change with voltage across the coil, but it does not provide a clear view of how the inductance will vary with current. The graphs at the top of page 62 are an attempt to illustrate (in relative terms only) how the relative inductance will change with changes in current.

Energy storage limits for temperature rises of 10C°, 25C° and 40 C° are also listed for 60 Hz applications for a number of different core sizes. For the same temperature rises, all core sizes operate at a similar flux density, but the loss distribution differs. With physically large cores, the majority of the loss is due to the core losses, while with the physically small cores the majority of the loss is due to the losses in winding. This phenomenon is not unique to iron powder.

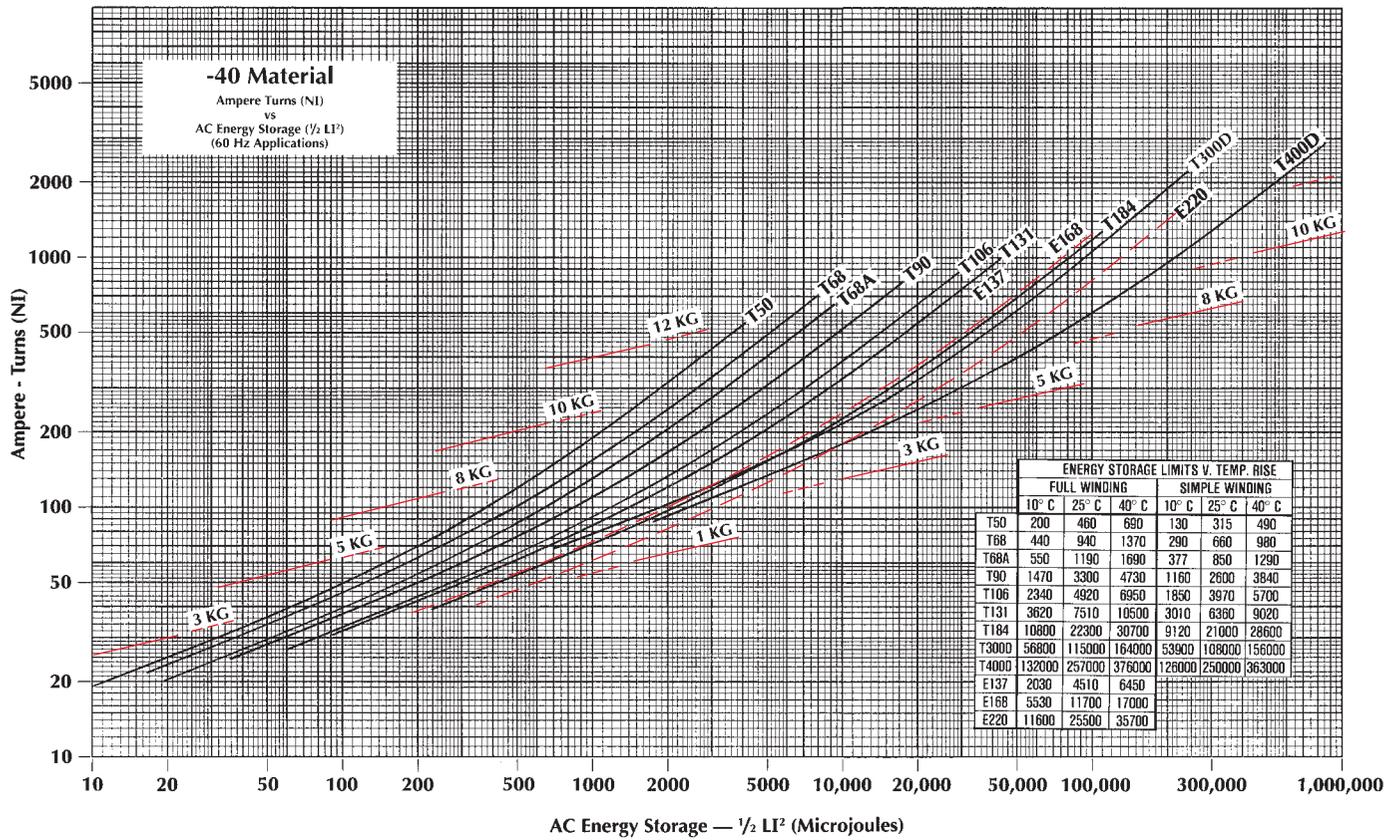
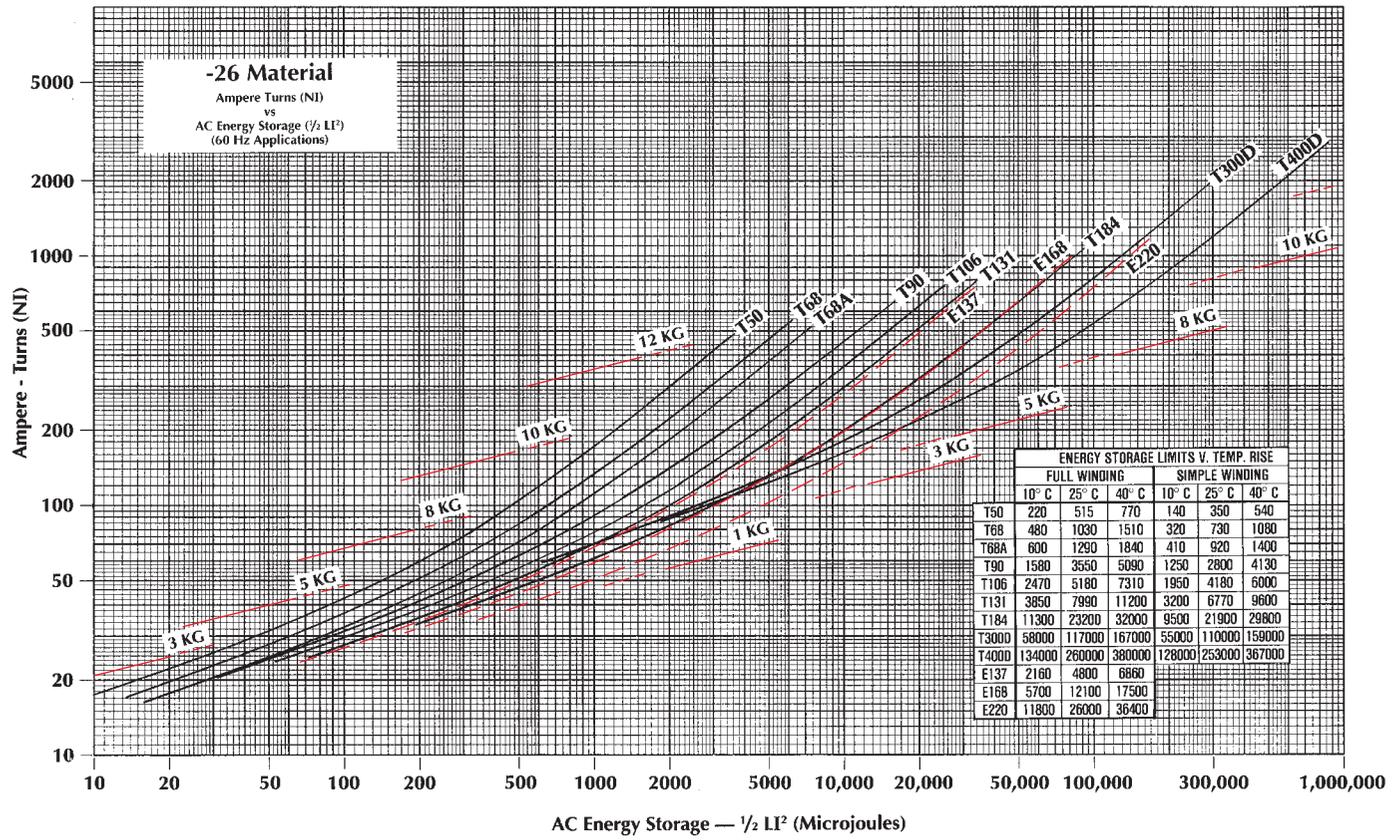
A design example can be found at the bottom of page 62. In addition, an inductance reference table is included on page 63.

For applications where it is unclear if the high frequency signal will experience the same increase in permeability as the 60 Hz signal, it is recommended that the 60 Hz signal be treated as DC current. This will produce a significantly different result but will be the most conservative approach.

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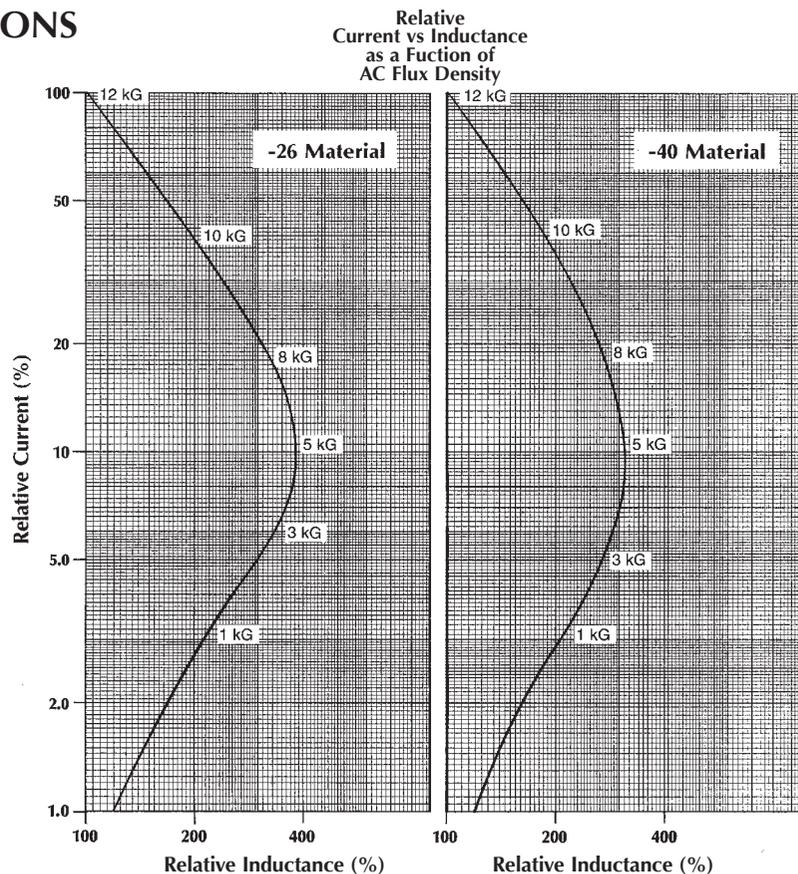
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Requirements: 500 μ H minimum from 1 to 5 amps of 60 Hz Current.

Consider minimum current level.

For this example, the inductor must maintain 500 μ H minimum from 1 to 5 amperes, or down to 20% of full-rated current (I max). The importance of this consideration is illustrated by the graph above. This shows that, in the case of -40 Material, if the inductor is designed to operate at 10 kG at I max, that the inductance will be greater than or equal to L at I max down to $2.5 \div 42 = 6.0\%$ of I max. Likewise, if the inductor operates at 8 kG at I max, the inductor can only be operated down to $4.6 \div 19.5 = 25\%$ of I max before lower inductance will result.

Calculate Energy Storage Required ($\frac{1}{2} LI^2$)

$$\frac{1}{2} LI^2 = (\frac{1}{2}) (500) (5^2) = 6250 \mu\text{J}$$

Select appropriate core size.

In this example -40 Material will be used. In order to maintain a minimum inductance down to 1 amp (20% of I max), the inductor must be designed to operate at greater than 8 kG at I max. This requires a core no larger than the E137 core or T131 toroidal core. To keep temperature rise down, the T131 will be selected.

Determine number of turns.

At 6250 μ J, the T131-40 indicates 235 ampere-turns.

$$NI = 235 \text{ N} = 235 / 5 = 47 \text{ turns}$$

Select wire size.

Since the "simple" winding results are a rough approximation of typical single-layer windings, the Single Layer Winding table on page 64 can be used as a guide in selecting the wire size. #19 will fit in a single layer and yield about 20C $^\circ$ temperature rise due to the winding losses.

Solution: Part no. T131-40
47 turns #19

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MICROMETALS

AC APPLICATIONS

| 60 Hz Inductor Examples | | | | | | | | | | |
|--|------------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------|---------------------------|---------------------------|--------------------------|--|--|
| TOROIDAL CORES: SINGLE LAYER WINDINGS (approximate) | | | | | | | | | | |
| 60Hz current WIRE * SIZE | 1.0 amps #28 AWG | 2.5 amps #24 AWG | 5.0 amps #20 AWG | 7.5 amps #18AWG | 10 amps #15 AWG | 15 amps #13 AWG | 20 amps #11 AWG | 30 amps #9 AWG | | |
| T50-26 | 460 μ H 63 turns | 136 μ H 47 turns | 40.8 μ H 21 turns | 22.0 μ H 16 turns | 8.2 μ H 9 turns | 3.6 μ H 6 turns | 2.4 μ H 5 turns | 0.9 μ H 3 turns | | |
| T68-26A | 1,200 μ H 79 turns | 352 μ H 47 turns | 113 μ H 28 turns | 47.3 μ H 18 turns | 25.6 μ H 13 turns | 11.8 μ H 15 turns | 5.6 μ H 11 turns | 3.5 μ H 7 turns | | |
| T90-26 | 3,100 μ H 120 turns | 960 μ H 74 turns | 308 μ H 44 turns | 140 μ H 30 turns | 77.0 μ H 22 turns | 35.1 μ H 15 turns | 19.3 μ H 11 turns | 8.0 μ H 8 turns | | |
| T106-26 | 4,600 μ H 125 turns | 1,140 μ H 77 turns | 452 μ H 46 turns | 213 μ H 32 turns | 120 μ H 24 turns | 53.3 μ H 16 turns | 30.0 μ H 12 turns | 13.3 μ H 8 turns | | |
| T131-26 | 7,100 μ H 141 turns | 2,140 μ H 87 turns | 704 μ H 53 turns | 331 μ H 37 turns | 180 μ H 27 turns | 80.0 μ H 18 turns | 46.5 μ H 14 turns | 20.0 μ H 9 turns | | |
| T157-26 | 13,600 μ H 213 turns | 4,000 μ H 132 turns | 1,340 μ H 82 turns | 729 μ H 64 turns | 370 μ H 44 turns | 198 μ H 34 turns | 180 μ H 25 turns | 56.7 μ H 19 turns | | |
| T184-26 | 22,400 μ H 213 turns | 6,720 μ H 132 turns | 2,240 μ H 82 turns | 1,050 μ H 57 turns | 590 μ H 43 turns | 258 μ H 28 turns | 140 μ H 21 turns | 64.4 μ H 14 turns | | |
| T300-26D | 88,000 μ H 435 turns | 25,900 μ H 272 turns | 8,560 μ H 169 turns | 4,730 μ H 135 turns | 2,420 μ H 93 turns | 1,290 μ H 72 turns | 760 μ H 56 turns | 344 μ H 38 turns | | |
| T400-26D | 180,000 μ H 507 turns | 57,600 μ H 317 turns | 19,200 μ H 197 turns | 10,700 μ H 157 turns | 5,400 μ H 108 turns | 2,840 μ H 83 turns | 1,700 μ H 65 turns | 811 μ H 46 turns | | |
| E CORES: FULL BOBBIN WINDINGS | | | | | | | | | | |
| 60Hz current WIRE * SIZE | 1.0 amps #23 AWG | 2.5 amps #19 AWG | 5.0 amps #16 AWG | 7.5 amps #15 AWG | 10 amps #13 AWG | 15 amps #12 AWG | 20 amps #11 AWG | 30 amps #10 AWG | | |
| E137-26 | 13,600 μ H 217 turns | 2,180 μ H 87 turns | 544 μ H 43 turns | 241 μ H 29 turns | 132 μ H 21 turns | 64.0 μ H 15 turns | 31.0 μ H 10 turns | 14.7 μ H 7 turns | | |
| E168-26 | 34,600 μ H 295 turns | 5,540 μ H 118 turns | 1,380 μ H 59 turns | 615 μ H 39 turns | 356 μ H 30 turns | 147 μ H 19 turns | 80.0 μ H 14 turns | 34.0 μ H 9 turns | | |
| E220-26 | 73,000 μ H 350 turns | 11,700 μ H 140 turns | 2,920 μ H 70 turns | 1,300 μ H 47 turns | 730 μ H 35 turns | 320 μ H 23 turns | 175 μ H 17 turns | 74.4 μ H 11 turns | | |

* Based on max temperature rise of 40C° due to copper and core loss

MICROMETALS
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WINDING TABLE

| SINGLE LAYER WINDING TABLE | | | | | | | | | | | | | | | | | | | | |
|----------------------------|-------------|------------------------------|-----------------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|---|------|------|------|------|
| WIRE SIZE (AWG) | 28 | 26 | 24 | 22 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | TOTAL POWER DISSIPATION (WATTS) VS TEMP. RISE | | | | |
| RESISTIVITY (mΩ/cm) | 2.13 | 1.34 | .842 | .530 | .330 | .264 | .210 | .166 | .132 | .104 | .0828 | .0651 | .0521 | .0413 | .0328 | | | | | |
| MAXIMUM AMPS 10C° | .64 | .90 | 1.29 | 1.83 | 2.62 | 3.12 | 3.72 | 4.45 | 5.33 | 6.35 | 7.60 | 9.03 | 10.8 | 12.9 | 15.4 | | | | | |
| PER ALLOWABLE 25C° | 1.07 | 1.52 | 2.17 | 3.09 | 4.41 | 5.26 | 6.27 | 7.50 | 8.97 | 10.7 | 12.8 | 15.2 | 18.2 | 21.7 | 26.0 | | | | | |
| TEMP RISE 40C° | 1.38 | 1.97 | 2.81 | 4.00 | 5.70 | 6.81 | 8.11 | 9.70 | 11.6 | 13.8 | 16.6 | 19.7 | 23.5 | 28.1 | 33.6 | | | | | |
| PART No. | MLT cm/turn | Surface Area cm ² | NUMBER OF TURNS | | | | | | | | | | | | | | 10C° | 25C° | 40C° | |
| | | | 9 | 6 | 4 | 2 | 1 | | | | | | | | | | | | | |
| T16 | .80 | .80 | 9 | 6 | 4 | 2 | 1 | | | | | | | | | | | .013 | .038 | .067 |
| T20 | .96 | 1.16 | 11 | 8 | 5 | 3 | 2 | 1 | | | | | | | | | | .018 | .055 | .097 |
| T25 | 1.19 | 1.88 | 18 | 14 | 10 | 7 | 5 | 4 | 3 | 2 | 1 | | | | | | | .030 | .089 | .157 |
| T26 | 1.74 | 2.67 | 15 | 11 | 8 | 5 | 3 | 2 | 1 | | | | | | | | | .042 | .127 | .223 |
| T30 | 1.44 | 2.79 | 25 | 20 | 15 | 11 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | | | | .044 | .133 | .233 |
| T37 | 1.53 | 3.77 | 37 | 29 | 22 | 17 | 12 | 11 | 9 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | .060 | .180 | .316 |
| T38 | 1.92 | 4.43 | 31 | 24 | 18 | 13 | 10 | 8 | 7 | 5 | 4 | 3 | 2 | 2 | 1 | | | .071 | .211 | .371 |
| T44 | 1.84 | 5.23 | 43 | 34 | 26 | 20 | 15 | 13 | 11 | 9 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | .083 | .249 | .437 |
| T50 | 2.01 | 6.86 | 59 | 47 | 37 | 28 | 22 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 6 | 4 | 3 | .109 | .326 | .574 |
| T50B | 2.32 | 7.83 | 59 | 47 | 37 | 28 | 22 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 6 | 4 | 3 | .125 | .373 | .659 |
| T50D | 2.95 | 9.87 | 59 | 47 | 37 | 28 | 22 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 6 | 4 | 3 | .157 | .470 | .826 |
| T51C | 2.58 | 7.56 | 36 | 28 | 22 | 16 | 12 | 10 | 9 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | .120 | .360 | .633 |
| T60 | 2.48 | 9.84 | 67 | 53 | 41 | 32 | 25 | 21 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 6 | 4 | .156 | .468 | .824 |
| T60D | 3.68 | 14.3 | 67 | 53 | 41 | 32 | 25 | 21 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 6 | 4 | .228 | .681 | 1.20 |
| T68 | 2.47 | 11.2 | 74 | 59 | 46 | 36 | 28 | 24 | 21 | 18 | 16 | 14 | 12 | 10 | 8 | 7 | 5 | .178 | .533 | .936 |
| T68A | 2.77 | 12.5 | 74 | 59 | 46 | 36 | 28 | 24 | 21 | 18 | 16 | 14 | 12 | 10 | 8 | 7 | 5 | .198 | .594 | 1.04 |
| T68D | 3.41 | 15.2 | 74 | 59 | 46 | 36 | 28 | 24 | 21 | 18 | 16 | 14 | 12 | 10 | 8 | 7 | 5 | .241 | .722 | 1.27 |
| T72 | 3.15 | 13.3 | 54 | 43 | 33 | 26 | 19 | 17 | 14 | 12 | 11 | 9 | 7 | 6 | 5 | 4 | 3 | .212 | .634 | 1.11 |
| T80 | 2.8 | 15.5 | 103 | 82 | 64 | 51 | 39 | 35 | 30 | 27 | 23 | 20 | 17 | 15 | 13 | 11 | 9 | .246 | .736 | 1.30 |
| T80B | 3.44 | 18.7 | 103 | 82 | 64 | 51 | 39 | 35 | 30 | 27 | 23 | 20 | 17 | 15 | 13 | 11 | 9 | .298 | .892 | 1.57 |
| T80D | 4.07 | 22.0 | 103 | 82 | 64 | 51 | 39 | 35 | 30 | 27 | 23 | 20 | 17 | 15 | 13 | 11 | 9 | .350 | 1.05 | 1.84 |
| T90 | 3.64 | 22.4 | 115 | 92 | 72 | 57 | 44 | 39 | 34 | 30 | 26 | 23 | 20 | 17 | 15 | 13 | 11 | .356 | 1.07 | 1.88 |
| T94 | 3.44 | 22.0 | 117 | 94 | 74 | 58 | 45 | 40 | 35 | 31 | 27 | 24 | 21 | 18 | 15 | 13 | 11 | .350 | 1.05 | 1.85 |
| T106 | 4.49 | 31.0 | 118 | 95 | 74 | 59 | 46 | 40 | 36 | 31 | 27 | 24 | 21 | 18 | 15 | 13 | 11 | .492 | 1.47 | 2.59 |
| T106A | 3.86 | 25.8 | 118 | 95 | 74 | 59 | 46 | 40 | 36 | 31 | 27 | 24 | 21 | 18 | 15 | 13 | 11 | .427 | 1.28 | 2.25 |
| T106B | 5.19 | 35.5 | 118 | 95 | 74 | 59 | 46 | 40 | 36 | 31 | 27 | 24 | 21 | 18 | 15 | 13 | 11 | .565 | 1.69 | 2.97 |
| T124 | 3.95 | 33.3 | 150 | 120 | 95 | 75 | 59 | 52 | 46 | 40 | 36 | 31 | 27 | 24 | 21 | 18 | 15 | .529 | 1.58 | 2.79 |
| T130 | 4.75 | 42.2 | 165 | 133 | 105 | 83 | 65 | 58 | 51 | 45 | 40 | 35 | 31 | 27 | 23 | 20 | 17 | .671 | 2.01 | 3.53 |
| T130A | 3.67 | 33.2 | 165 | 133 | 105 | 83 | 65 | 58 | 51 | 45 | 40 | 35 | 31 | 27 | 23 | 20 | 17 | .529 | 1.58 | 2.78 |
| T131 | 5.11 | 42.1 | 134 | 107 | 85 | 67 | 52 | 46 | 41 | 36 | 32 | 28 | 24 | 21 | 18 | 16 | 13 | .669 | 2.00 | 3.52 |
| T132 | 4.95 | 42.2 | 147 | 118 | 93 | 74 | 58 | 51 | 45 | 40 | 35 | 31 | 27 | 23 | 20 | 18 | 15 | .671 | 2.01 | 3.53 |
| T141 | 4.75 | 46.8 | 188 | 151 | 119 | 95 | 75 | 66 | 59 | 52 | 46 | 40 | 35 | 31 | 27 | 24 | 20 | .744 | 2.23 | 3.92 |
| T150 | 5.28 | 53.2 | 180 | 145 | 114 | 91 | 71 | 63 | 56 | 49 | 44 | 38 | 34 | 29 | 26 | 22 | 19 | .846 | 2.53 | 4.45 |
| T157 | 5.89 | 63.2 | 204 | 164 | 129 | 103 | 81 | 72 | 64 | 56 | 50 | 44 | 39 | 34 | 30 | 26 | 23 | 1.01 | 3.01 | 5.29 |
| T175 | 6.58 | 79.1 | 230 | 186 | 147 | 117 | 92 | 82 | 73 | 64 | 57 | 50 | 44 | 39 | 34 | 30 | 26 | 1.26 | 3.76 | 6.16 |
| T184 | 7.54 | 89.2 | 202 | 163 | 129 | 102 | 81 | 72 | 63 | 56 | 50 | 44 | 38 | 34 | 29 | 26 | 22 | 1.42 | 4.25 | 7.47 |
| T200 | 6.50 | 90.9 | 270 | 217 | 172 | 137 | 108 | 96 | 86 | 76 | 67 | 60 | 53 | 46 | 41 | 36 | 31 | 1.45 | 4.33 | 7.61 |
| T200B | 8.78 | 120 | 270 | 217 | 172 | 137 | 108 | 96 | 86 | 76 | 67 | 60 | 53 | 46 | 41 | 36 | 31 | 1.91 | 5.74 | 10.1 |
| T201 | 8.90 | 111 | 202 | 163 | 129 | 102 | 81 | 72 | 63 | 56 | 50 | 44 | 38 | 34 | 29 | 26 | 22 | 1.76 | 5.28 | 9.28 |
| T225 | 6.93 | 109 | 305 | 245 | 195 | 155 | 123 | 109 | 97 | 86 | 78 | 68 | 60 | 53 | 48 | 41 | 36 | 1.74 | 5.21 | 9.16 |
| T225B | 9.21 | 143 | 305 | 245 | 195 | 155 | 123 | 109 | 97 | 86 | 78 | 68 | 60 | 53 | 48 | 41 | 36 | 2.27 | 6.79 | 11.9 |
| T250 | 10.4 | 166 | 270 | 217 | 172 | 137 | 108 | 96 | 86 | 76 | 67 | 60 | 53 | 46 | 41 | 36 | 31 | 2.63 | 7.88 | 13.9 |
| T300 | 7.95 | 173 | 422 | 341 | 271 | 216 | 171 | 153 | 136 | 121 | 108 | 96 | 85 | 75 | 66 | 58 | 52 | 2.75 | 8.23 | 14.5 |
| T300D | 10.5 | 223 | 422 | 341 | 271 | 216 | 171 | 153 | 136 | 121 | 108 | 96 | 85 | 75 | 66 | 58 | 52 | 3.55 | 10.6 | 18.7 |
| T400 | 11.1 | 301 | 494 | 399 | 317 | 254 | 201 | 179 | 160 | 142 | 126 | 113 | 100 | 88 | 78 | 69 | 61 | 4.79 | 14.3 | 25.3 |
| T400D | 14.4 | 384 | 494 | 399 | 317 | 254 | 201 | 179 | 160 | 142 | 126 | 113 | 100 | 88 | 78 | 69 | 61 | 6.10 | 18.2 | 32.1 |
| T520 | 13.7 | 496 | 680 | 550 | 437 | 350 | 278 | 248 | 221 | 197 | 176 | 156 | 139 | 123 | 109 | 97 | 86 | 7.88 | 23.6 | 41.5 |
| T520D | 17.7 | 629 | 680 | 550 | 437 | 350 | 278 | 248 | 221 | 197 | 176 | 156 | 139 | 123 | 109 | 97 | 86 | 10.0 | 30.0 | 52.7 |
| T650 | 23.1 | 986 | 789 | 621 | 494 | 396 | 315 | 281 | 250 | 223 | 199 | 177 | 158 | 139 | 124 | 110 | 98 | 15.7 | 46.9 | 82.5 |

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PACKAGE SIZE AND WEIGHTS

Due to the relatively low price and high density of iron powder cores, freight charges can be a significant part of the total cost. The following table is provided to assist in planning shipment sizes and estimating freight costs.

Micrometals standard box size is 6 x 9 x 12 inches. Standard pallets contain 48 boxes with dimensions 38 x 48 x 32 inches. Weights specified below include box and packaging materials for the -26 Material. Weights for other material will vary in accordance with the densities listed on page 1. Add approximately 50 pounds for each pallet for large volume shipments.

| Part Prefix | Qty./Box (pieces) | Weight/Box lbs/kg | Part Prefix | Qty./Box (pieces) | Weight/Box lbs/kg |
|-------------|----------------------|----------------------|-------------|----------------------|----------------------|
| T14A | 250,000 | 41/19 | T150 | 350 | 51/23 |
| T16 | 200,000 | 51/23 | T150A | 420 | 44/20 |
| T20 | 100,000 | 45/20 | T157 | 240 | 45/20 |
| T22 | 40,000 | 43/20 | T175 | 140 | 36/16 |
| T25 | 40,000 | 39/18 | T184 | 140 | 51/23 |
| T26 | 20,000 | 45/21 | T200 | 120 | 33/15 |
| T27 | 30,000 | 41/19 | T200B | 75 | 36/16 |
| T30 | 25,000 | 42/19 | T201 | 90 | 52/24 |
| T37 | 20,000 | 44/20 | T224C | 90 | 50/23 |
| T38 | 10,000 | 43/19 | T225 | 120 | 42/19 |
| T40 | 10,000 | 37/17 | T225B | 60 | 39/18 |
| T44 | 10,000 | 46/21 | T249 | 45 | 40/18 |
| T44C | 5,000 | 42/19 | T250 | 45 | 44/20 |
| T44D | 4,000 | 35/16 | T300 | 54 | 31/14 |
| T50 | 6,000 | 37/17 | T300D | 30 | 35/16 |
| T50B | 5,000 | 41/19 | T400 | 21 | 31/14 |
| T50C | 3,000 | 34/15 | T400B | 15 | 34/15 |
| T50D | 3,000 | 37/17 | T400D | 12 | 35/16 |
| T51C | 4,000 | 43/19 | T520 | 12 | 34/15 |
| T57 | 4,000 | 42/19 | T520D | 6 | 33/15 |
| T57A | 3,000 | 42/19 | T650 | 2 | 25/11 |
| T60 | 3,000 | 36/16 | E49 | 10,000 | 24/17 |
| T60D | 1,600 | 39/18 | E50 | 10,000 | 34/15 |
| T68 | 3,000 | 39/18 | E65 | 4,000 | 27/12 |
| T68A | 3,000 | 53/24 | E75 | 4,000 | 31/14 |
| T68D | 1,600 | 40/18 | E80 | 3,000 | 38/17 |
| T69 | 1,600 | 43/19 | E99 | 1,500 | 40/18 |
| T72 | 2,000 | 48/22 | E100 | 2,000 | 34/15 |
| T80 | 2,000 | 40/18 | E101 | 1,000 | 41/19 |
| T80B | 1,250 | 39/18 | E118 | 1,225 | 44/20 |
| T80D | 1,000 | 42/19 | E125 | 504 | 29/13 |
| T90 | 1,000 | 39/18 | E137 | 800 | 39/18 |
| T94 | 1,250 | 46/21 | E145 | 360 | 29/13 |
| T106 | 700 | 52/24 | E162 | 300 | 34/15 |
| T106A | 1,000 | 50/23 | E168 | 200 | 30/14 |
| T106B | 560 | 54/25 | E168A | 150 | 30/14 |
| T124 | 600 | 37/17 | E187 | 240 | 48/22 |
| T130 | 500 | 50/23 | E220 | 80 | 31/14 |
| T130A | 600 | 31/14 | E225 | 110 | 38/17 |
| T131 | 500 | 59/27 | E305 | 48 | 36/16 |
| T132 | 500 | 56/25 | E305A | 36 | 37/17 |
| T141 | 400 | 42/19 | E450 | 18 | 37/17 |
| | | | E450H | 36 | 40/18 |

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MICROMETALS

GLOSSARY

AL Value (nH/N²): The inductance rating of a core in nanohenries (10⁻⁹ henries) per turn squared based on a peak AC flux density of 10 gauss (1 millitesla) at a frequency of 10 kHz. Note: 35.0 nH/N² = 350 μH for 100 turns = 35.0 mH for 1000 turns.

Butt-Gap: The gapping of E Cores by equally spacing all three legs of the cores rather than introducing a gap in the center-leg only. Twice as much center-leg gap is required to electrically duplicate a given butt-gap.

Choke: Another term for an inductor which is intended to filter or choke out signals.

Common-Mode Noise: Electrical interference that is common to both lines in relation to earth ground. Copper Loss (watts): The power loss (I²R) or heat generated by current (I) flowing in a winding with resistance (R).

Core Loss (watts): The power loss or heat generated by a magnetic material subjected to an alternating magnetic field.

Cross-Sectional Area (A): The effective cross-sectional area (cm²) of a core available for magnetic flux. The cross-sectional area listed for toroidal cores is based on bare core dimensions with a 5% radius correction.

Differential-Mode Noise: Electrical interference that is not common to both lines but is present between both lines. This is also known as normal-mode noise.

Energy Storage (1/2LI²): The amount of energy stored in microjoules (10⁻⁶ joules) is the product of one-half the inductance (L) in microhenries (10⁻⁶ henries) times the current (I) squared in amperes.

Full Winding: A winding for toroidal cores which will result in 45% of the core's inside diameter remaining. A winding for E Cores which will result in a full bobbin. The type of insulation, tightness of winding, and coil winding equipment limitations will all introduce variations.

Initial Permeability (μ₀): That value of permeability at a peak AC flux density of 10 gauss (1 millitesla). μ=B/H. The permeability listed for each material is for reference only. The cores are manufactured to the listed A_L values.

Magnetizing Force (H): The magnetic field strength which produces magnetic flux. 1 oersted = 79.58 A/m = .7958 A/cm

In cgs units:

$$H = \frac{.4 \pi N I}{\ell} \quad \text{Where: } H = \text{oersteds (Oe)}$$

N = Number of turns
I = Current (amperes)
ℓ = Mean Magnetic Path (cm)

In SI units:

$$H = \frac{N I}{\ell} \quad \text{Where: } H = \text{amperes per meter}$$

N = Number of turns
I = Current (amperes)
ℓ = Mean Magnetic Path (cm)

Mean Magnetic Path Length (ℓ): The effective magnetic length of a core structure (cm).

MLT (cm): The mean length per turn of wire for a core. See figures on pages 64 and 65.

Peak AC Flux Density (B_{pk}): The number of lines of flux per unit of cross-sectional area generated by an alternating magnetic field (from zero or a net DC). In general: (1 gauss = 10⁻⁴ tesla)

In cgs units:

$$B_{pk} = \frac{E_{avg} 10^8}{4 A N f} \quad \text{Where:}$$

B_{pk} = Gauss (G)
E_{avg} = Average voltage per half cycle (volts)
A = Cross-sectional area (cm²)
N = Number of turns
F = Frequency (hertz)

Peak to Peak Flux Density (ΔB): In an alternating magnetic field, it is assumed that the peak to peak flux density is twice the value of peak AC flux density. ΔB = 2 B_{pk}.

Percent Initial Permeability (%μ₀): Represents the percent change in permeability from the initial value. Since the cores are manufactured to the A_L value rather than to the listed reference permeability, this can also be considered Percent A_L Value.

Percent Ripple: The percentage of ripple or AC flux to total flux; or in an inductor, the percentage of alternating current to average current.

Percent Saturation: This is equal to 100% – Percent Initial Permeability. ie: 20% saturation = 80% of initial permeability.

Simple Winding: A winding for toroidal cores which will result in 78% of the core's inside diameter remaining. Often times this will produce a single-layer winding.

Single-Layer Winding: A winding for a toroidal core which will result in the full utilization of the inside circumference of the core without the overlapping of turns. The thickness of insulation and tightness of winding will affect results.

Swing: A term used to describe how inductance responds to changes in current. Example: A 2:1 swing corresponds to an inductor which exhibits 2 times more inductance at very low current than it does at its maximum rated current. This would also correspond to the core operating at 50% of initial permeability (also 50% saturation) at maximum current.

Surface Area (cm²): The effective surface area of a typical wound core available to dissipate heat. See figures on pages 64 and 65.

Temperature Rise (ΔT): The increase in surface temperature of a component in free-standing air due to the total power dissipation (both copper and core loss). See pages 64 and 65.

The following formula has been used to approximate temperature rise:

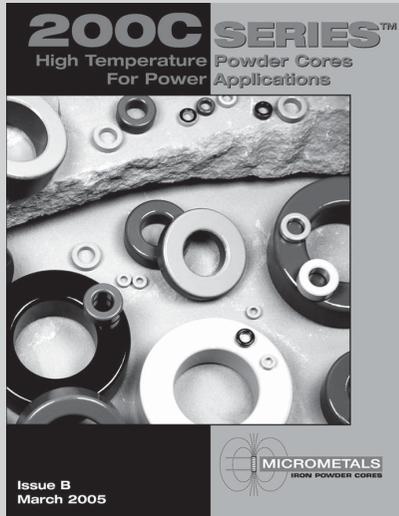
$$\Delta T (C^{\circ}) = \left[\frac{\text{Total Power Dissipation (milliwatts)}}{\text{Surface Area (cm}^2\text{)}} \right]^{.833}$$

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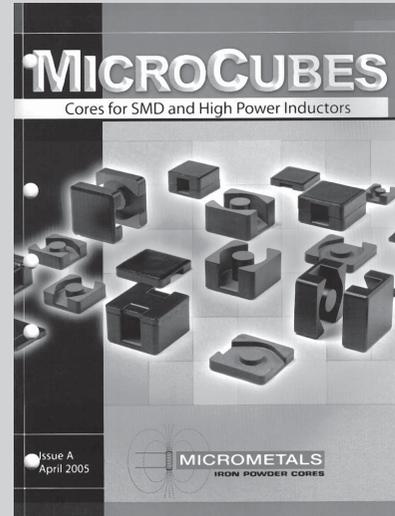
ADDITIONAL LITERATURE

200C Series™ High Temperature Powder Cores



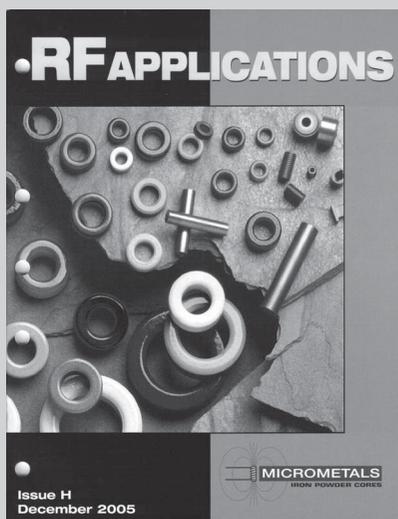
Micrometals 200C Series™ of magnetic alloy materials are specifically designed for severe environment applications where cores are exposed to or generate elevated temperatures. These cost competitive core materials are not subject to thermal aging for operating temperatures up to +200°C. Materials permeabilities range from 35 to 125 with toroid geometries up to 4.0 inches and E-cores up to 4.5 inches.

Microcubes Low Profile Linear Wound HC/IC Cores



Micrometals series of cores for high density inductors are well-suited for either through-hole or surface mount applications. Microcubes are ideal for low inductance, high current applications such as voltage regulated modules (VRM's), point of load power supplies and other DC/DC applications. The geometries shown in this catalog are offered in traditional iron powder material and magnetic alloy powder.

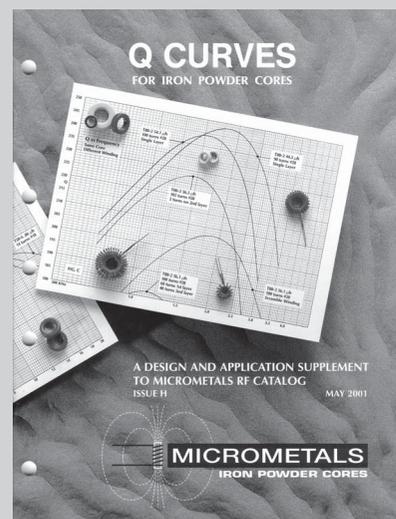
Radio Frequency Applications



Micrometals RF catalog contains iron powder toroids, balun core, plain cores, hollow cores, sleeves, threaded cores, cups, disks, bobbins, bobbin sleeves and squared bobbins in the following materials: -1, -2, -3, -4, -6, -7, -10, -12, -17, -42 and -0. Permeabilities range from 1 to 35 for applications from 10 khz to 500 MHz.

The Q Curve catalog is a design and application supplement containing over 30 pages of Q versus Frequency curves and other useful information.

Q Curves Supplement to RF Catalog



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