Ferrite Toroids Catalog

Steward

www.steward.com

ISO 9001:2000 and QS 9000 Certified

10th Edition!

CATTTFC 10th Edition REV 2 04 / 2004

STEWARD TOROIDS
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STEWARD PROFILE

Steward is a leading producer of ferrite and related materials used in the electronics, copier, telecommunications, military and automotive industries. Established in 1876, Steward has corporate offices in Chattanooga, Tennessee, U.S.A. with three manufacturing facilities in North America, and markets its products around the world. Steward manufactures ferrite EMI shielding and filtering components, wide band transformer and filter cores, custom ferrite powders, and iron silicide powders.

Ferrite: EMI Suppressor Materials

Steward's nickel-zinc ferrite parts are used extensively in the suppression of electromagnetic interference, commonly known as EMI. Suppression of EMI has become a major concern in the transmission, reception, and processing of electronic data. By changing the ferrite composition, attenuation can be enhanced in selected frequency ranges. Steward offers a family of nickel-zinc and manganese-zinc ferrites of differing compositions to allow the user to select the optimum type for a given application. Pressed parts, components and powders are available.

Ferrite: Wide Band Transformer & Filter Cores

Steward's nickel-zinc and manganese-zinc ferrite toroids range in initial permeabilities from 16 to 15000. These products are used primarily in pulse and isolation transformers, dataline and power filters, and ground fault interrupters. A wide selection of bare or coated cores is available.

Ferrite: Powders

CARRIER BEAD POWDERS: Steward is *the* custom manufacturer of carrier bead ferrite materials for dual component xerographic applications. A wide range of particle distributions and properties is available. Our carrier bead powders are supplied to copy machine manufacturers around the world.

FERRITE LOADING POWDERS: Steward produces a wide selection of sintered fine particle ferrite powders with average particle sizes ranging down to submicron. These energy attenuating powders may be loaded into injection molded, extruded, coated, roll compacted or multi-layer laminated products. Other uses include inductive filters, pigments, fibers and microwave heating coatings.

FERRITE PRESSING POWDERS: Steward offers a wide range of both Inductance and Impedance materials for dry compaction pressing needs.

IRON SILICIDE: Steward's iron silicide powder provides solutions for many problems currently experienced with standard microwave absorbing materials, and has characteristics suitable for metallurgical uses as well. This patented iron silicide alloy, typically available in two particle sizes, is rust resistant, abrasion resistant, erosion resistant, chemical resistant, and less dense than iron. Iron silicide provides excellent survivability and low maintenance.

POWDER FOR COFIRED APPLICATIONS: Steward is a custom manufacturer of powder for co-fired applications.

Steward & Soft Ferrites

Steward Today

Steward's experience in the technical ceramics industry reaches back over a century. Steward has been producing ferrite materials, a special class of ceramics, for over 40 years. While most of the early ferrite products were directed toward the rapidly expanding television electronics industry during the 1950's, today, manufacturing and marketing are focused on three segments of the electronic information processing industries in three distinct product lines:

- Ferrites for the suppression of electromagnetic interference (EMI)
- Ferrite Cores for broadband transformer and filter applications, and
- Custom Ferrite Powders and Ferrite Carrier Bead Powder used in developers in copy machines.

This catalog describes Steward's broadband core products and small toroids for electromagnetic interference (EMI) applications. Additional literature on our EMI suppression products and other ferrite materials is available upon request.

Steward's manufacturing facilities located in North America and Asia and our products are marketed world-wide. Steward's operations are highly integrated and include all powder produced from pure oxides through finished high quality ferrite parts and assemblies.

Soft Ferrites

Most of the ferrites produced by Steward are magnetically soft; that is, they are easily magnetized and demagnetized. By virtue of their oxide nature, they possess high resistivities relative to metals. These properties, along with their high permeability, make them the materials of choice for magnetics in high frequency applications.

There are three general applications areas for soft ferrites:

- Magnetic power circuits for energy conversion, such as in DC-DC power supply design.
- High frequency noise suppression to meet FCC, VDE, CISPR, 89/336/EEC, ECCI, and signal integrity design requirements.
- Small signal transformers, especially for the construction of broadband, matching, pulse, and isolation transformers.

Steward specializes in products designed for interference suppression and small signal applications. The most common EMI applications are as series filters and common-mode chokes. Several of Steward's EMI materials are suitable for high-frequency transformers.

Small-signal inductance applications may be further divided into several segments:

- High Q inductors,
- Common-mode inductors, and
- Broadband, matching, and pulse and isolation transformers.

For other applications, Steward's engineers will gladly assist you in the selection of the proper material and core for your requirements.

Characteristics of Steward's Soft Ferrites In This Catalog

The requirements to deliver interference-free signals in digital telecommunications have never been more demanding. In order to provide solutions to these requirements, Steward offers a full range of ferrites for a full range of applications. Depending on operating frequency, these ferrites can be used either as inductance cores for broadband impedance matching and isolation, or for EMI suppression.

For inductive applications a range of moderate to high permeability, low loss materials is offered. Information provided for the materials includes intrinsic and graphic data relating to the effects of temperature, flux density, and frequency.

For EMI suppression applications Steward includes impedance-frequency response data for select materials. Curves are provided with various turn configurations and under different DC bias levels. For comparison purposes, all data are given with one size core. Also provided is a comparison of differential vs. common mode winding techniques.

Steward & Soft Ferrites

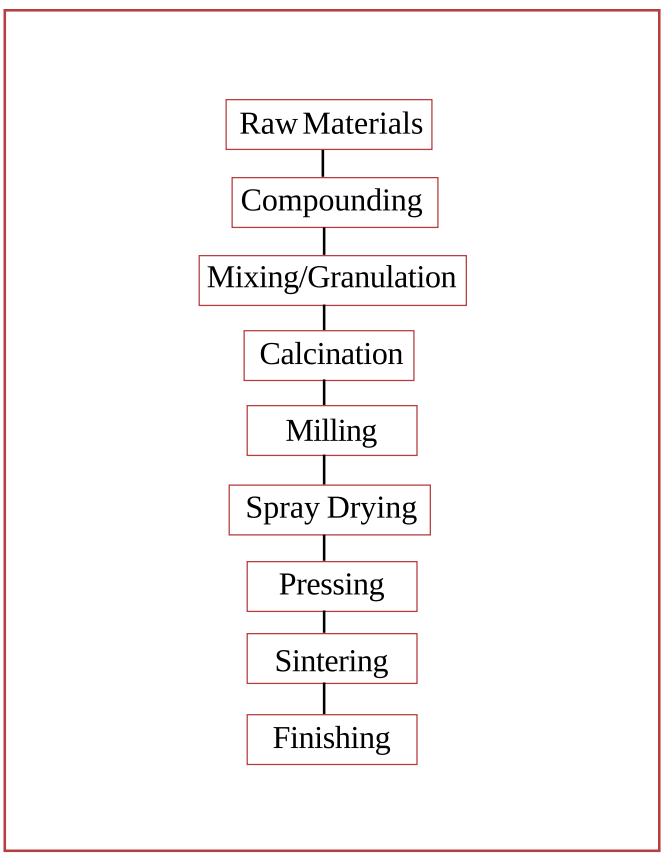
A Brief Overview of Ferrite Production

Soft ferrites are, generally, cubic crystalline ceramics. Chemically, they are composed of metallic oxides in the form $MeFe_2O_4$, where Me is commonly manganese, nickel, cobalt, copper, or iron in combination with zinc in varying ratios. The uniting of these oxides into crystalline cubic structures is accomplished at very high temperatures, resulting in dense, hard ceramic materials. The position of the metal ion in the cubic lattice influences the magnetic properties of the ferrite. The position of the ion is dependent on the metal chosen to accompany the iron oxide and the processing performed to produce that particular ferrite material.

Processing Ferrites

The flow diagram describes the general steps carried out in the production of Steward's broadband cores.

The raw materials are oxides or carbonates of the metallic elements specified for each ferrite material. Their purity greatly affects the magnetic properties of the product.



Compounding — Control of the proportions of each of the raw materials used is a very important factor in the production of high quality soft ferrites.

Mixing/Granulation — In order to produce a homogeneous composition, it is vital to distribute the raw materials uniformly. This is done by wet milling with a subsequent drying step, or by a high energy mixing process. A granulation step or pelletization prevents dusting in the calcination step which follows.

Calcination — Calcination is a pre-sintering process, generally performed at about 1000° C., which initiates the formation of ferrite from the individual oxide components. It decomposes any carbonate used, provides a more homogeneous composition, initiates grain growth and aids in controlling the shrinkage incurred in the final sintering step.

Milling — To further promote homogeneity and to control density and grain growth during sintering, the calcined product is milled to a small particle size.

Spray Drying — Spray drying converts slurry formed in the milling operation into a uniform, free flowing powder from which compression molded shapes may be formed.

Pressing — The powder is metered into a die cavity and precision compressed to form a strong, "green" part.

Sintering — This is the most critical step in processing soft ferrites. The organics used in the pressing step must be completely removed. Parts must then be heated at the proper rate to the final sintering temperature to achieve optimal grain structure. During this period, and on through the cooling part of the cycle, specified amounts of nitrogen and oxygen must be regulated to achieve the proper valence state for the constituents. Sintering of MnZn ferrite is performed at temperatures up to 1400° C.

Finishing — Deburring, tumbling, grinding and coating are important final steps required to achieve the quality necessary for many parts.

In order to produce high quality ferrite products, close control of the manufacturing operations is vital. Statistical Process Control must be exercised in every step, and ISO 9001 provides the organization, methodology and documentation necessary to produce consistent products.

Steward & Quality Assurance

Quality Philosophy

At Steward, customer focus is paramount in our quality program. Our quality philosophy is outlined as follows:

- Steward is a company committed to continuous improvement. We fulfill this commitment by continually improving the quality of the products and services we provide our customers, both external and internal.
- We recognize that our customers define quality. We further recognize that continuous improvement can only result from the fullest development of our people and technologies.
- We believe that to pursue this course, we must set unselfish service as our standard for conduct. Building on the values of our history, we will raise our standards of performance through continuous improvement and imagination. In addition, our actions must demonstrate integrity, honesty, excellence and self-discipline.
- We believe in teamwork. Our commitment to continuous improvement is fulfilled and maintained by the combined, cohesive efforts of people with a common goal.

Quality Measurement System

Steward's Quality Management Systems have been certified to the ISO 9001 requirements by Ceramic Industry Certification Scheme Ltd.

CICS
UKAS QUALITY MANAGEMENT 006
ISO 9001:2000
QS 9000
Certified

Quality Testing

We test on the following equipment:

Inductance, Loss Factor:	Hewlett-Packard 4274A Multi-Frequency LCR Meter
	Hewlett-Packard 4275A Multi-Frequency LCR Meter
	Hewlett-Packard 4284A Multi-Frequency LCR Meter
Impedance:	Hewlett-Packard 4195A Network/Spectrum Analyzer

Part Identification

Part Numbers

Steward's part numbers use a ten character alphanumeric nomenclature providing:

- The material designation
- The product type (shape)
- A basic size description
- A parts modifier series

Example :

35T0155-01P is a 5000 permeability toroid 0.155" (3.94 mm) in diameter and 0.100" (2.54 mm) thick with Parylene coating

Steward PART NUMBERING SYSTEM

35	T	0155	- 0	1	P
MATERIAL TYPE	PRODUCT CODE	PART SIZE CODE	PART THICKNESS	CUSTOM SPECIFICATION	PARYLENE COATING

Product Types 35 T ______ - __ __ __

Steward's Transformer and Filter Core Division uses four basic shape designators:

T for toroidal cores
Example: 35T0155-01P

Basic Size Description 35 T 0155 - __ __ __

The four digits following the product description provide the largest dimension of the part in thousandths of an inch. For toroids and similar shapes, it usually describes the outside or major diameter of the core. For other types of parts, it is the largest dimension specified in the part's description.

Parts Modifier Series 35 T 0155 - 01P

The first of the three digits following the dash refers to the part thickness. A zero through nine digit refers variations in thickness from the same tool. The second modifying digit relates to a custom requirement (electrical testing or physical specification). The third digit or letter describes a coating or finish.

Material Designator 35 __ ______ - __ __ __

A two digit material designator is assigned to materials on the basis of initial permeability.

Material	Initial Permeability
21	16
25	125
28	850
24	1050
38	1700
33	2700
46	4000
36	4500
35	5000
42	7500
40	10000
45	15000

Please consult Steward's Website for other products.

Coating Designations

P — Parylene
Hi-Pot Rating 1000 VAC minimum
Nominal Thickness: 0.5 mils

Q — Parylene
Hi-Pot Rating 1500 VAC minimum
Nominal Thickness: 1.0 mils

G — Epoxy
Hi-Pot Rating 500 VAC minimum
Nominal Thickness: 1.5 mils

H — Epoxy
Hi-Pot Rating 1000 VAC minimum
Nominal Thickness: 3.0 mils

0 — No coating

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Standard Components

Soft Ferrite Typical Physical Constants	
Specific Heat	0.25 cal/g/°C
Thermal Conductivity	10^{-2} cal/sec/cm/°C
Coefficient of Linear Expansion	8-10 x 10^{-6}/°C
Tensile Strength	500 kg/cm^2
Compressive Strength	4200 kg/cm^2
Youngs Modulus	1260 kg/cm^2
Hardness (Knoop)	650
Density	4.6 to 4.9 g/cm^3

Mechanical Tolerances	
OD — ID Tolerances	
OD — ID	**TOL**
- .199	.005
.200 - .374	.006
.375 - .499	.008
.500 - .624	.010
.625 - .749	.012
HT Tolerances	
HT	**TOL**
- .249	.005
.250 - .289	.007
• .290	.010

Toroidal Core Coatings

As required by some customer applications, smooth, resistive coatings may be provided. Standard dimensions for each toroid are listed in the parts chart, and coating may alter these slightly. Inductance values are as shown for standard sizes and cores are checked after coating to ensure compliance.

Parylene

Parylene is ideally suited for core sizes with outside diameters less than 9.5 mm (0.375"). Parylene is a highly conformal coating with uniform thickness even around corners and edges. It is applied by vapor deposition, which prevents clogging of small apertures. Because of its standard 0.5 mil thickness, the addition of Parylene results in very little increase in core size. It has a high resistivity and a low coefficient of friction (close to that of Teflon), which results in a low wire insulation abrasion during winding. Parylene's relatively low dielectric constant is 2.95, resulting in only a small increase of winding-to-core capacitance. After coating, cores are Hi-Pot tested to 1000 VAC volts for single thickness and higher voltages for additional coating thicknesses.

Epoxy

Epoxy coating is the choice for cores about 9.5mm (0.375") diameter or larger. It is applied by spraying, resulting in a typical single coat thickness varying from 2 to 3 mils. Because of its thickness, epoxy coating provides some cushioning during winding. Epoxy coating provides inherent toughness, corrosion resistance, and very good adhesion. This coating retains these properties even after long term heat aging. After coating, cores are Hi-Pot tested to 500 VAC, higher for additional coating thicknesses.

For specialized applications, Steward offers five specifically designed materials:

1) 21 material for temperature-stable high frequency inductor and very high frequency choke applications;
2) 36 & 46 material for high frequency LAN (HFLAN) applications;
3) 38 material for broadband, environmentally friendly EMI suppression;
4) 42 material for guarantee of minimum permeability over a wide temperature range.

Steward Ferrite Core Materials

* Broadband Common Mode Choke Cores
** Specialty Material

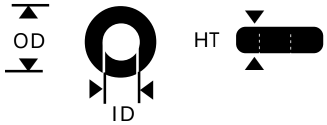
PARAMETER	SYMBOL	UNIT	MATERIALS					
			21**	25	28	24	38*	33
Relative Initial Permeability	μi		16	125	850	1050	1700	2700
Tolerance		%	Typical	± 30	± 20	± 30	± 30	± 20
Saturation Flux Density	B_s	Gauss	2500	3600	3250	2750	3000	4700
		mT	250	360	325	275	300	470
at Field Intensity	*H*	Oersteds	80	10	10	10	10	10
		A/m	6400	800	800	800	800	800
Residual Flux Density	B_r	Gauss	1500	2600	2000	1400	1450	1200
		mT	150	260	200	140	145	120
Coercive Force	H_c	Oersteds	20	1.6	0.4	0.3		0.2
		A/m	1600	127	3	24		16
Relative Loss Factor	tan δ μ i	10^{-6}				30		6
at Freqency	f	MHz				0.10		0.10
Disaccommodation Factor		10^{-6}						< 2.5
Currie Temperature	T_c	°C	> 500	> 225	> 175	> 140	> 120	> 200
Resistivity	ρ	-cm	10^7	10^6	10^5	10^6	10^5	25^2
Density		g/cm^3	4.5	4.9	4.9	4.9	4.8	4.7

* High Frequency LAN Cores
** Broad Temperature Telecommunication Cores

PARAMETER	SYMBOL	UNIT	MATERIALS					
			46*	36*	35	42**	40	45
Relative Initial Permeability	μi		4000	4500	5000	7500	10000	15000
Tolerance		%	± 25	± 25	± 20	± 25	± 30	± 30
Saturation Flux Density	B_s	Gauss			4100	4100	4000	
		mT			410	410	400	
at Field Intensity	*H*	Oersteds			10	10	10	
		A/m			800	800	800	
Residual Flux Density	B_r	Gauss			1300	1100	1000	
		mT			130	110	100	
Coercive Force	H_c	Oersteds			0.10	0.08	0.04	
		A/m			8	6	3	
Relative Loss Factor	tan δ μ i	10^{-6}	10	10	20	6	5	5
at Freqency	f	MHz	0.10	0.10	0.10	0.010	0.100	0.010
Disaccommodation Factor		10^{-6}			< 2.0	< 3.0	< 2.5	
Currie Temperature	T_c	°C	> 130	> 160	> 150	> 130	> 120	> 110
Resistivity	ρ	-cm			10^2	10^2	50	
Density		g/cm^3	4.8	4.8	4.8	4.8	4.8	4.8

Design Service is offered by Steward technical staff. Send us your application and we will find the correct material and part for your design needs. Please call 423/867-4100 for this free service.

Steward Toroids



Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM OD	MM ID	MM HT	INCHES OD	INCHES ID	INCHES HT	l_e mm	A_e mm^2	V_e mm^3	C_1 mm^{-1}	MLT mm/Turn
T0081-00	2.03	1.27	0.64	0.080	0.050	0.025	5.001	0.238	1.188	21.053	2.03
T0081-10	2.03	1.27	0.76	0.080	0.050	0.030	5.001	0.285	1.425	17.544	2.29
T0100-00	2.54	1.27	1.27	0.100	0.050	0.050	5.531	0.775	4.286	7.138	3.81
T0100-10	2.54	1.27	1.78	0.100	0.050	0.070	5.531	1.085	6.001	5.098	4.83
T0100-20	2.54	1.27	0.76	0.100	0.050	0.030	5.531	0.465	2.572	11.896	2.79
T0100-30	2.54	1.27	0.99	0.100	0.050	0.039	5.531	0.604	3.343	9.151	3.25
T0100-40	2.54	1.27	2.54	0.100	0.050	0.100	5.531	1.550	8.572	3.569	6.35
T0101-00	2.54	1.50	1.27	0.100	0.059	0.050	6.059	0.646	3.915	9.377	3.58
T0101-10	2.54	1.50	0.99	0.100	0.059	0.039	6.059	0.504	3.054	12.021	3.02
T0101-20	2.54	1.50	0.76	0.100	0.059	0.030	6.059	0.388	2.349	15.628	2.57
T0115-00	2.92	1.63	1.78	0.115	0.064	0.070	6.749	1.119	7.553	6.030	4.85
T0115-10	2.92	1.63	2.41	0.115	0.064	0.095	6.749	1.519	10.251	4.443	6.12
T0119-00	3.05	1.27	1.27	0.120	0.050	0.050	5.988	1.060	6.345	5.651	4.32
T0119-10	3.05	1.27	0.76	0.120	0.050	0.030	5.988	0.636	3.807	9.419	3.30
T0119-20	3.05	1.27	0.86	0.120	0.050	0.034	5.988	0.721	4.314	8.310	3.51
T0119-30	3.05	1.27	0.99	0.120	0.050	0.039	5.988	0.826	4.949	7.245	3.76
T0119-40	3.05	1.27	2.54	0.120	0.050	0.100	5.988	2.119	12.690	2.826	6.86
T0119-50	3.05	1.27	2.03	0.120	0.050	0.080	5.988	1.695	10.152	3.532	5.84
T0120-00	3.05	1.78	1.52	0.120	0.070	0.060	7.226	0.945	6.826	7.649	4.32
T0120-10	3.05	1.78	1.27	0.120	0.070	0.050	7.226	0.787	5.688	9.179	3.81
T0120-20	3.05	1.78	2.54	0.120	0.070	0.100	7.226	1.574	11.376	4.589	6.35
T0120-40	3.05	1.78	0.99	0.120	0.070	0.039	7.226	0.614	4.437	11.768	3.25
T0120-70	3.05	1.78	1.78	0.120	0.070	0.070	7.226	1.102	7.963	6.556	4.83
T0120-80	3.05	1.78	2.03	0.120	0.070	0.080	7.226	1.260	9.101	5.737	5.33
T0121-00	3.05	1.52	0.79	0.120	0.060	0.031	6.637	0.577	3.827	11.512	3.10
T0121-10	3.05	1.52	2.54	0.120	0.060	0.100	6.637	1.860	12.344	3.569	6.60
T0121-20	3.05	1.52	2.06	0.120	0.060	0.081	6.637	1.506	9.999	4.406	5.64
T0121-30	3.05	1.52	2.39	0.120	0.060	0.094	6.637	1.748	11.603	3.797	6.30

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Steward Toroids

PART NUMBER	21	25	28	24	38	33	46	36	35	42	40	45
	A_L (nH per turn squared)											
	Materials											
	Initial Permeability											
	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0081-00	1	7	51	63	101	161	239	269	298	448	597	895
T0081-10	1	9	61	75	122	193	287	322	358	537	716	1,074
T0100-00	3	22	150	185	299	475	704	792	880	1,320	1,761	2,641
T0100-10	4	31	210	259	419	666	986	1,109	1,232	1,849	2,465	3,697
T0100-20	2	13	90	111	180	285	423	475	528	792	1,056	1,585
T0100-30	2	17	117	144	233	371	549	618	687	1,030	1,373	2,060
T0100-40	6	44	299	370	599	951	1,408	1,585	1,761	2,641	3,521	5,282
T0101-00	2	17	114	141	228	362	536	603	670	1,005	1,340	2,010
T0101-10	2	13	89	110	178	282	418	470	523	784	1,045	1,568
T0101-20	1	10	68	84	137	217	322	362	402	603	804	1,206
T0115-00	3	26	177	219	354	563	834	938	1,042	1,563	2,084	3,126
T0115-10	5	35	240	297	481	764	1,131	1,273	1,414	2,121	2,828	4,242
T0119-00	4	28	189	233	378	600	889	1,001	1,112	1,668	2,224	3,336
T0119-10	2	17	113	140	227	360	534	600	667	1,001	1,334	2,001
T0119-20	2	19	129	159	257	408	605	680	756	1,134	1,512	2,268
T0119-30	3	22	147	182	295	468	694	781	867	1,301	1,734	2,602
T0119-40	7	56	378	467	756	1,201	1,779	2,001	2,224	3,336	4,447	6,671
T0119-50	6	44	302	374	605	961	1,423	1,601	1,779	2,668	3,558	5,337
T0120-00	3	21	140	173	279	444	657	739	821	1,232	1,643	2,464
T0120-10	2	17	116	144	233	370	548	616	685	1,027	1,369	2,054
T0120-20	4	34	233	288	465	739	1,095	1,232	1,369	2,054	2,738	4,107
T0120-40	2	13	91	112	182	288	427	481	534	801	1,068	1,602
T0120-70	3	24	163	201	326	518	767	863	958	1,438	1,917	2,875
T0120-80	4	27	186	230	372	591	876	986	1,095	1,643	2,190	3,286
T0121-00	2	14	93	115	186	295	437	491	546	819	1,092	1,637
T0121-10	6	44	299	370	599	951	1,408	1,585	1,761	2,641	3,521	5,282
T0121-20	5	36	242	299	485	770	1,141	1,283	1,426	2,139	2,852	4,278
T0121-30	5	41	281	348	563	894	1,324	1,489	1,655	2,482	3,310	4,965

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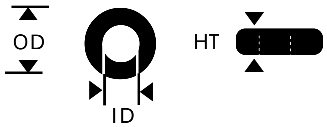


Steward Toroids

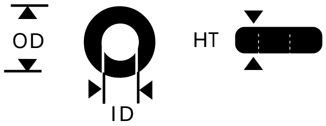
Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM OD	MM ID	MM HT	INCHES OD	INCHES ID	INCHES HT	l_e mm	A_e mm^2	V_e mm^3	C_1 mm^{-1}	MLT mm/Turn
T0121-40	3.05	1.52	2.18	0.120	0.060	0.086	6.637	1.599	10.616	4.150	5.89
T0122-00	3.05	1.65	1.65	0.120	0.065	0.065	6.938	1.118	7.755	6.207	4.70
T0122-10	3.05	1.65	2.54	0.120	0.065	0.100	6.938	1.720	11.931	4.035	6.48
T0122-20	3.05	1.65	2.06	0.120	0.065	0.081	6.938	1.393	9.664	4.981	5.51
T0122-30	3.05	1.65	2.39	0.120	0.065	0.094	6.938	1.616	11.215	4.292	6.17
T0130-00	3.30	1.27	1.27	0.130	0.050	0.050	6.195	1.196	7.412	5.178	4.57
T0130-10	3.30	1.27	0.99	0.130	0.050	0.039	6.195	0.933	5.781	6.638	4.01
T0130-20	3.30	1.27	0.76	0.130	0.050	0.030	6.195	0.718	4.447	8.630	3.56
T0135-00	3.43	1.78	1.27	0.135	0.070	0.050	7.619	1.011	7.707	7.533	4.19
T0135-10	3.43	1.78	2.06	0.135	0.070	0.081	7.619	1.639	12.485	4.650	5.77
T0135-20	3.43	1.78	0.86	0.135	0.070	0.034	7.619	0.688	5.241	11.078	3.38
T0135-30	3.43	1.78	2.54	0.135	0.070	0.100	7.619	2.023	15.414	3.766	6.73
T0135-40	3.43	1.78	1.78	0.135	0.070	0.070	7.619	1.416	10.790	5.381	5.21
T0135-50	3.43	1.78	1.40	0.135	0.070	0.055	7.619	1.113	8.478	6.848	4.45
T0135-60	3.43	1.78	1.52	0.135	0.070	0.060	7.619	1.214	9.248	6.277	4.70
T0135-70	3.43	1.78	0.76	0.135	0.070	0.030	7.619	0.607	4.624	12.555	3.18
T0135-80	3.43	1.78	1.55	0.135	0.070	0.061	7.619	1.234	9.403	6.174	4.75
T0135-90	3.43	1.78	2.79	0.135	0.070	0.110	7.619	2.225	16.955	3.424	7.24
T0136-00	3.51	1.60	6.50	0.138	0.063	0.256	7.253	5.886	42.690	1.232	14.91
T0137-00	3.43	1.52	0.76	0.135	0.060	0.030	6.989	0.687	4.803	10.168	3.43
T0139-10	3.43	1.30	1.27	0.135	0.051	0.050	6.367	1.253	7.976	5.082	4.67
T0139-20	3.43	1.30	0.99	0.135	0.051	0.039	6.367	0.977	6.221	6.516	4.11
T0145-00	3.68	1.65	2.54	0.145	0.065	0.100	7.543	2.447	18.454	3.083	7.11
T0145-10	3.68	1.65	2.03	0.145	0.065	0.080	7.543	1.957	14.763	3.854	6.10
T0153-00	3.94	1.78	1.27	0.155	0.070	0.050	8.097	1.301	10.534	6.224	4.70
T0153-10	3.94	1.78	0.99	0.155	0.070	0.039	8.097	1.015	8.217	7.979	4.14
T0153-20	3.94	1.78	2.03	0.155	0.070	0.080	8.097	2.082	16.855	3.890	6.22
T0153-40	3.94	1.78	2.54	0.155	0.070	0.100	8.097	2.602	21.068	3.112	7.24

Steward Toroids

	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
PART NUMBER	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0121-40	5	38	257	318	515	818	1,211	1,363	1,514	2,271	3,028	4,542
T0122-00	3	25	172	213	344	547	810	911	1,012	1,518	2,024	3,037
T0122-10	5	39	265	327	529	841	1,246	1,402	1,557	2,336	3,115	4,672
T0122-20	4	32	214	265	429	681	1,009	1,135	1,261	1,892	2,523	3,784
T0122-30	5	37	249	307	498	790	1,171	1,317	1,464	2,196	2,928	4,392
T0130-00	4	30	206	255	413	655	971	1,092	1,213	1,820	2,427	3,640
T0130-10	3	24	161	199	322	511	757	852	947	1,420	1,893	2,840
T0130-20	2	18	124	153	248	393	582	655	728	1,092	1,456	2,184
T0135-00	3	21	142	175	284	450	667	751	834	1,251	1,668	2,502
T0135-10	4	34	230	284	459	730	1,081	1,216	1,351	2,027	2,703	4,054
T0135-20	2	14	96	119	193	306	454	510	567	851	1,134	1,702
T0135-30	5	42	284	350	567	901	1,335	1,501	1,668	2,502	3,336	5,005
T0135-40	4	29	199	245	397	631	934	1,051	1,168	1,752	2,336	3,503
T0135-50	3	23	156	193	312	495	734	826	918	1,376	1,835	2,753
T0135-60	3	25	170	210	340	541	801	901	1,001	1,501	2,002	3,003
T0135-70	2	13	85	105	170	270	400	450	500	751	1,001	1,501
T0135-80	3	25	173	214	346	550	814	916	1,018	1,526	2,035	3,053
T0135-90	6	46	312	385	624	991	1,468	1,652	1,835	2,753	3,670	5,505
T0136-00	16	127	867	1,071	1,734	2,753	4,079	4,589	5,099	7,648	10,197	15,296
T0137-00	2	15	105	130	210	334	494	556	618	927	1,236	1,854
T0139-10	4	31	210	260	420	668	989	1,113	1,236	1,854	2,473	3,709
T0139-20	3	24	164	203	328	521	771	868	964	1,446	1,929	2,893
T0145-00	7	51	346	428	693	1,100	1,630	1,834	2,038	3,057	4,076	6,114
T0145-10	5	41	277	342	554	880	1,304	1,467	1,630	2,446	3,261	4,891
T0153-00	3	25	172	212	343	545	808	909	1,010	1,514	2,019	3,029
T0153-10	3	20	134	165	268	425	630	709	787	1,181	1,575	2,362
T0153-20	5	40	275	339	549	872	1,292	1,454	1,615	2,423	3,231	4,846
T0153-40	6	50	343	424	687	1,090	1,615	1,817	2,019	3,029	4,038	6,057



Steward Toroids

Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM			INCHES			l_e	A_e	V_e	C_1	MLT
	OD	ID	HT	OD	ID	HT	mm	mm^2	mm^3	mm^{-1}	mm/Turn
T0153-60	3.94	1.78	1.52	0.155	0.070	0.060	8.097	1.561	12.641	5.186	5.21
T0153-70	3.94	1.78	1.78	0.155	0.070	0.070	8.097	1.821	14.748	4.445	5.72
T0153-80	3.94	1.78	1.65	0.155	0.070	0.065	8.097	1.691	13.694	4.787	5.46
T0153-90	3.94	1.78	0.89	0.155	0.070	0.035	8.097	0.911	7.374	8.891	3.94
T0154-00	3.94	1.68	1.37	0.155	0.066	0.054	7.831	1.459	11.429	5.366	5.00
T0154-10	3.94	1.68	0.76	0.155	0.066	0.030	7.831	0.811	6.349	9.658	3.78
T0154-20	3.94	1.68	0.99	0.155	0.066	0.039	7.831	1.054	8.254	7.429	4.24
T0154-30	3.94	1.68	1.52	0.155	0.066	0.060	7.831	1.622	12.699	4.829	5.31
T0154-40	3.94	1.68	0.89	0.155	0.066	0.035	7.831	0.946	7.408	8.278	4.04
T0154-50	3.94	1.68	0.94	0.155	0.066	0.037	7.831	1.000	7.831	7.831	4.14
T0154-60	3.94	1.68	1.09	0.155	0.066	0.043	7.831	1.162	9.101	6.738	4.45
T0155-00	3.94	2.24	2.54	0.155	0.088	0.100	9.196	2.104	19.353	4.370	6.78
T0155-10	3.94	2.24	1.27	0.155	0.088	0.050	9.196	1.052	9.677	8.740	4.24
T0155-20	3.94	2.24	2.01	0.155	0.088	0.079	9.196	1.663	15.289	5.531	5.72
T0155-30	3.94	2.24	1.78	0.155	0.088	0.070	9.196	1.473	13.547	6.243	5.26
T0155-40	3.94	2.24	1.52	0.155	0.088	0.060	9.196	1.263	11.612	7.283	4.75
T0155-70	3.94	2.24	0.99	0.155	0.088	0.039	9.196	0.821	7.548	11.205	3.68
T0155-80	3.94	2.24	1.65	0.155	0.088	0.065	9.196	1.368	12.580	6.723	5.00
T0157-00	3.99	2.01	2.01	0.157	0.079	0.079	8.715	1.911	16.657	4.559	5.99
T0157-10	3.99	2.01	0.99	0.157	0.079	0.039	8.715	0.944	8.223	9.235	3.96
T0157-20	3.99	2.01	1.24	0.157	0.079	0.049	8.715	1.186	10.332	7.351	4.47
T0157-40	3.99	2.01	0.86	0.157	0.079	0.034	8.715	0.823	7.169	10.593	3.71
T0157-50	3.99	2.01	1.50	0.157	0.079	0.059	8.715	1.428	12.440	6.105	4.98
T0157-60	3.99	2.01	2.24	0.157	0.079	0.088	8.715	2.129	18.555	4.093	6.45
T0159-00	4.06	1.52	1.02	0.160	0.060	0.040	7.514	1.192	8.954	6.305	4.57
T0159-10	4.06	1.52	1.17	0.160	0.060	0.046	7.514	1.370	10.297	5.483	4.88
T0159-20	4.06	1.52	0.76	0.160	0.060	0.030	7.514	0.894	6.715	8.407	4.06
T0160-00	4.06	1.78	1.02	0.160	0.070	0.040	8.209	1.097	9.008	7.481	4.32

Steward Toroids

	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
PART NUMBER	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0153-60	4	30	206	254	412	654	969	1,090	1,211	1,817	2,423	3,634
T0153-70	5	35	240	297	481	763	1,131	1,272	1,413	2,120	2,827	4,240
T0153-80	4	33	223	276	446	709	1,050	1,181	1,312	1,969	2,625	3,937
T0153-90	2	18	120	148	240	382	565	636	707	1,060	1,413	2,120
T0154-00	4	29	199	246	398	632	937	1,054	1,171	1,757	2,342	3,513
T0154-10	2	16	111	137	221	351	520	586	651	976	1,301	1,952
T0154-20	3	21	144	178	288	457	677	761	846	1,269	1,691	2,537
T0154-30	4	33	221	273	442	703	1,041	1,171	1,301	1,952	2,602	3,903
T0154-40	2	19	129	159	258	410	607	683	759	1,139	1,518	2,277
T0154-50	3	20	136	168	273	433	642	722	802	1,204	1,605	2,407
T0154-60	3	23	159	196	317	504	746	839	932	1,399	1,865	2,797
T0155-00	5	36	244	302	489	776	1,150	1,294	1,438	2,157	2,876	4,314
T0155-10	2	18	122	151	244	388	575	647	719	1,078	1,438	2,157
T0155-20	4	28	193	239	386	613	909	1,022	1,136	1,704	2,272	3,408
T0155-30	3	25	171	211	342	544	805	906	1,007	1,510	2,013	3,020
T0155-40	3	22	147	181	293	466	690	776	863	1,294	1,725	2,588
T0155-70	2	14	95	118	191	303	449	505	561	841	1,122	1,682
T0155-80	3	23	159	196	318	505	748	841	935	1,402	1,869	2,804
T0157-00	4	34	234	289	469	744	1,103	1,240	1,378	2,067	2,756	4,134
T0157-10	2	17	116	143	231	367	544	612	680	1,021	1,361	2,041
T0157-20	3	21	145	180	291	462	684	769	855	1,282	1,710	2,564
T0157-40	2	15	101	125	202	320	474	534	593	890	1,186	1,779
T0157-50	3	26	175	216	350	556	823	926	1,029	1,544	2,058	3,088
T0157-60	5	38	261	322	522	829	1,228	1,382	1,535	2,303	3,070	4,605
T0159-00	3	25	169	209	339	538	797	897	997	1,495	1,993	2,990
T0159-10	4	29	195	241	390	619	917	1,031	1,146	1,719	2,292	3,438
T0159-20	2	19	127	157	254	404	598	673	747	1,121	1,495	2,242
T0160-00	3	21	143	176	286	454	672	756	840	1,260	1,680	2,520

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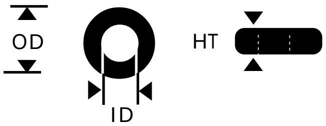

Steward Toroids

Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM			INCHES			l_e	A_e	V_e	C_1	MLT
	OD	ID	HT	OD	ID	HT	mm	mm^2	mm^3	mm^{-1}	mm/Turn
T0190-00	4.83	2.29	2.54	0.190	0.090	0.100	10.196	3.080	31.401	3.311	7.62
T0190-10	4.83	2.29	1.27	0.190	0.090	0.050	10.196	1.540	15.701	6.621	5.08
T0190-20	4.83	2.29	1.02	0.190	0.090	0.040	10.196	1.232	12.561	8.276	4.57
T0190-30	4.83	2.29	2.29	0.190	0.090	0.090	10.196	2.772	28.261	3.678	7.11
T0190-50	4.83	2.29	0.76	0.190	0.090	0.030	10.196	0.924	9.420	11.035	4.06
T0190-60	4.83	2.29	1.52	0.190	0.090	0.060	10.196	1.848	18.841	5.518	5.59
T0190-70	4.83	2.29	5.08	0.190	0.090	0.200	10.196	6.160	62.803	1.655	12.70
T0195-00	4.95	1.57	1.02	0.195	0.062	0.040	8.312	1.540	12.801	5.397	5.41
T0195-10	4.95	1.57	1.27	0.195	0.062	0.050	8.312	1.925	16.001	4.318	5.92
T0195-20	4.95	1.57	0.76	0.195	0.062	0.030	8.312	1.155	9.600	7.196	4.90
T0195-40	4.95	1.57	0.89	0.195	0.062	0.035	8.312	1.348	11.201	6.168	5.16
T0230-00	5.84	3.30	1.52	0.230	0.130	0.060	13.613	1.884	25.644	7.226	5.59
T0230-30	5.84	3.30	2.21	0.230	0.130	0.087	13.613	2.732	37.184	4.984	6.96
T0230-40	5.84	3.30	4.50	0.230	0.130	0.177	13.613	5.557	75.649	2.450	11.53
T0231-00	5.84	3.05	1.52	0.230	0.120	0.060	13.026	2.055	26.775	6.337	5.84
T0231-10	5.84	3.05	3.05	0.230	0.120	0.120	13.026	4.111	53.549	3.169	8.89
T0231-20	5.84	3.05	3.18	0.230	0.120	0.125	13.026	4.282	55.780	3.042	9.14
T0231-30	5.84	3.05	2.54	0.230	0.120	0.100	13.026	3.426	44.624	3.802	7.87
T0231-40	5.84	3.05	4.57	0.230	0.120	0.180	13.026	6.166	80.324	2.112	11.94
T0231-50	5.84	3.05	2.03	0.230	0.120	0.080	13.026	2.741	35.699	4.753	6.86
T0231-60	5.84	3.05	3.91	0.230	0.120	0.154	13.026	5.276	68.721	2.469	10.62
T0231-70	5.84	3.05	4.29	0.230	0.120	0.169	13.026	5.790	75.415	2.250	11.38
T0231-80	5.84	3.05	8.99	0.230	0.120	0.354	13.026	12.127	157.970	1.074	20.78
T0235-00	5.99	3.00	1.50	0.236	0.118	0.059	13.053	2.158	28.169	6.049	5.99
T0235-10	5.99	3.00	3.00	0.236	0.118	0.118	13.053	4.316	56.338	3.024	8.99
T0238-00	6.05	2.95	3.18	0.238	0.116	0.125	12.978	4.713	61.163	2.754	9.45
T0243-00	6.17	2.87	3.30	0.243	0.113	0.130	12.905	5.193	67.016	2.485	9.91
T0243-10	6.17	2.87	1.27	0.243	0.113	0.050	12.905	1.997	25.775	6.461	5.84

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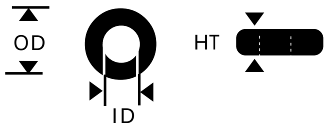
Steward Toroids

[X] - Denotes Special Order Request

PART NUMBER	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0190-00	6	47	323	399	645	1,025	1,518	1,708	1,898	2,847	3,796	5,694
T0190-10	3	24	161	199	323	512	759	854	949	1,423	1,898	2,847
T0190-20	2	19	129	159	258	410	607	683	759	1,139	1,518	2,278
T0190-30	5	43	290	359	581	922	1,367	1,537	1,708	2,562	3,416	5,124
T0190-50	2	14	97	120	194	307	456	512	569	854	1,139	1,708
T0190-60	4	28	194	239	387	615	911	1,025	1,139	1,708	2,278	3,416
T0190-70	12	95	645	797	1,291	2,050	3,037	3,416	3,796	5,694	7,592	11,388
T0195-00	4	29	198	244	396	629	931	1,048	1,164	1,746	2,328	3,493
T0195-10	5	36	247	306	495	786	1,164	1,310	1,455	2,183	2,910	4,366
T0195-20	3	22	148	183	297	472	699	786	873	1,310	1,746	2,619
T0195-40	3	25	173	214	346	550	815	917	1,019	1,528	2,037	3,056
T0230-00	3	22	148	183	296	470	696	783	870	1,304	1,739	2,609
T0230-30	4	32	214	265	429	681	1,009	1,135	1,261	1,891	2,522	3,782
T0230-40	8	64	436	539	872	1,385	2,052	2,309	2,565	3,848	5,130	7,695
T0231-00	3	25	169	208	337	535	793	892	991	1,487	1,983	2,974
T0231-10	6	50	337	416	674	1,071	1,586	1,785	1,983	2,974	3,966	5,949
T0231-20	7	52	351	434	702	1,115	1,652	1,859	2,066	3,098	4,131	6,197
T0231-30	5[X]	41[X]	280[X]	347[X]	562	892	1321[X]	1487[X]	1,652	2478[X]	3,305	4957[X]
T0231-40	9[X]	74[X]	505[X]	624[X]	1,011	1,606	2379[X]	2677[X]	2,974	4461[X]	5,949	8923[X]
T0231-50	4[X]	33[X]	224[X]	277[X]	449	714	1057[X]	1189[X]	1,322	1982[X]	2,644	3965[X]
T0231-60	8[X]	63[X]	432[X]	534[X]	865	1,374	2035[X]	2290[X]	2,545	3817[X]	5,090	7634[X]
T0231-70	8[X]	69[X]	474[X]	586[X]	950	1,508	2234[X]	2513[X]	2,793	4189[X]	5,585	8378[X]
T0231-80	18[X]	146[X]	994[X]	1228[X]	1,989	3,159	4679[X]	5264[X]	5,850	8774[X]	11,700	17549[X]
T0235-00	3[X]	25[X]	176[X]	218[X]	353	561	831[X]	934[X]	1,039	1558[X]	2,078	3116[X]
T0235-10	6[X]	51[X]	353[X]	436[X]	706	1,122	1662[X]	1869[X]	2,078	3116[X]	4,155	6232[X]
T0238-00	7[X]	57[X]	387[X]	479[X]	776	1,232	1825[X]	2053[X]	2,282	3422[X]	4,564	6845[X]
T0243-00	8[X]	63[X]	429[X]	530[X]	860	1,365	2022[X]	2275[X]	2,528	3792[X]	5,057	7584[X]
T0243-10	3[X]	24[X]	165[X]	204[X]	331	525	777[X]	875[X]	972	1458[X]	1,945	2917[X]



Steward Toroids

Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM OD	MM ID	MM HT	INCHES OD	INCHES ID	INCHES HT	l_e mm	A_e mm^2	V_e mm^3	C_1 mm^{-1}	MLT mm/Turn
T0250-00	6.35	3.81	1.91	0.250	0.150	0.075	15.286	2.367	36.188	6.457	6.35
T0250-10	6.35	3.81	3.18	0.250	0.150	0.125	15.286	3.946	60.313	3.874	8.89
T0250-20	6.35	3.81	4.01	0.250	0.150	0.158	15.286	4.987	76.236	3.065	10.57
T0250-30	6.35	3.81	2.49	0.250	0.150	0.098	15.286	3.093	47.285	4.941	7.52
T0250-40	6.35	3.81	2.18	0.250	0.150	0.086	15.286	2.715	41.495	5.631	6.91
T0251-10	6.35	3.18	3.00	0.250	0.125	0.118	13.828	4.572	63.221	3.024	9.17
T0255-00	6.48	2.49	2.49	0.255	0.098	0.098	12.146	4.602	55.893	2.640	8.97
T0255-10	6.48	2.49	3.99	0.255	0.098	0.157	12.146	7.372	89.543	1.648	11.96
T0300-00	7.62	1.75	5.08	0.300	0.069	0.200	10.509	12.487	131.230	0.842	16.03
T0300-10	7.62	1.75	3.18	0.300	0.069	0.125	10.509	7.805	82.019	1.347	12.22
T0301-00	7.62	3.18	4.78	0.300	0.125	0.188	14.970	9.960	149.103	1.503	14.00
T0301-10	7.62	3.18	3.18	0.300	0.125	0.125	14.970	6.622	99.138	2.260	10.80
T0301-20	7.62	3.18	5.72	0.300	0.125	0.225	14.970	11.920	178.448	1.256	15.88
T0301-30	7.62	3.18	5.08	0.300	0.125	0.200	14.970	10.596	158.621	1.413	14.61
T0302-00	7.62	2.79	4.78	0.300	0.110	0.188	13.905	10.603	147.433	1.311	14.38
T0302-10	7.62	2.79	3.18	0.300	0.110	0.125	13.905	7.050	98.027	1.972	11.18
T0302-20	7.62	2.79	5.72	0.300	0.110	0.225	13.905	12.689	176.449	1.096	16.26
T0315-00	8.00	3.18	4.78	0.315	0.125	0.188	15.284	10.736	164.094	1.424	14.38
T0315-10	8.00	3.18	5.99	0.315	0.125	0.236	15.284	13.477	205.991	1.134	16.81
T0315-20	8.00	3.18	3.43	0.315	0.125	0.135	15.284	7.709	117.834	1.983	11.68
T0325-00	8.26	4.45	4.78	0.325	0.175	0.188	18.730	8.812	165.042	2.126	13.36
T0325-10	8.26	4.45	3.18	0.325	0.175	0.125	18.730	5.859	109.735	3.197	10.16
T0325-20	8.26	4.45	6.30	0.325	0.175	0.248	18.730	11.624	217.715	1.611	16.41
T0354-00	8.99	5.99	3.99	0.354	0.236	0.157	22.907	5.895	135.035	3.886	10.97
T0354-10	8.99	5.99	6.50	0.354	0.236	0.256	22.907	9.612	220.185	2.383	16.00
T0354-20	8.99	5.99	3.00	0.354	0.236	0.118	22.907	4.431	101.492	5.170	8.99
T0355-00	9.02	5.00	3.99	0.355	0.197	0.157	20.800	7.775	161.715	2.675	11.99
T0355-10	9.02	5.00	3.00	0.355	0.197	0.118	20.800	5.843	121.544	3.560	10.01

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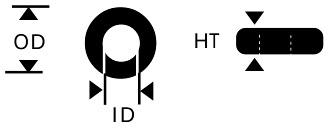
Steward Toroids

[x] - Denotes Special Order Request

	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
PART NUMBER	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0250-00	3[x]	24[x]	165[x]	204[x]	331	525	778[x]	875[x]	973	1459[x]	1,946	2919[x]
T0250-10	5[x]	40[x]	275[x]	340[x]	551	876	1297[x]	1459[x]	1,622	2432[x]	3,244	4865[x]
T0250-20	6[x]	51[x]	348[x]	430[x]	697	1,107	1640[x]	1845[x]	2,050	3075[x]	4,100	6150[x]
T0250-30	4[x]	31[x]	216[x]	267[x]	432	687	1017[x]	1144[x]	1,272	1907[x]	2,543	3814[x]
T0250-40	3[x]	27[x]	189[x]	234[x]	379	603	892[x]	1004[x]	1,116	1673[x]	2,232	3347[x]
T0251-10	6[x]	51[x]	353[x]	436[x]	706	1,122	1662[x]	1869[x]	2,078	3116[x]	4,155	6232[x]
T0255-00	7[x]	59[x]	404[x]	499[x]	809	1,285	1904[x]	2142[x]	2,380	3570[x]	4,761	7141[x]
T0255-10	12[x]	95[x]	648[x]	800[x]	1,297	2,059	3050[x]	3432[x]	3,814	5720[x]	7,627	11440[x]
T0300-00	23[x]	186[x]	1269[x]	1567[x]	2,538	4,032	5972[x]	6719[x]	7,466	11198[x]	14,932	22397[x]
T0300-10	14[x]	116[x]	793[x]	979[x]	1,587	2,520	3732[x]	4199[x]	4,666	6999[x]	9,332	13998[x]
T0301-00	13[x]	104[x]	710[x]	877[x]	1,421	2,257	3344[x]	3762[x]	4,181	6270[x]	8,361	12541[x]
T0301-10	8[x]	69[x]	472[x]	583[x]	945	1,501	2223[x]	2501[x]	2,780	4169[x]	5,559	8338[x]
T0301-20	16[x]	125[x]	850[x]	1050[x]	1,701	2,702	4002[x]	4502[x]	5,003	7504[x]	10,007	15009[x]
T0301-30	14[x]	111[x]	756[x]	933[x]	1,512	2,402	3557[x]	4002[x]	4,447	6671[x]	8,895	13342[x]
T0302-00	15[x]	119[x]	814[x]	1006[x]	1,629	2,587	3832[x]	4311[x]	4,791	7186[x]	9,582	14372[x]
T0302-10	10[x]	79[x]	541[x]	668[x]	1,083	1,720	2548[x]	2866[x]	3,185	4778[x]	6,371	9556[x]
T0302-20	18[x]	143[x]	974[x]	1204[x]	1,950	3,096	4587[x]	5160[x]	5,734	8600[x]	11,468	17201[x]
T0315-00	14[x]	110[x]	750[x]	926[x]	1,501	2,383	3530[x]	3972[x]	4,414	6620[x]	8,827	13240[x]
T0315-10	17[x]	138[x]	941[x]	1163[x]	1,884	2,992	4432[x]	4986[x]	5,540	8310[x]	11,081	16621[x]
T0315-20	10[x]	79[x]	538[x]	665[x]	1,078	1,711	2535[x]	2852[x]	3,169	4753[x]	6,339	9507[x]
T0325-00	9[x]	73[x]	502[x]	620[x]	1,005	1,596	2364[x]	2660[x]	2,956	4434[x]	5,912	8868[x]
T0325-10	6[x]	49[x]	334[x]	412[x]	668	1,061	1572[x]	1768[x]	1,965	2948[x]	3,931	5896[x]
T0325-20	12[x]	97[x]	662[x]	818[x]	1,326	2,106	3119[x]	3509[x]	3,899	5849[x]	7,799	11698[x]
T0354-00	5[x]	40[x]	274[x]	339[x]	550	873	1293[x]	1455[x]	1,617	2425[x]	3,234	4850[x]
T0354-10	8[x]	65[x]	448[x]	553[x]	896	1,424	2109[x]	2372[x]	2,636	3954[x]	5,273	7909[x]
T0354-20	3[x]	30[x]	206[x]	255[x]	413	656	972[x]	1093[x]	1,215	1822[x]	2,431	3645[x]
T0355-00	7[x]	58[x]	399[x]	493[x]	798	1,268	1878[x]	2113[x]	2,348	3522[x]	4,697	7045[x]
T0355-10	5[x]	44[x]	300[x]	370[x]	600	953	1412[x]	1588[x]	1,765	2647[x]	3,530	5295[x]



Steward Toroids

Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM OD	MM ID	MM HT	INCHES OD	INCHES ID	INCHES HT	I_e mm	A_e mm^2	V_e mm^3	C_1 mm^{-1}	MLT mm/Turn
T0355-20	9.02	5.00	3.68	0.355	0.197	0.145	20.800	7.180	149.355	2.897	11.38
T0375-00	9.53	4.75	6.35	0.375	0.187	0.250	20.711	14.564	301.632	1.422	17.48
T0375-10	9.53	4.75	3.18	0.375	0.187	0.125	20.711	7.282	150.816	2.844	11.13
T0375-30	9.53	4.75	4.78	0.375	0.187	0.188	20.711	10.952	226.827	1.891	14.33
T0375-40	9.53	4.75	7.49	0.375	0.187	0.295	20.711	17.186	355.925	1.205	19.76
T0375-60	9.53	4.75	5.08	0.375	0.187	0.200	20.711	11.651	241.305	1.778	14.94
T0376-00	9.53	5.08	6.35	0.375	0.200	0.250	21.497	13.657	293.595	1.574	17.15
T0376-10	9.53	5.08	4.83	0.375	0.200	0.190	21.497	10.379	223.132	2.071	14.10
T0376-30	9.53	5.08	2.67	0.375	0.200	0.105	21.497	5.736	123.310	3.748	9.78
T0377-00	9.53	5.59	4.78	0.375	0.220	0.188	22.650	9.180	207.938	2.467	13.49
T0377-10	9.53	5.59	7.11	0.375	0.220	0.280	22.650	13.673	309.695	1.657	18.16
T0394-00	10.01	5.00	5.00	0.394	0.197	0.197	21.792	12.030	262.154	1.812	15.01
T0394-10	10.01	5.00	7.01	0.394	0.197	0.276	21.792	16.854	367.281	1.293	19.02
T0394-20	10.01	5.00	3.99	0.394	0.197	0.157	21.792	9.587	208.925	2.273	12.98
T0395-00	10.01	5.97	5.97	0.394	0.235	0.235	24.013	11.789	283.076	2.037	15.98
T0395-10	10.01	5.97	3.99	0.394	0.235	0.157	24.013	7.876	189.119	3.049	12.01
T0395-20	10.01	5.97	5.00	0.394	0.235	0.197	24.013	9.882	237.302	2.430	14.05
T0433-00	11.00	5.00	3.00	0.433	0.197	0.118	22.714	8.533	193.818	2.662	11.99
T0433-10	11.00	5.00	3.99	0.433	0.197	0.157	22.714	11.353	257.877	2.001	13.97
T0433-20	11.00	5.00	6.50	0.433	0.197	0.256	22.714	18.512	420.488	1.227	19.00
T0472-00	11.99	5.99	3.99	0.472	0.236	0.157	26.107	11.485	299.834	2.273	13.97
T0472-10	11.99	5.99	5.99	0.472	0.236	0.236	26.107	17.264	450.706	1.512	17.98
T0472-20	11.99	5.99	7.49	0.472	0.236	0.295	26.107	21.580	563.383	1.210	20.98
T0500-00	12.70	7.92	3.18	0.500	0.312	0.125	31.227	7.442	232.380	4.196	11.13
T0500-10	12.70	7.92	6.35	0.500	0.312	0.250	31.227	14.883	464.761	2.098	17.48
T0500-40	12.70	7.92	5.08	0.500	0.312	0.200	31.227	11.907	371.809	2.623	14.94
T0500-60	12.70	7.92	7.49	0.500	0.312	0.295	31.227	17.562	548.418	1.778	19.76
T0501-00	12.70	7.14	4.78	0.500	0.281	0.188	29.500	12.920	381.139	2.283	15.11

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Steward Toroids

[x] - Denotes Special Order Request

	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
PART NUMBER	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0355-20	6[x]	54[x]	368[x]	455[x]	737	1,171	1735[x]	1952[x]	2,169	3253[x]	4,338	6506[x]
T0375-00	14[x]	110[x]	751[x]	927[x]	1,502	2,386	3534[x]	3976[x]	4,418	6627[x]	8,837	13255[x]
T0375-10	7[x]	55[x]	375[x]	463[x]	751	1,193	1767[x]	1988[x]	2,209	3313[x]	4,418	6627[x]
T0375-30	10[x]	83[x]	564[x]	697[x]	1,130	1,794	2658[x]	2990[x]	3,323	4984[x]	6,645	9968[x]
T0375-40	16[x]	130[x]	886[x]	1094[x]	1,773	2,815	4171[x]	4692[x]	5,214	7820[x]	10,428	15641[x]
T0375-60	11[x]	88[x]	600[x]	742[x]	1,202	1,909	2827[x]	3181[x]	3,535	5302[x]	7,070	10604[x]
T0376-00	12[x]	99[x]	678[x]	838[x]	1,357	2,155	3193[x]	3592[x]	3,992	5987[x]	7,983	11974[x]
T0376-10	9[x]	75[x]	515[x]	637[x]	1,031	1,638	2426[x]	2730[x]	3,034	4550[x]	6,067	9100[x]
T0376-30	5[x]	41[x]	285[x]	352[x]	570	905	1341[x]	1508[x]	1,676	2514[x]	3,353	5029[x]
T0377-00	8[x]	63[x]	432[x]	534[x]	866	1,375	2037[x]	2291[x]	2,547	3819[x]	5,093	7639[x]
T0377-10	12[x]	94[x]	644[x]	796[x]	1,290	2,048	3034[x]	3413[x]	3,793	5689[x]	7,586	11378[x]
T0394-00	11[x]	86[x]	589[x]	728[x]	1,179	1,873	2774[x]	3121[x]	3,468	5202[x]	6,937	10405[x]
T0394-10	15[x]	121[x]	826[x]	1020[x]	1,652	2,624	3887[x]	4373[x]	4,859	7288[x]	9,718	14577[x]
T0394-20	8[x]	69[x]	469[x]	580[x]	940	1,493	2211[x]	2487[x]	2,764	4146[x]	5,528	8292[x]
T0395-00	9[x]	77[x]	524[x]	647[x]	1,049	1,666	2467[x]	2776[x]	3,085	4626[x]	6,169	9253[x]
T0395-10	6[x]	51[x]	350[x]	432[x]	701	1,113	1648[x]	1854[x]	2,061	3091[x]	4,122	6182[x]
T0395-20	8[x]	64[x]	439[x]	543[x]	879	1,396	2068[x]	2327[x]	2,586	3878[x]	5,172	7757[x]
T0433-00	7[x]	59[x]	401[x]	495[x]	803	1,275	1888[x]	2124[x]	2,360	3540[x]	4,721	7081[x]
T0433-10	10[x]	78[x]	533[x]	659[x]	1,068	1,696	2512[x]	2826[x]	3,141	4710[x]	6,281	9421[x]
T0433-20	16[x]	128[x]	870[x]	1075[x]	1,741	2,765	4096[x]	4608[x]	5,121	7681[x]	10,242	15362[x]
T0472-00	8[x]	69[x]	469[x]	580[x]	940	1,493	2211[x]	2487[x]	2,764	4146[x]	5,528	8292[x]
T0472-10	13[x]	103[x]	706[x]	872[x]	1,413	2,244	3324[x]	3739[x]	4,155	6232[x]	8,310	12465[x]
T0472-20	16[x]	129[x]	882[x]	1090[x]	1,766	2,805	4155[x]	4674[x]	5,194	7790[x]	10,388	15581[x]
T0500-00	4[x]	37[x]	254[x]	314[x]	509	809	1197[x]	1347[x]	1,497	2246[x]	2,995	4492[x]
T0500-10	9[x]	74	509[x]	628[x]	1,018	1,617	2395[x]	2695[x]	2,995	4492[x]	5,989	8984[x]
T0500-40	7[x]	59[x]	407[x]	503[x]	815	1,294	1916[x]	2156[x]	2,396	3593[x]	4,792	7187[x]
T0500-60	11[x]	88[x]	600[x]	742[x]	1,201	1,908	2826[x]	3180[x]	3,534	5300[x]	7,067	10601[x]
T0501-00	8[x]	68[x]	467[x]	577[x]	936	1,486	2201[x]	2476[x]	2,752	4127[x]	5,503	8255[x]

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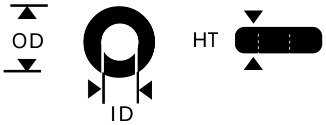
Steward Toroids



Custom Parts Also Available

* Available Coatings & Materials on Page 7

PART NUMBER	MM			INCHES			l_e	A_e	V_e	C_1	MLT
	OD	ID	HT	OD	ID	HT	mm	mm^2	mm^3	mm^{-1}	mm/Turn
T0501-10	12.70	7.14	6.35	0.500	0.281	0.250	29.500	17.181	506.834	1.717	18.26
T0501-20	12.70	7.14	8.26	0.500	0.281	0.325	29.500	22.335	658.885	1.321	22.07
T0501-30	12.70	7.14	7.49	0.500	0.281	0.295	29.500	20.273	598.065	1.455	20.55
T0502-00	12.70	5.16	6.35	0.500	0.203	0.250	24.582	22.394	550.473	1.098	20.24
T0502-10	12.70	5.16	4.70	0.500	0.203	0.185	24.582	16.571	407.350	1.483	16.94
T0502-20	12.70	5.16	8.00	0.500	0.203	0.315	24.582	28.216	693.596	0.871	23.55
T0520-00	13.21	7.37	3.96	0.520	0.290	0.156	30.551	11.251	343.728	2.715	13.77
T0520-20	13.21	7.37	6.05	0.520	0.290	0.238	30.551	17.165	524.406	1.780	17.93
T0550-00	13.97	8.00	6.99	0.550	0.315	0.275	32.788	20.315	666.098	1.614	19.94
T0550-20	13.97	8.00	5.51	0.550	0.315	0.217	32.788	16.031	525.612	2.045	16.99
T0550-30	13.97	8.00	8.00	0.550	0.315	0.315	32.788	23.270	762.985	1.409	21.97
T0551-00	14.00	8.99	5.00	0.551	0.354	0.197	34.956	12.317	430.548	2.838	15.01
T0551-10	14.00	8.99	6.50	0.551	0.354	0.256	34.956	16.006	559.494	2.184	18.01
T0551-20	14.00	8.99	8.00	0.551	0.354	0.315	34.956	19.694	688.440	1.775	21.01
T0552-10	14.00	7.01	5.99	0.551	0.276	0.236	30.507	20.121	613.836	1.516	18.97
T0552-20	14.00	7.01	7.49	0.551	0.276	0.295	30.507	25.151	767.296	1.213	21.97
T0552-30	14.00	7.01	5.00	0.551	0.276	0.197	30.507	16.796	512.397	1.816	16.99
T0570-00	14.48	8.51	5.51	0.570	0.335	0.217	34.462	16.068	553.743	2.145	16.99
T0570-10	14.48	8.51	6.50	0.570	0.335	0.256	34.462	18.956	653.264	1.818	18.97
T0570-20	14.48	8.51	9.53	0.570	0.335	0.375	34.462	27.767	956.930	1.241	25.02
T0625-00*	15.88	8.89	4.70	0.625	0.350	0.185	36.804	15.959	587.354	2.306	16.38
T0625-10	15.88	8.89	3.99	0.625	0.350	0.157	36.804	13.544	498.457	2.717	14.96
T0625-40	15.88	8.89	9.53	0.625	0.350	0.375	36.804	32.350	1190.582	1.138	26.04
T0631-00	16.00	5.00	10.01	0.630	0.197	0.394	26.589	49.232	1309.037	0.540	31.01

Steward Toroids

[x] - Denotes Special Order Request

	AL (nH per turn squared)											
	Materials											
	21	25	28	24	38	33	46	36	35	42	40	45
	Initial Permeability											
PART NUMBER	16	125	850	1050	1700	2700	4000	4500	5000	7500	10000	15000
T0501-10	11[x]	91[x]	622[x]	768[x]	1,244	1,976	2927[x]	3293[x]	3,659	5488[x]	7,318	10977[x]
T0501-20	15[x]	118[x]	808[x]	998[x]	1,617	2,569	3805[x]	4281[x]	4,757	7135[x]	9,514	14270[x]
T0501-30	13[x]	107[x]	734[x]	906[x]	1,468	2,332	3454[x]	3886[x]	4,318	6476[x]	8,636	12953[x]
T0502-00	18[x]	143[x]	973[x]	1202[x]	1,946	3,091	4579[x]	5151[x]	5,724	8585[x]	11,448	17171[x]
T0502-10	13[x]	105[x]	720[x]	889[x]	1,440	2,287	3388[x]	3812[x]	4,236	6353[x]	8,471	12707[x]
T0502-20	23[x]	180[x]	1226[x]	1514[x]	2,452	3,895	5769[x]	6490[x]	7,212	10818[x]	14,424	21636[x]
T0520-00	7[x]	57[x]	393[x]	485[x]	787	1,249	1851[x]	2082[x]	2,314	3470[x]	4,628	6941[x]
T0520-20	11[x]	88[x]	600[x]	741[x]	1,200	1,906	2824[x]	3177[x]	3,530	5295[x]	7,060	10590[x]
T0550-00	12[x]	97[x]	661[x]	817[x]	1,324	2,102	3114[x]	3503[x]	3,893	5839[x]	7,786	11679[x]
T0550-20	9[x]	76[x]	522[x]	645[x]	1,044	1,659	2457[x]	2764[x]	3,072	4607[x]	6,144	9215[x]
T0550-30	14[x]	111[x]	758[x]	936[x]	1,516	2,408	3567[x]	4013[x]	4,459	6688[x]	8,919	13377[x]
T0551-00	7[x]	55[x]	376[x]	464[x]	753	1,195	1771[x]	1992[x]	2,214	3320[x]	4,428	6641[x]
T0551-10	9[x]	71[x]	489[x]	604[x]	978	1,554	2301[x]	2589[x]	2,877	4315[x]	5,754	8630[x]
T0551-20	11[x]	88[x]	601[x]	743[x]	1,204	1,912	2831[x]	3185[x]	3,540	5309[x]	7,080	10619[x]
T0552-10	13[x]	103[x]	704[x]	870[x]	1,409	2,238	3315[x]	3729[x]	4,144	6216[x]	8,288	12432[x]
T0552-20	16[x]	129[x]	880[x]	1087[x]	1,761	2,797	4144[x]	4662[x]	5,180	7770[x]	10,360	15540[x]
T0552-30	11[x]	86[x]	588[x]	726[x]	1,176	1,868	2767[x]	3113[x]	3,459	5188[x]	6,919	10377[x]
T0570-00	9[x]	73[x]	498[x]	615[x]	996	1,582	2343[x]	2636[x]	2,930	4394[x]	5,859	8788[x]
T0570-10	11[x]	86[x]	587[x]	725[x]	1,175	1,866	2764[x]	3110[x]	3,456	5184[x]	6,912	10368[x]
T0570-20	16[x]	126[x]	860[x]	1063[x]	1,721	2,734	4050[x]	4556[x]	5,063	7593[x]	10,125	15187[x]
T0625-00	8[x]	68[x]	463[x]	572[x]	926	1,471	2179[x]	2452[x]	2,725	4086[x]	5,449	8173[x]
T0625-10	7[x]	57[x]	393[x]	485[x]	786	1,249	1849[x]	2080[x]	2,312	3468[x]	4,624	6936[x]
T0625-40	17[x]	138[x]	938[x]	1159[x]	1,878	2,982	4418[x]	4970[x]	5,523	8284[x]	11,046	16568[x]
T0631-00	37[x]	290	1977[x]	2443[x]	3,956	6,282	9307[x]	10470[x]	1,634	17450[x]	23,268	34901[x]

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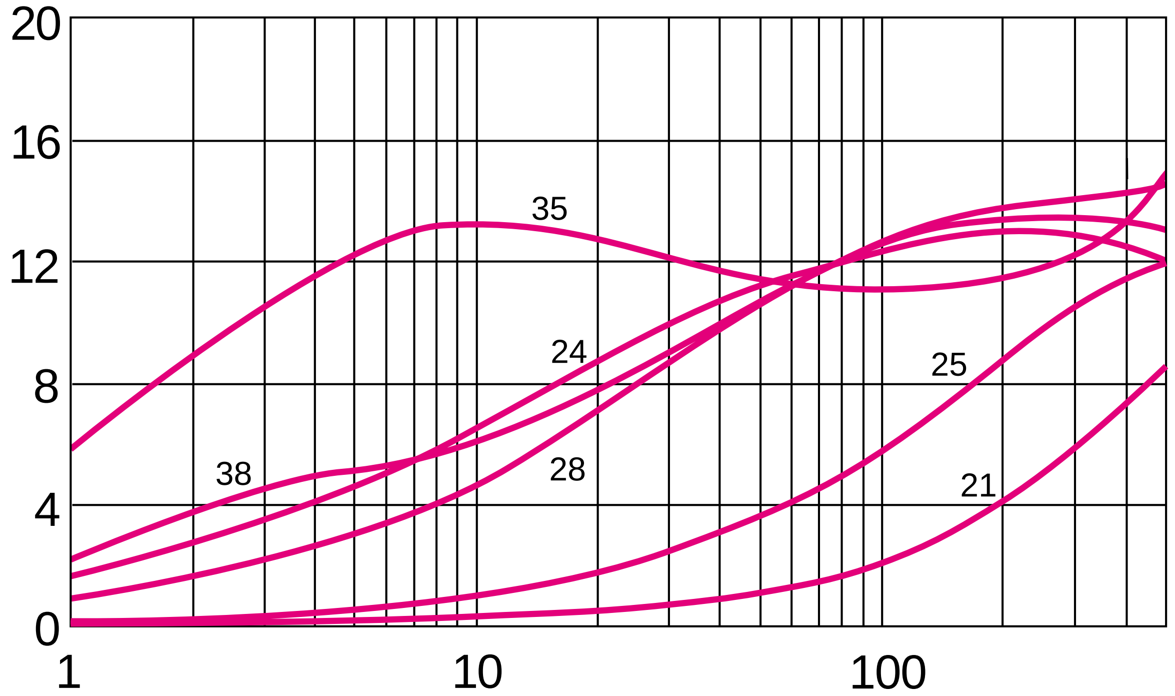
Comparing Materials

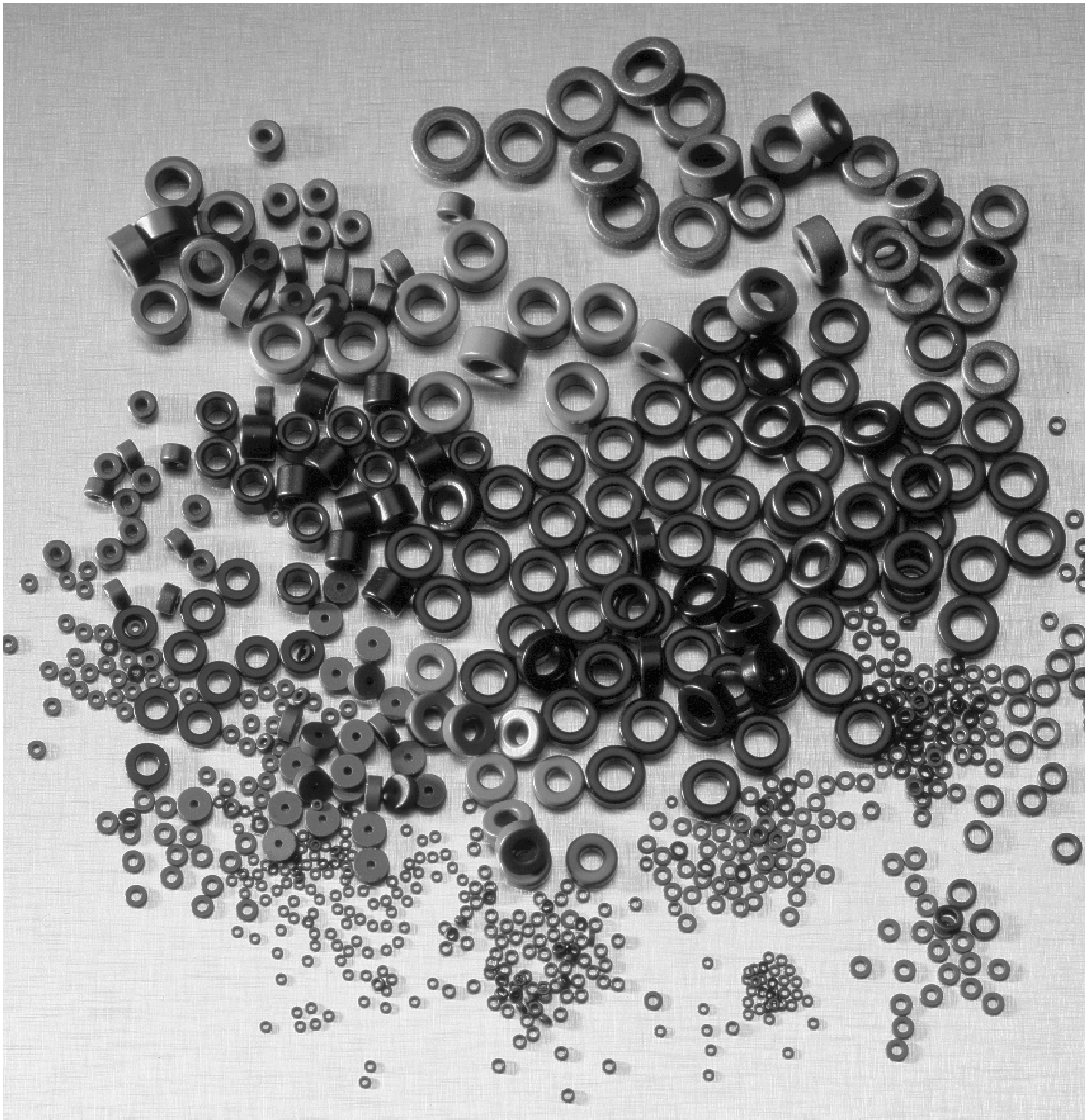
_ _T0155-200

"Core Size 3.94 (O.D.) x 2.24 (I.D.) x 2.01 (H.T.)"



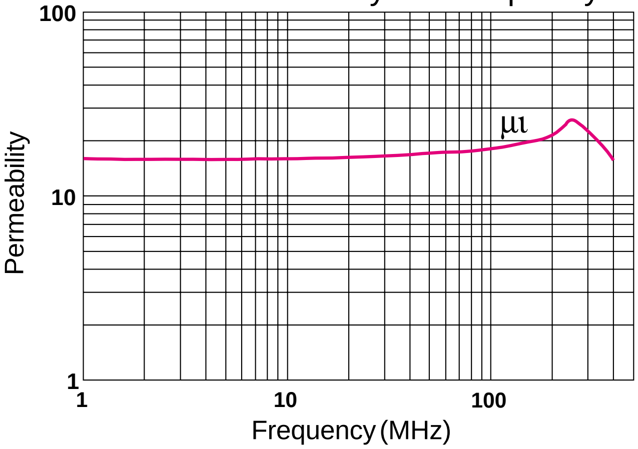
Effect Of Turns On Impedance

Ideally, impedance would be proportional to frequency and the square of the number of turns regardless of the magnitude of either. This is generally the case at very low frequencies, but becomes less valid as frequency increases. The predominant cause of such behavior is interwinding capacitance. Capacitance is directly proportional to the area of the conductor and inversely proportional to the distance between the conductors. As the number of turns increases, the area of the conductor (the length of the wire) increases and the distance between the conductors (the spacing between turns) decreases. The end result is an LC resonance above which capacitive reactance decreases impedance. The number of turns, their spacing, and the uniformity of their spacing are major factors in the frequency response of wound toroidal filters and must therefore be carefully considered in their assembly.

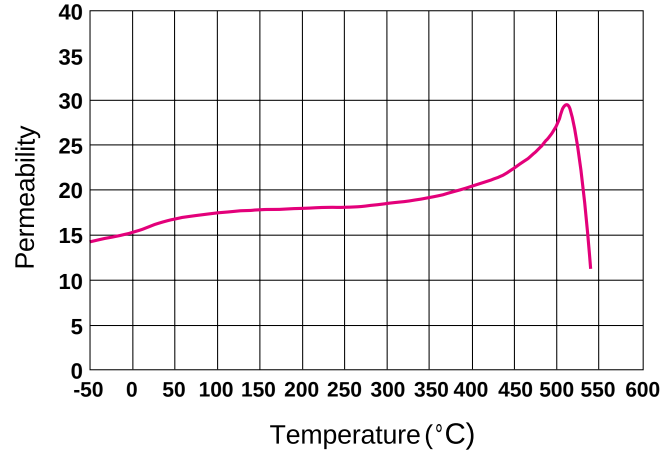


16 Permeability / Material 21

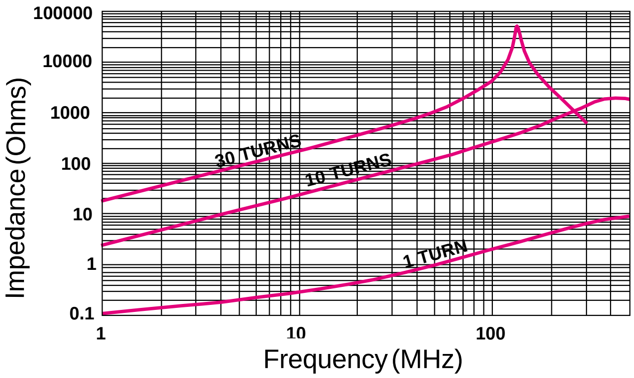
Initial Permeabillity VS Frequency



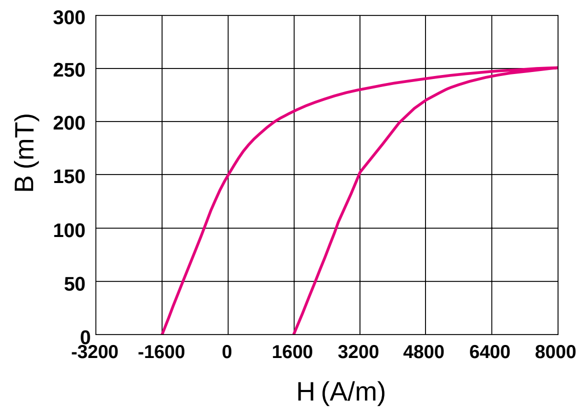
Initial Permeabillity VS Temperature



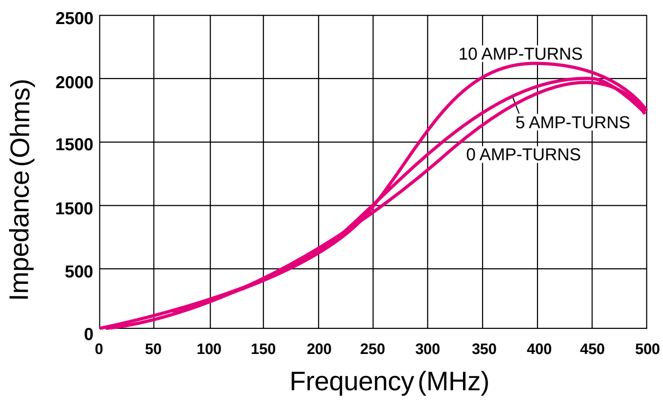
Comparing Turns



Magnetization Curves



Impedance with DC Bias



21T0155-200, 10 turns

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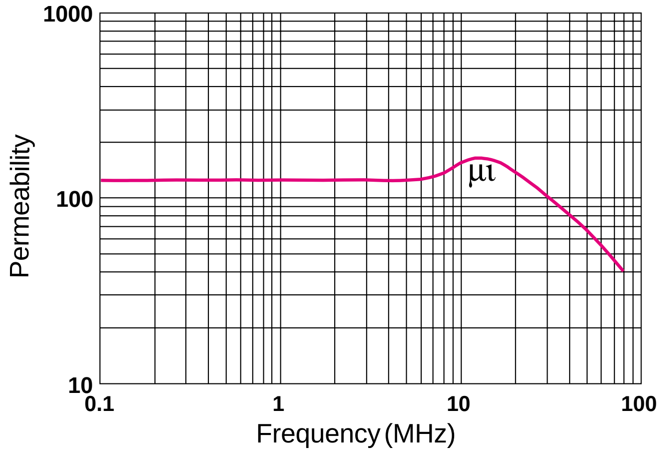
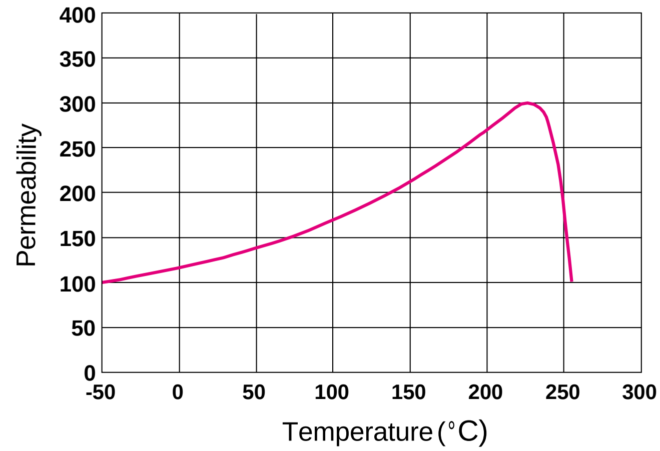
125 Permeability / Material 25

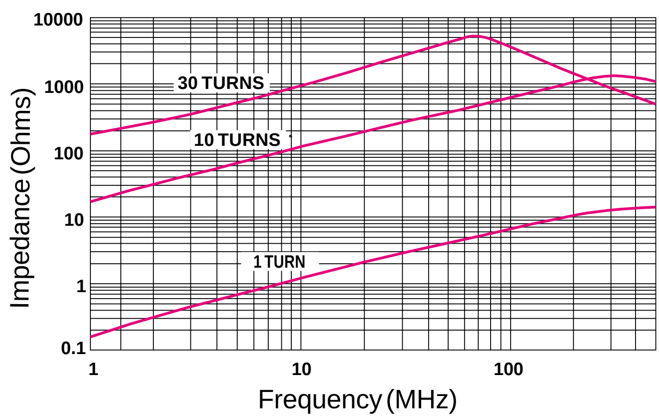
Initial Permeabillity VS Frequency



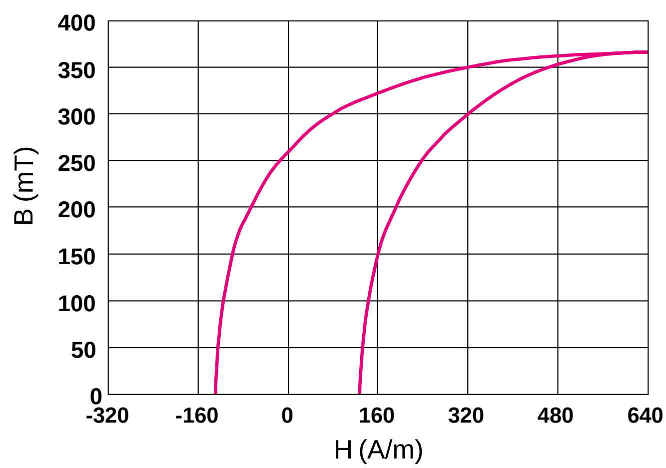
Initial Permeabillity VS Temperature



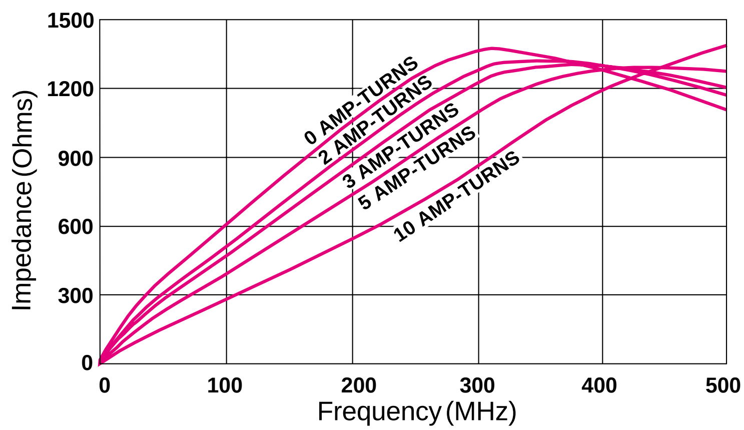
Comparing Turns



Magnetization Curves



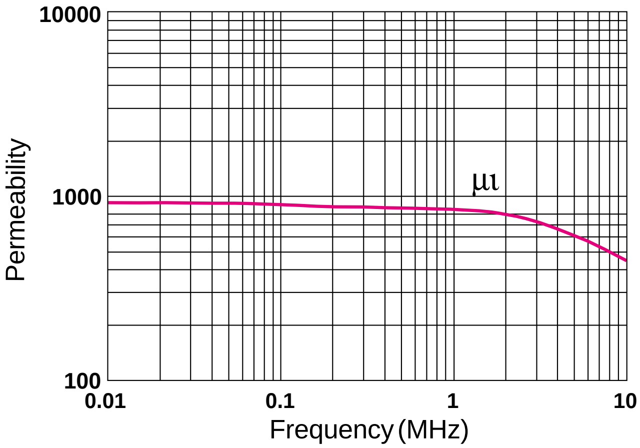
Impedance with DC Bias



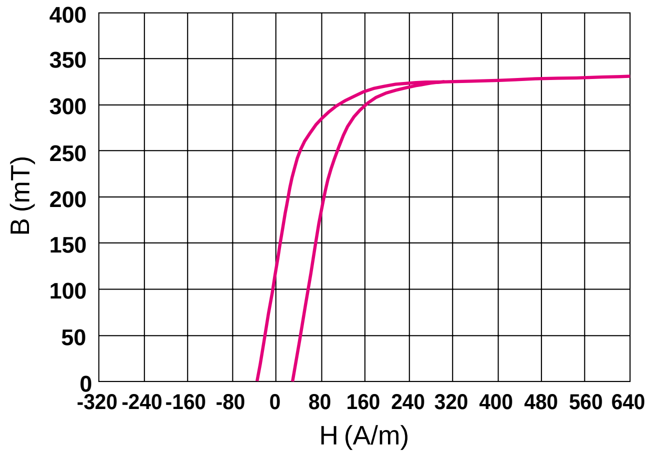
25T0155-200, 10 TURNS

850 Permeability / Material 28

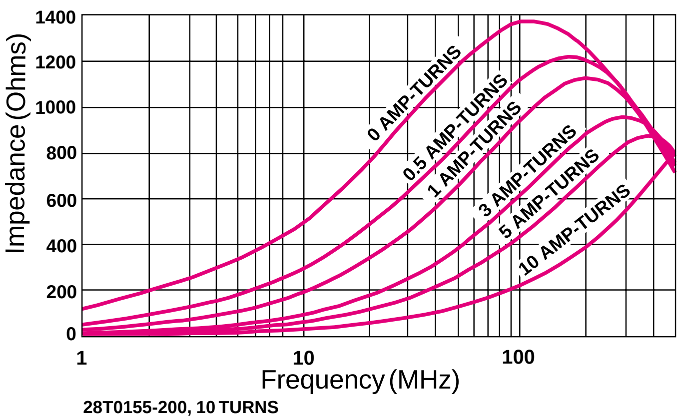
Initial Permeabillity VS Frequency



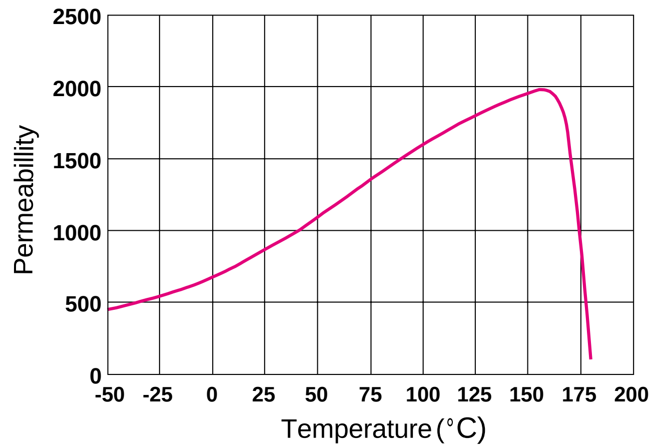
Magnetization Curve



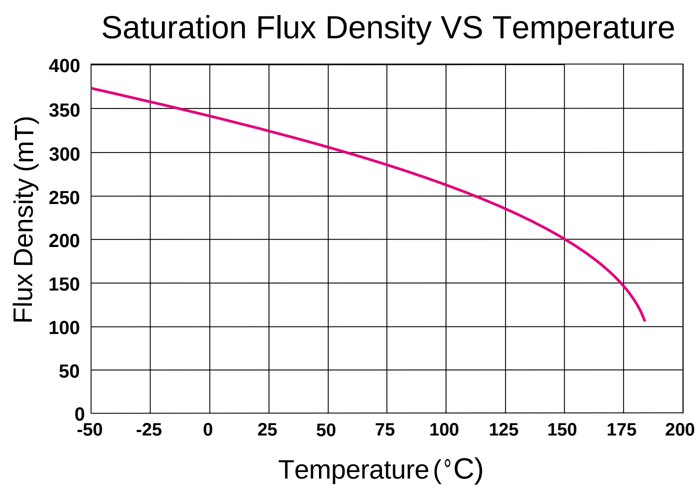
Impedance with DC Bias

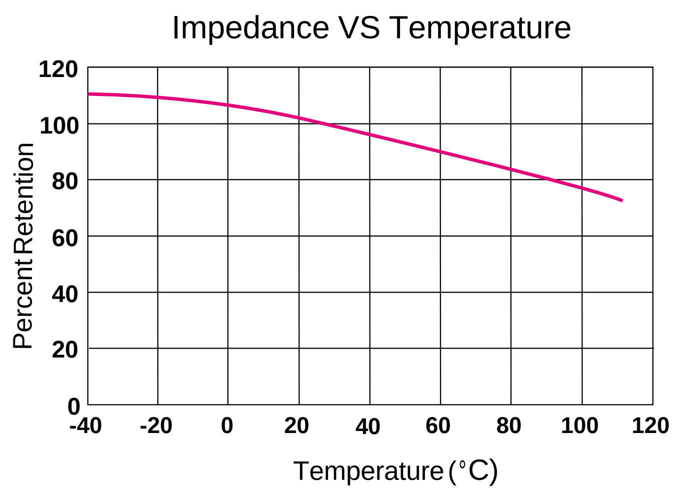


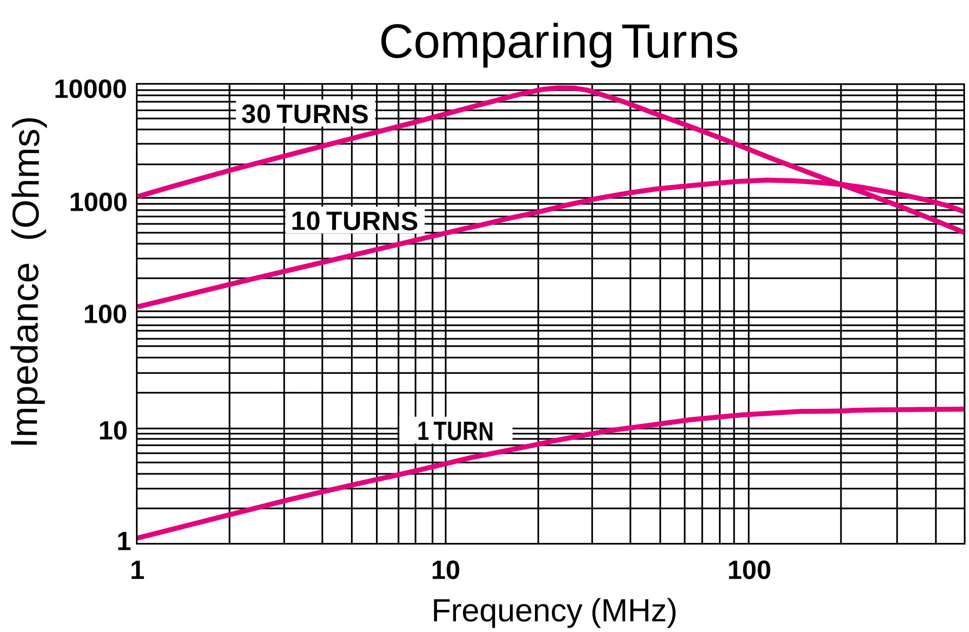
Initial Permeability vs Temperature



850 Permeability / Material 28

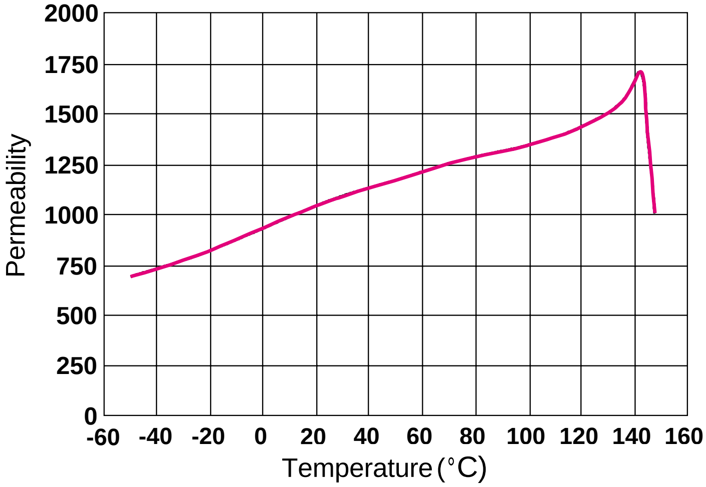




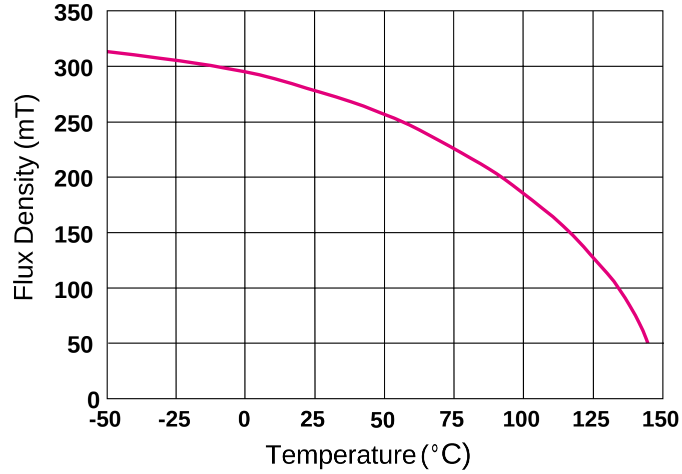


1,050 Permeability / Material 24

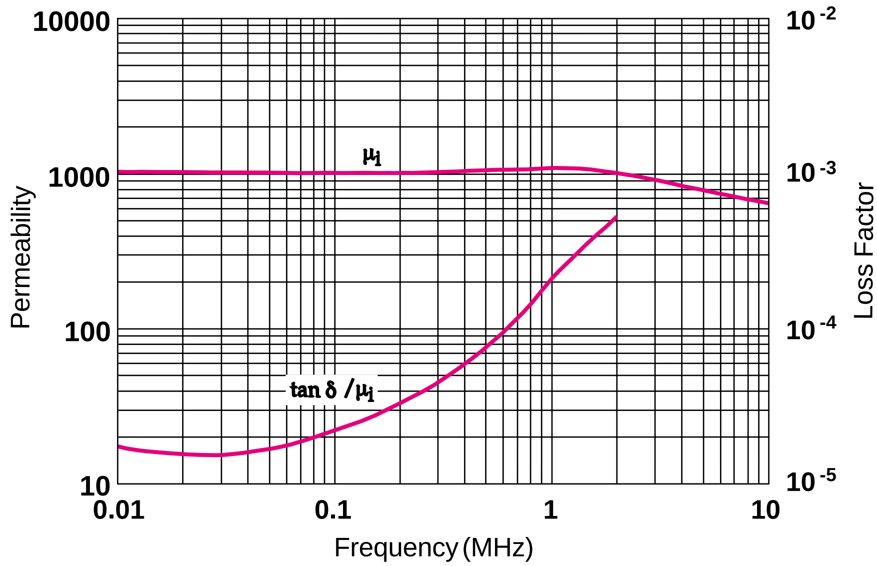
Initial Permeabillity VS Temperature



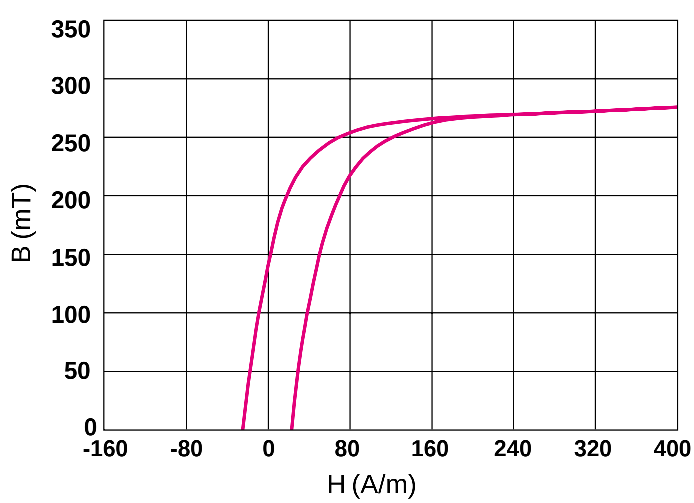
Saturation Flux Density VS Temperature



Initial Permeability & Loss Factor VS Frequency



Magnetization Curve



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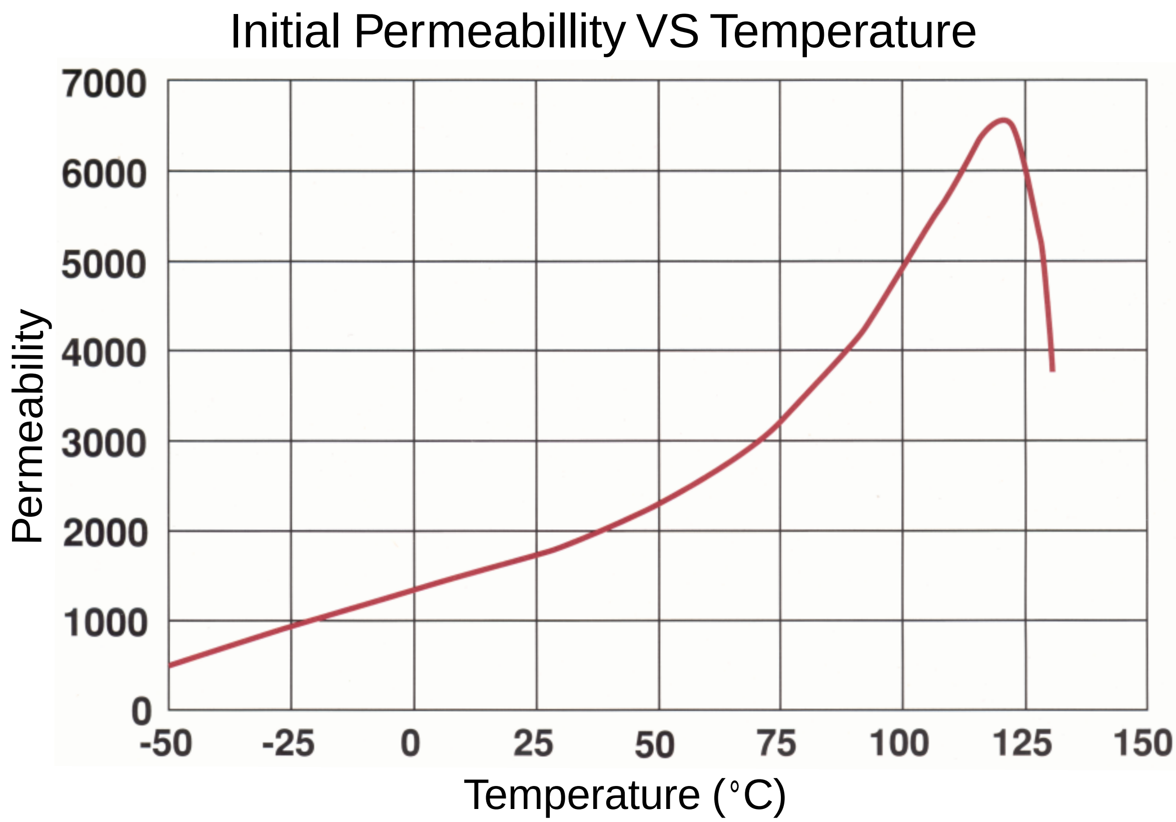
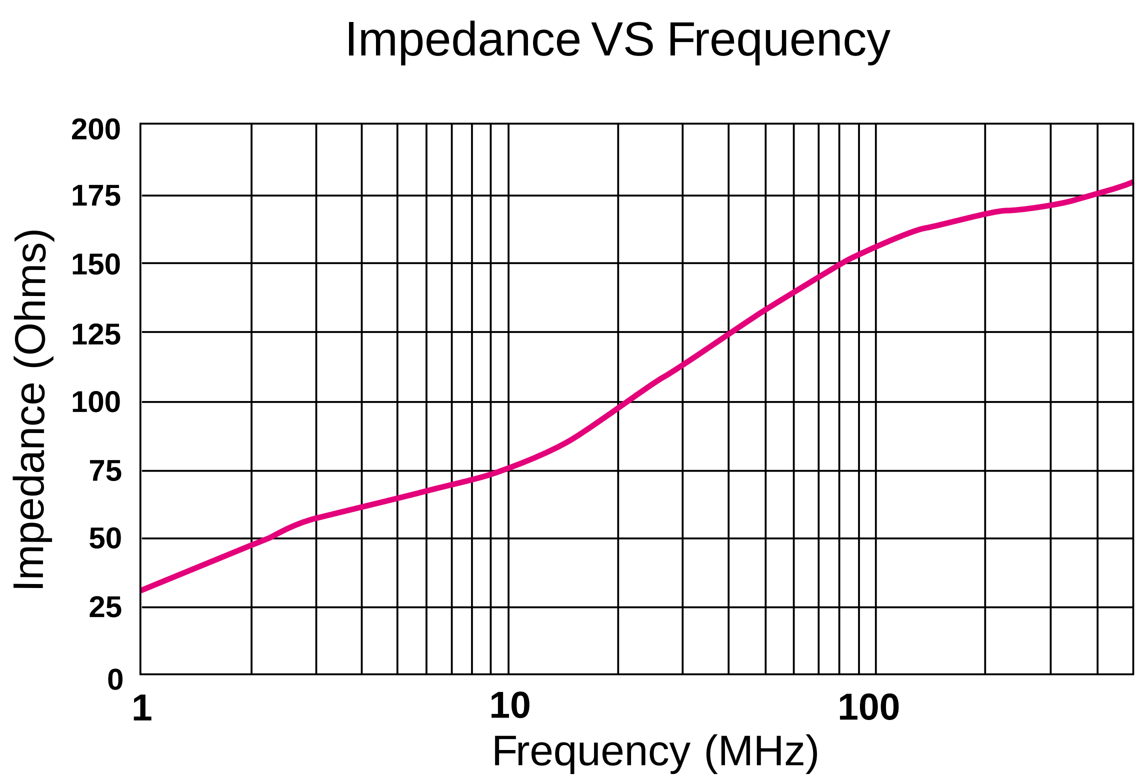
1,700 Permeability / Material 38





Measured on a bead .138″ OD, .034″ ID, .355″ TH

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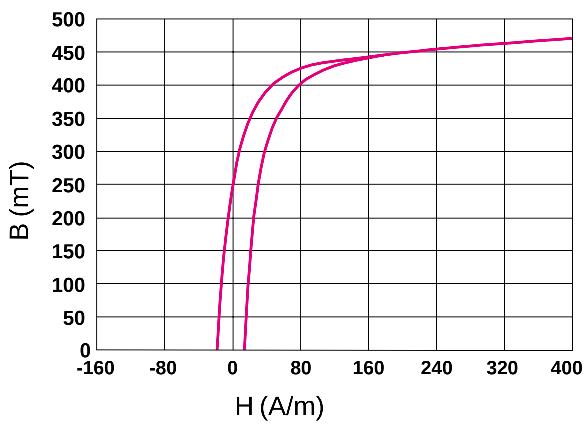
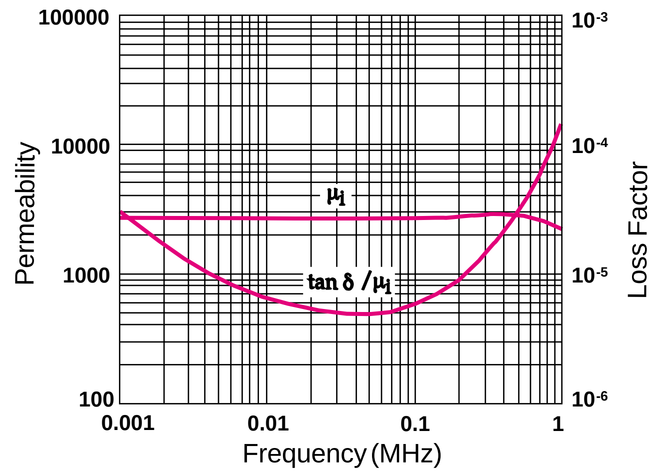
2,700 Permeability / Material 33

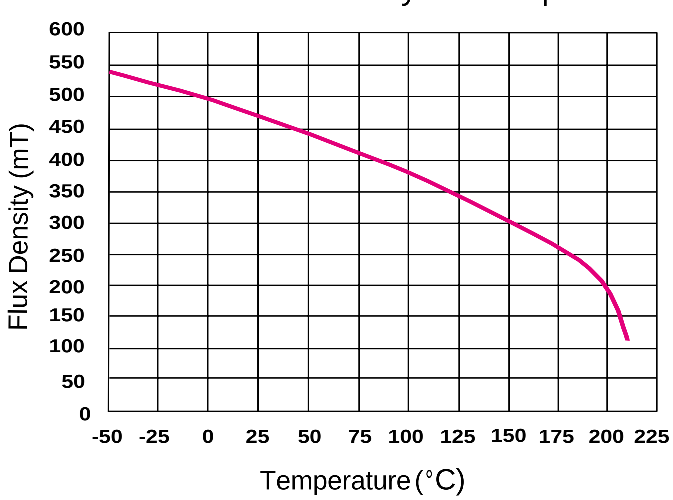
Magnetization Curve



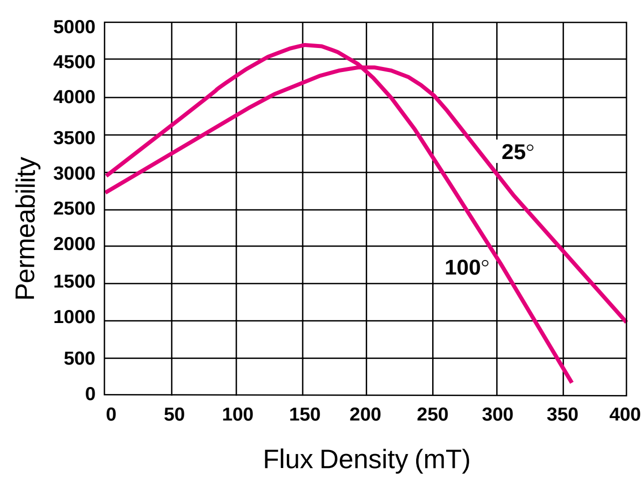
Initial Permeability & Loss Factor VS Frequency



Saturation Flux Density VS Temperature



Amplitude Permeability



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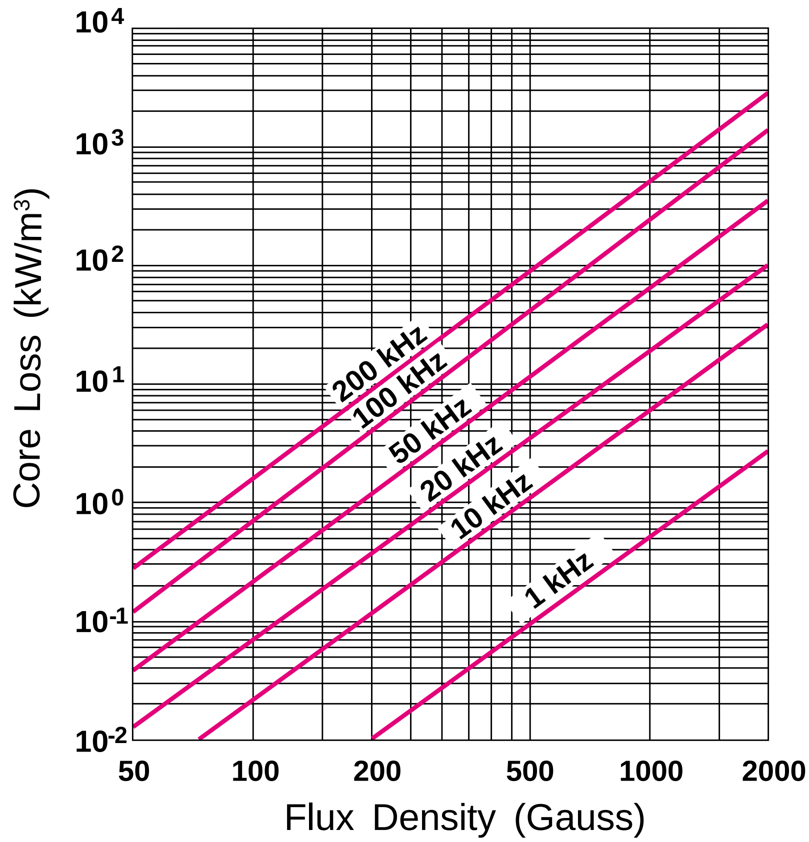
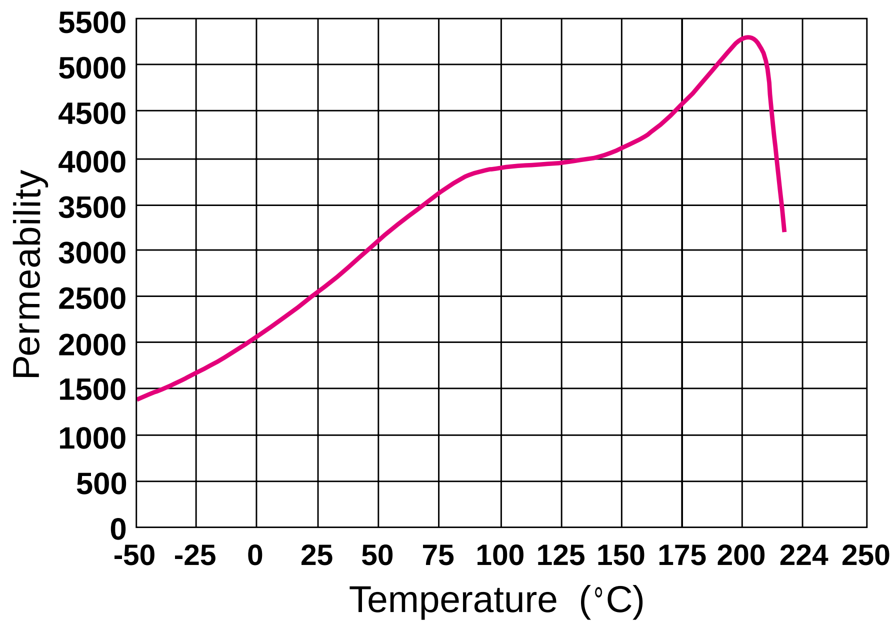
2,700 Permeability / Material 33

Core Loss VS Flux Density (25°C)

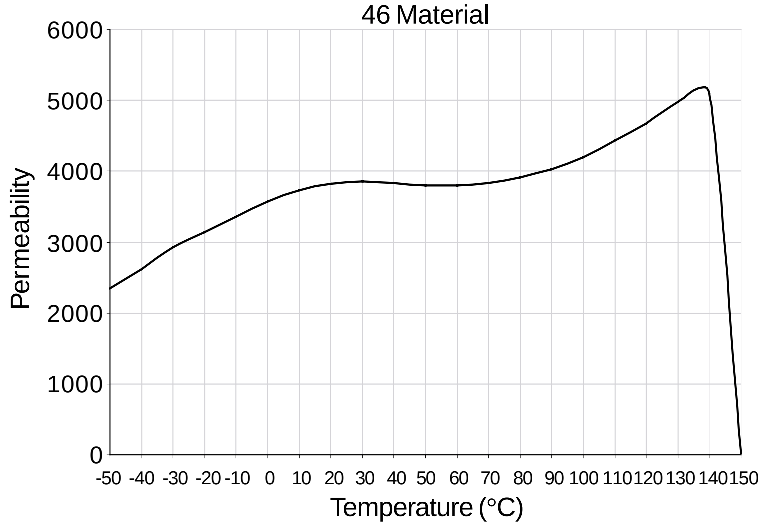


Initial Permeabillity VS Temperature

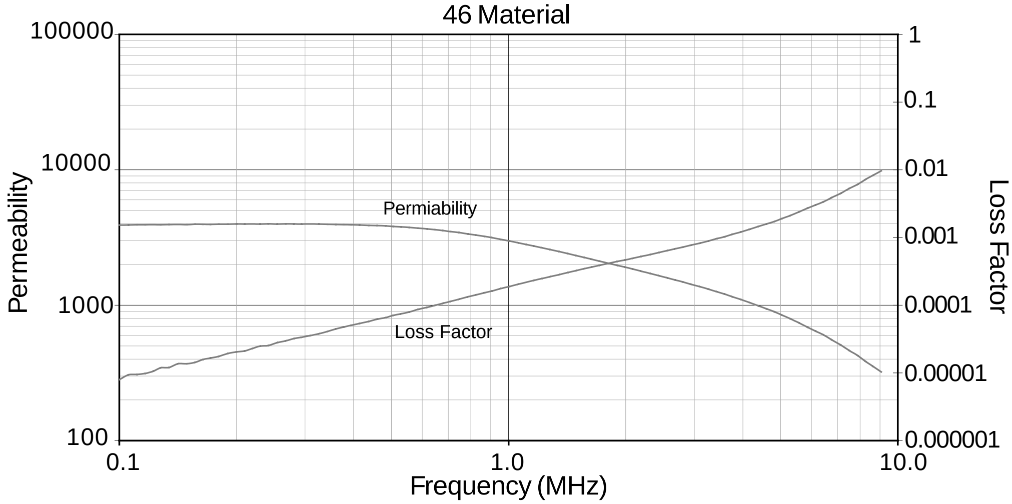


4,000 Permeability / Material 46

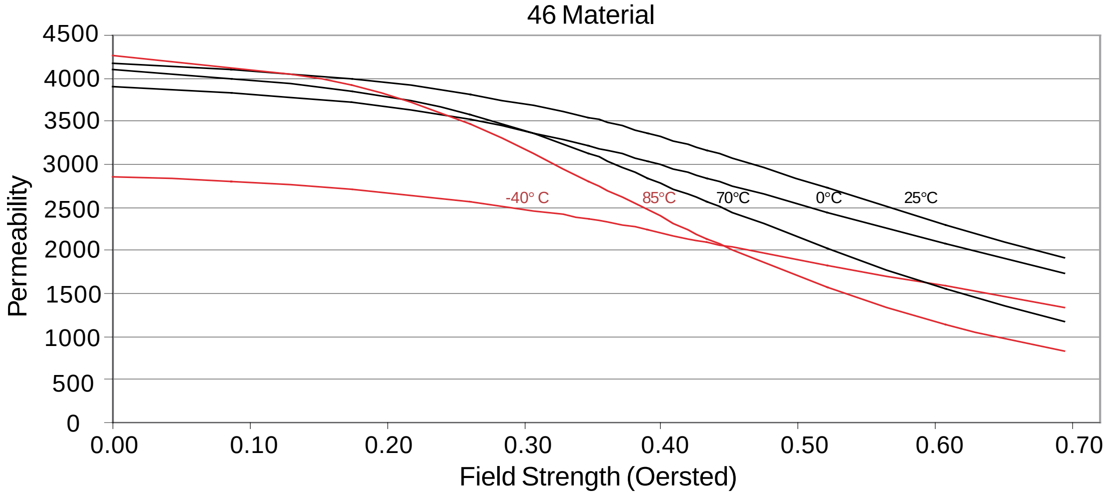
Initial Permeability vs. Temperature
46 Material



Permeability & Loss Factor vs. Temperature
46 Material

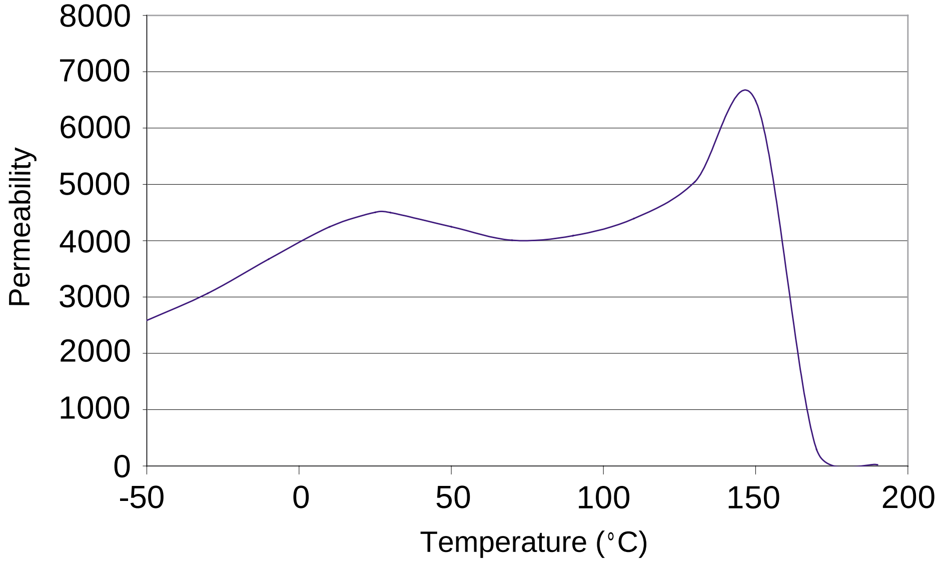


Permeability vs. Field Strength
46 Material

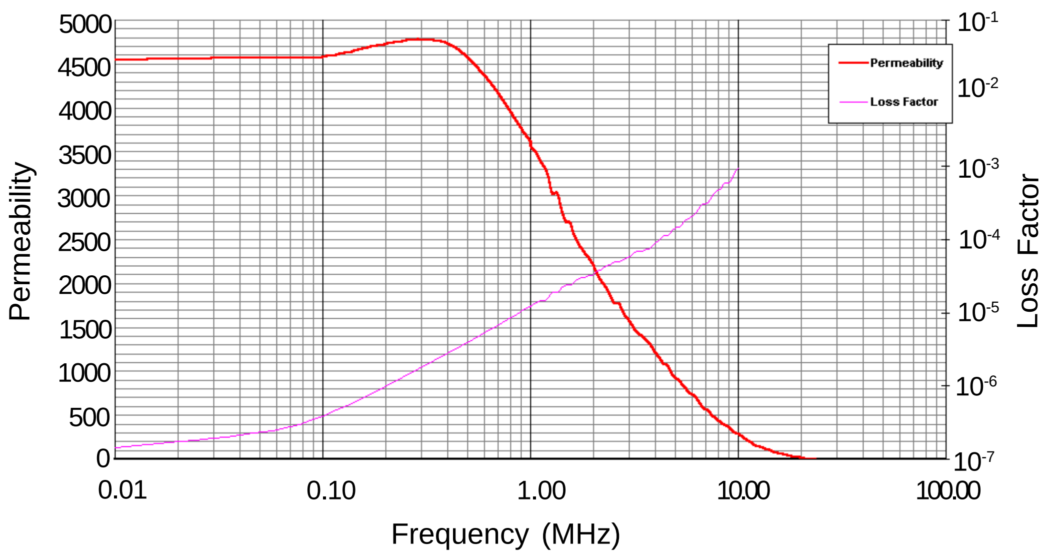


4,500 Permeability / Material 36

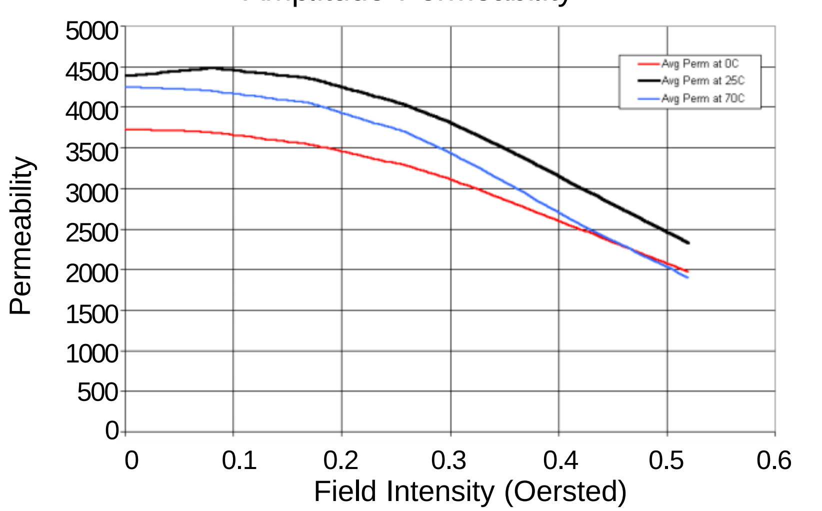
Initial Permeabillity VS Temperature



Initial Permeability & Loss Factor VS Frequency



Amplitude Permeability



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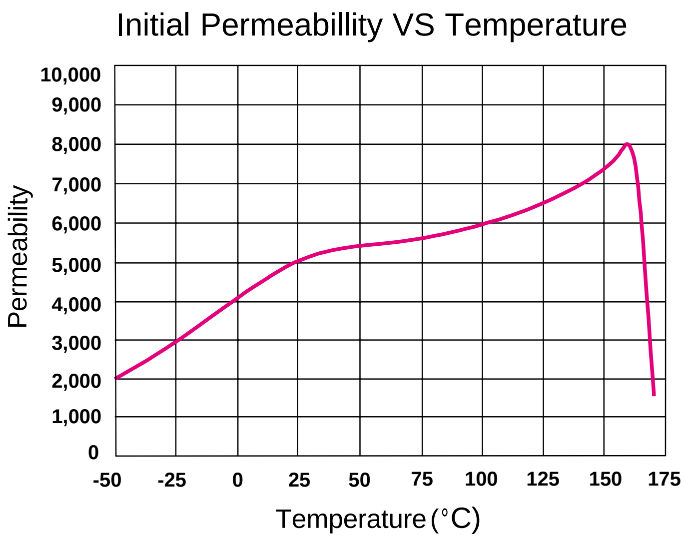
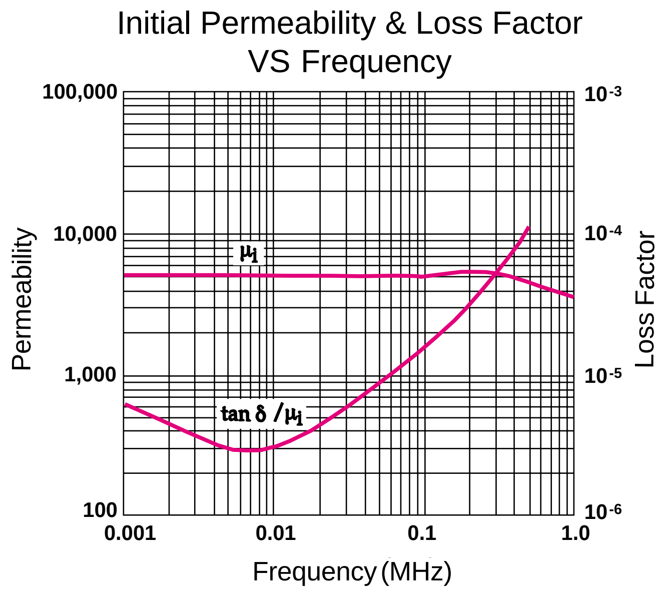
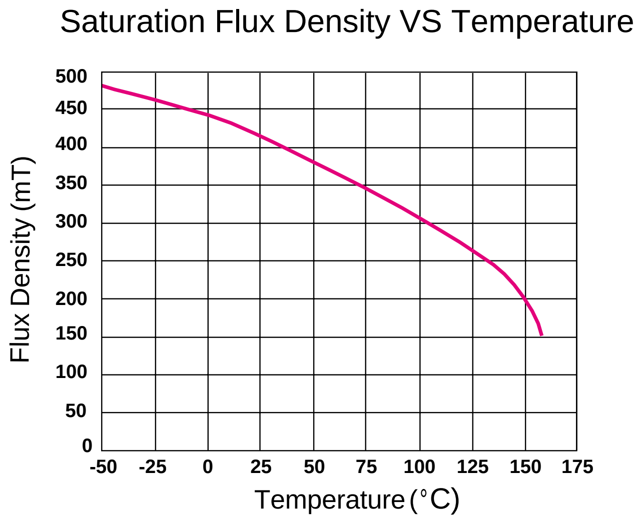
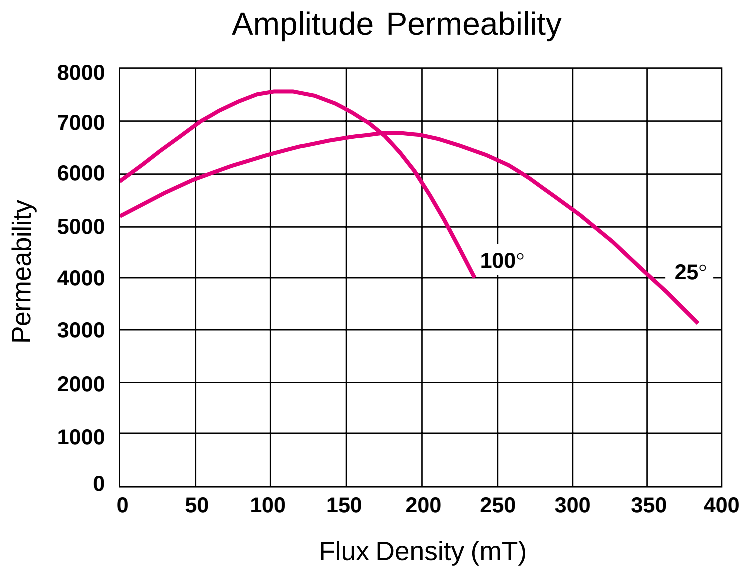
5,000 Permeability / Material 35









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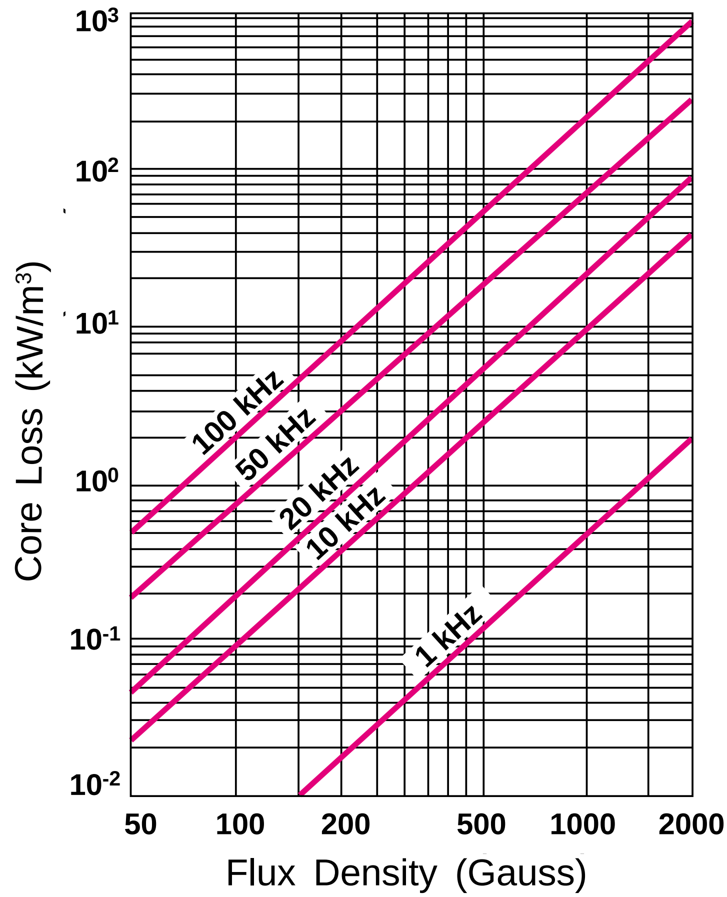
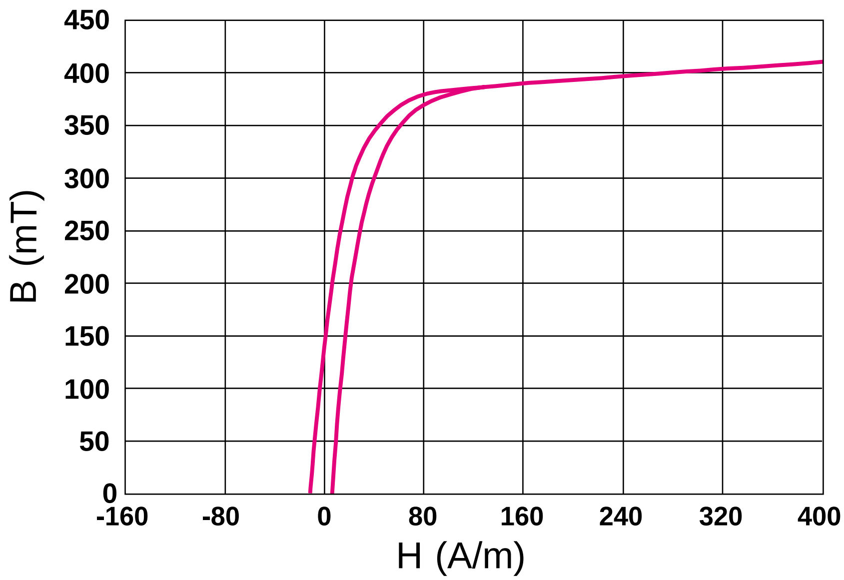
5,000 Permeability / Material 35

Core Loss VS Flux Density (25°C)



Magnetization Curve



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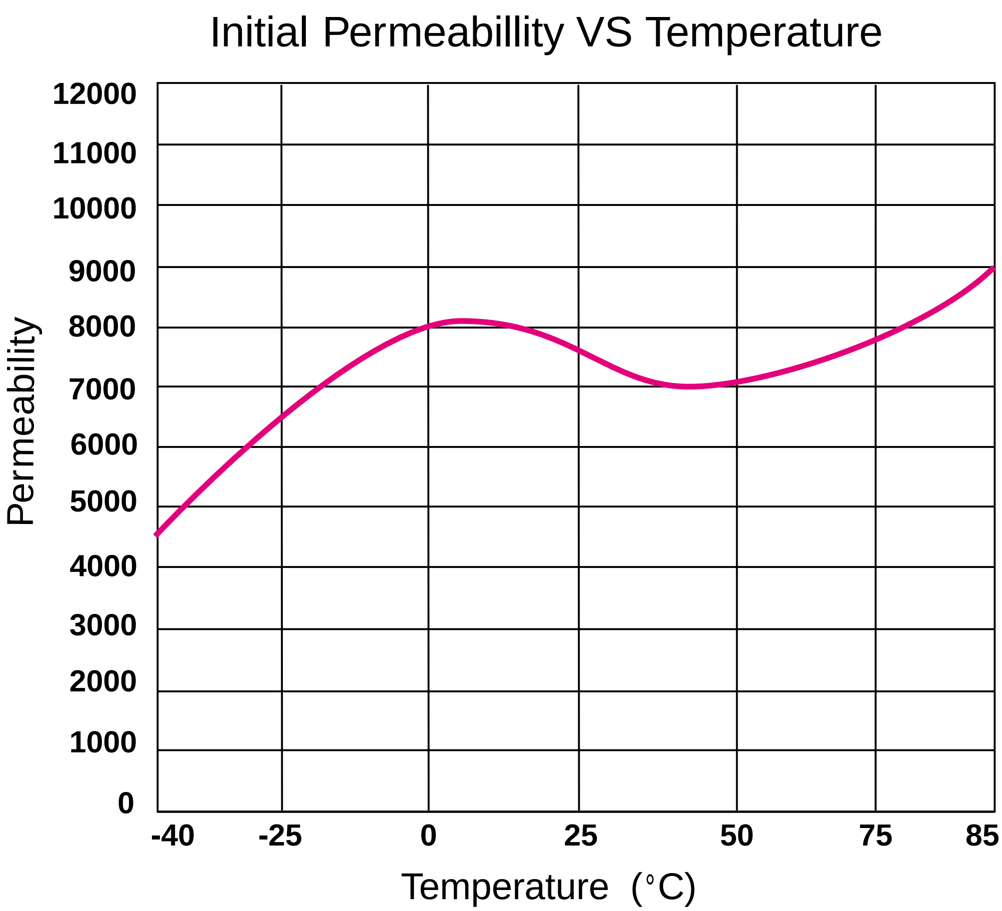
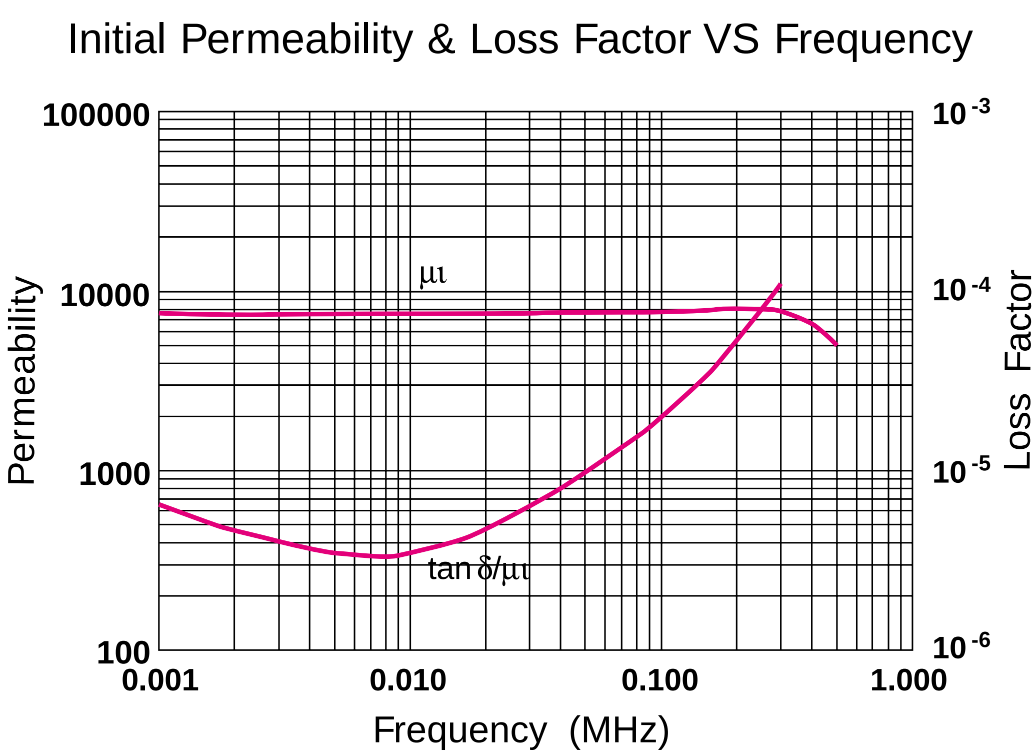
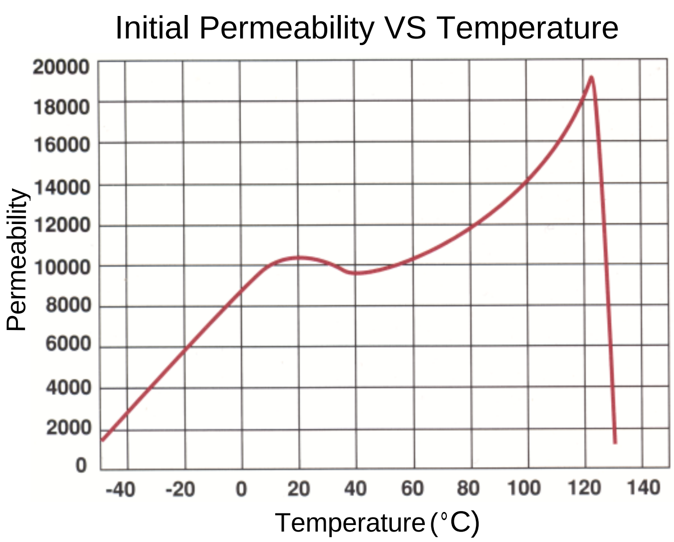
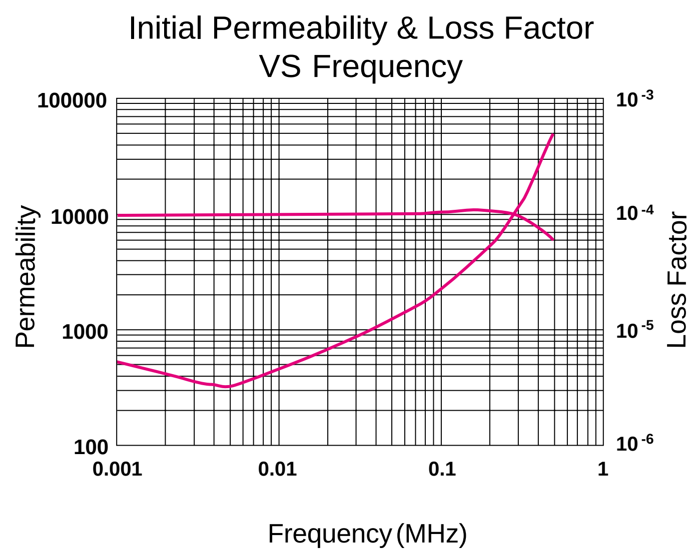
7,500 Permeability / Material 42

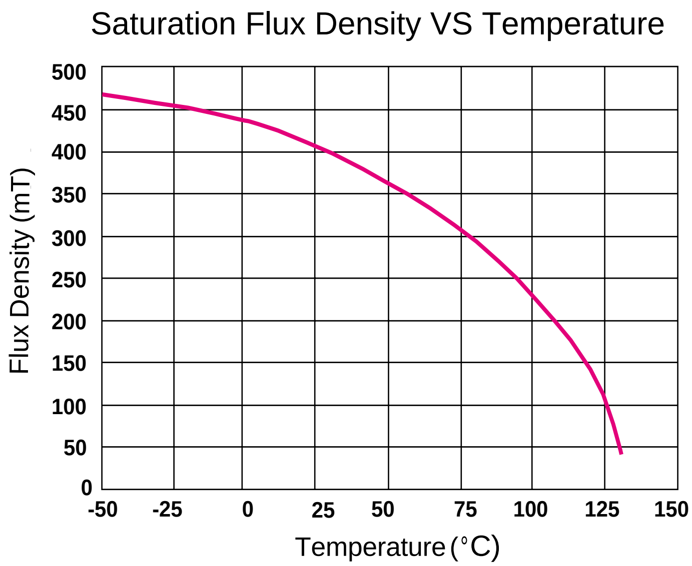


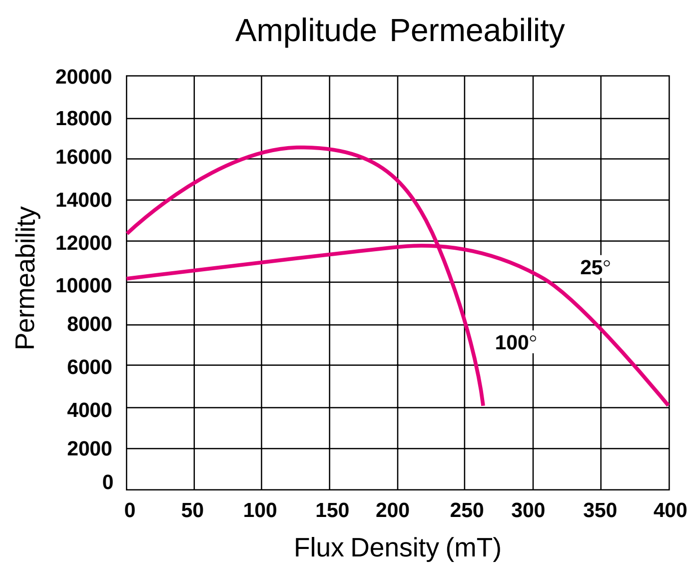


10,000 Permeability / Material 40



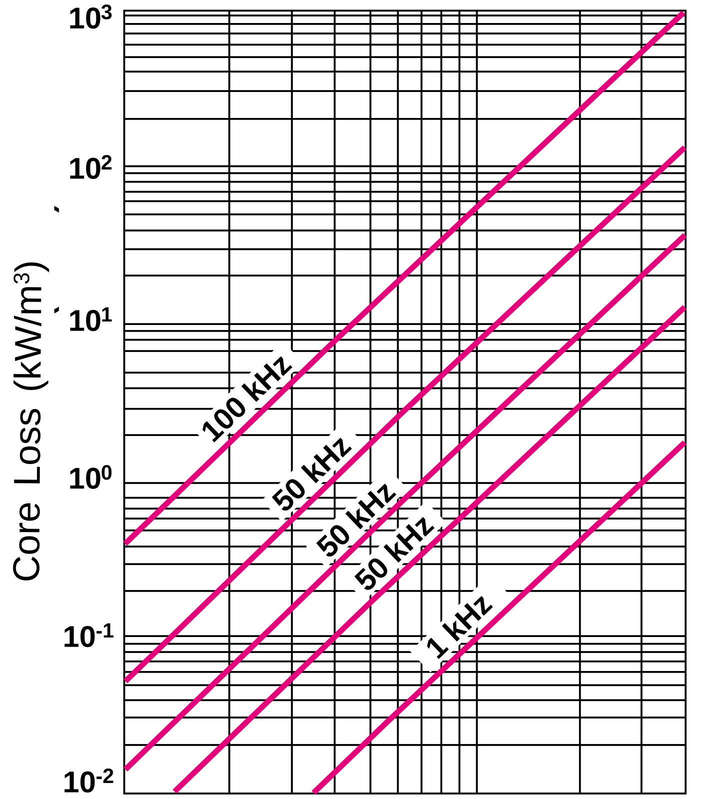




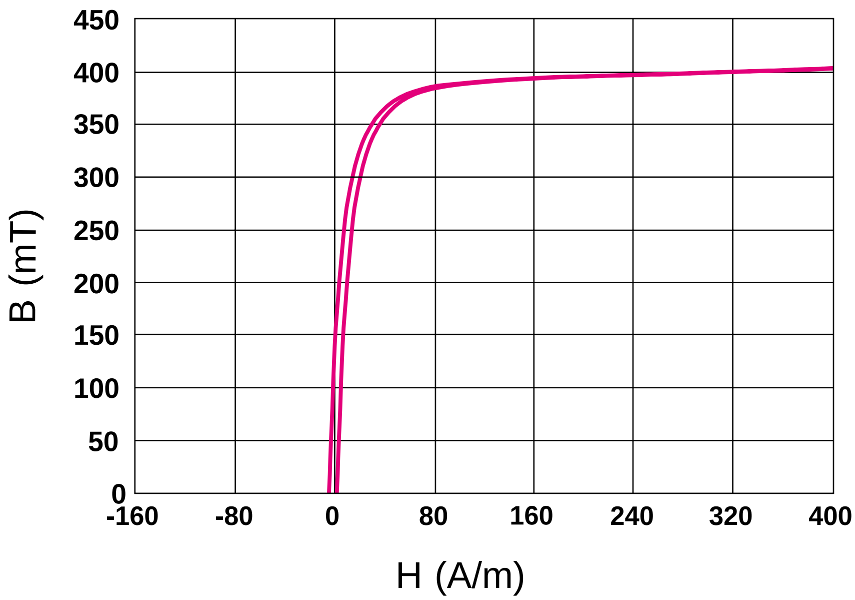


10,000 Permeability / Material 40

Core Loss VS Flux Density (25°C)

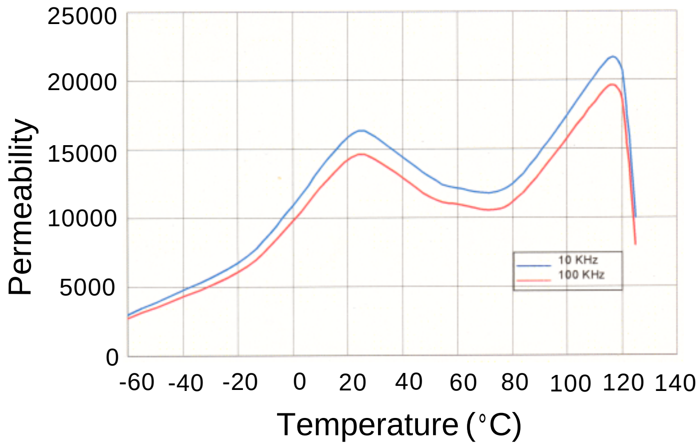


Magnetization Curve

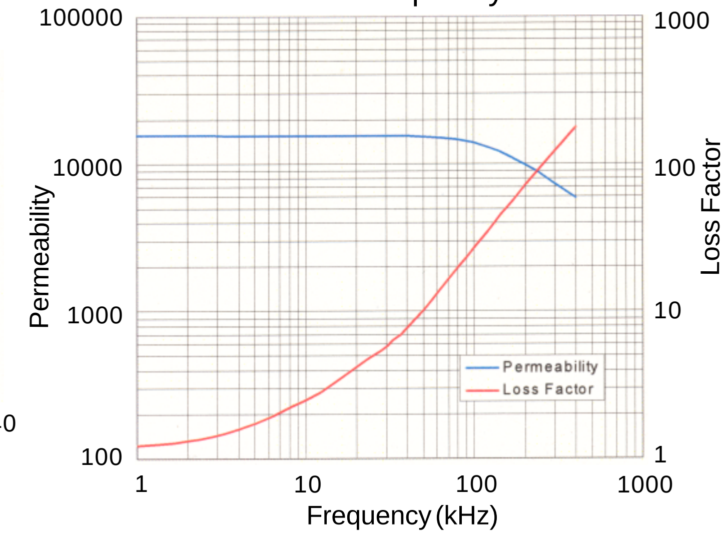


15,000 Permeability / Material 45

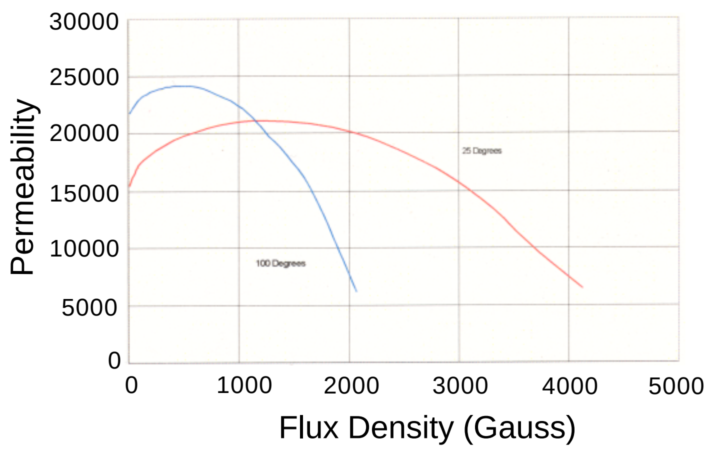
Initial Permeability VS Temperature



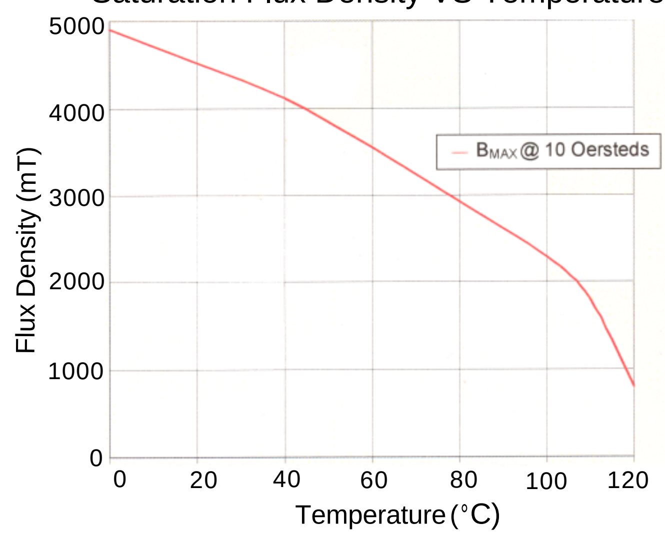
Initial Permeability & Loss Factor VS Frequency



Initial Permeability VS Flux Density



Saturation Flux Density VS Temperature



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Ferrite Property Measurement

Initial Permeability, Losses & Inductance Factor

Three properties can be measured, using only an inductance meter to measure an equivalent series inductance and resistance. From these values, and a knowledge of the inductor sample, three parameters may be derived. These are:

Inductance Factor, A_L, given by

$$A_{L[nH/t^2]} = \frac{L_{[nH]}}{n^2}$$

where L is the inductance in nH, and
n is the number of turns,

Initial Permeability (the real part only), μ_i, given by

$$\mu_i = \frac{L}{L_o}$$

where L is the measured inductance, and
L_o is the air core inductance.

Losses, described by $\tan\delta/\mu_i$, given by

$$\frac{\tan\delta}{\mu_i} = \frac{L_o R_s}{\omega L^2}$$

where μ_i is the initial permeability,
$\tan\delta/\mu_i$, is the lossy component of the total reactance,
ω is $2\pi f$, and
other terms as defined above.

Equipment: Precision LCR meter.

Test Conditions: Flux Density < 10 Gauss

Frequency: as specified.

The core is stabilized at room temperature (22° C) and wound with the correct number of turns. Since most LCR meters have a resistor, usually 100 Ω, in series between the oscillator and the unknown to be measured, the number of turns should be chosen such that the reactance of the core is at least 10 Ω. This condition ensures that a minimum of 10% of the test signal is applied to the core.

With the frequency set and voltage adjusted for test conditions, the LCR meter will measure R_S and L_S. Caution: When measuring very small value reactances, be sure to test the accuracy of the measurement instrument.

Changes in Inductance versus Temperature & Curie Temperature

These two tests may be performed using an inductance meter and a temperature controlled oven. The inductance meter will measure R_S and L_S.

Equipment: Precision LCR meter
Temperature Controlled Chamber for DUT

Test Conditions: Flux Density <10 Gauss
Temperature as specified

Frequency: 10 to 100 kHz.

The cores to be tested are placed in the temperature chamber and subjected to two stabilizing temperature cycles, with approximately two hours at each temperature.

The first inductance measurement, L_1 is made at the lowest temperature, θ_1, after a thirty minute soak at that temperature. This procedure is repeated up to the highest specified temperature, θ_2. A measurement made in the 20°C to 25°C range is considered the reference inductance, L_{ref}, at the reference temperature, θ_{ref}.

After measuring the highest temperature, a final measurement should be made again at the reference temperature. Both measurements of the reference inductance should be the same within the bridge accuracy. If these two readings are significantly dissimilar, more temperature stabilizing cycles may be needed to eliminate irreversible inductance changes in the samples.

Ferrite Property Measurement

From the inductance reading at various temperatures, the temperature coefficient of inductance may be calculated from

$$T.C. = \frac{L_{\theta 2} - L_{ref}}{L_{ref}\,(\theta_2 - \theta_{ref})} = \frac{L_{\theta 2} - L_{\theta 1}}{L_{ref}\,(\theta_2 - \theta_1)}$$

where all terms are as defined above.

For Curie Temperature measurement, temperature is slowly increased while inductance is monitored. The temperature at which core inductance decreases to 10% of the room temperature value is the Curie Temperature.

Flux Density, Residual Flux Density, Coercive Force, & Amplitude Permeability

There are four intrinsic material parameters that can be determined from the B-H loop measurement. The core under test is used as a transformer and the relationship between winding current (H) and secondary winding integrated voltage (B) is measured. This relationship is displayed using the “X versus Y” display mode on an oscilloscope. Magnetic terms are readily expressed in electrical terms to calibrate the display in units of Oersteds (Oe) versus Gauss (G). Once this calibration is achieved, salient points on the B-H curve may be easily obtained.

Equipment: Function Generator
Amplifier
RC Network
Dual Channel Oscilloscope

The test circuit is as shown at the right. Resistor R_1 is kept small in comparison with the inductive reactance of the wound sample. Cores must be properly installed and wound with primary and secondary winding. Field strength, H, is set by varying the current which is read as voltage across resistor R_1.

$$H_{[Oe]} = \frac{0.4\pi nI}{l_{e[cm]}} = \frac{0.4\pi n_p V_p}{l_{e(cm)} R_1}$$

Flux density of the cores is determined by integrating the secondary voltage using the RC circuit.

$$B_{[G]} = \frac{R_2 C V_p 10^8}{n_s A_{e[cm^2]}}$$

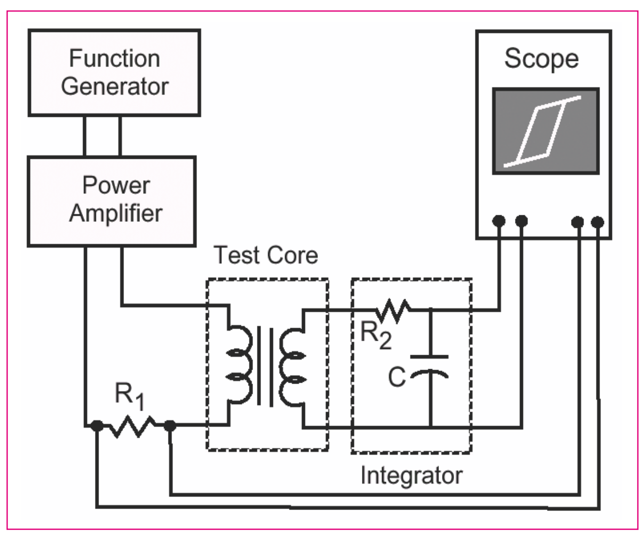
where R_2 is the integrating resistance, and C is the integrating capacitor.

From the displayed hysteresis loop saturation flux density, B_S, valueVs for coercive force, H_c, and residual flux density, B_r, may be determined once the oscilloscope is calibrated.

Finally, amplitude permeability, μ_a, is given by

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

where *B* represents peak flux density between 10 Gauss and saturation, an H is the corresponding field strength.



Test set up for measuring parameters of the B-H Loop.

Ferrite Property Measurement

Pulse Characteristics

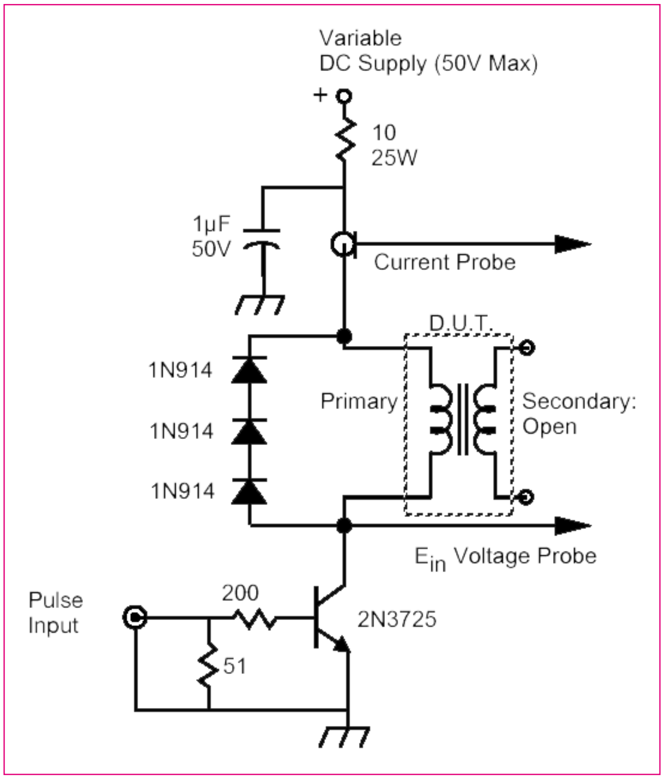
An open collector drive circuit is used to drive a pulse through a transformer with the secondary open circuited. The effect of the transformer on the pulse is observed by monitoring waveforms.

Equipment: Pulse Generator
DC Power Supply
Pulse Drive Circuit–appropriate for application
Dual Channel Oscilloscope
Current Probe

Test Conditions: Pulse Amplitude, Pulse Width,
and Pulse Repetition Rate as specified.
Temperature; 23°C ± 3°C.

The test toroid to be measured is wound with a sufficient number of turns to produce at least 100 µH of inductance. The core is excited by applying square voltage pulses. The test circuit is shown below.

Pulse inductance, L_P, pulse Inductance Factor, A_{LP}, and the voltage time product, E-T, are measured in accordance with section 16.7 of IEC367-1.



Test set up for measuring pulse characteristics

Pulse inductance is specified as greater than 90% of sine wave initial inductance.

Power Loss

Power loss is readily measured using a Volt-Amp-Watt (VAW) meter.

Equipment: Signal Generator
Power Amplifier
Clark Hess 256 VAW Meter
Temperature Chamber

The equipment is connected as shown below.

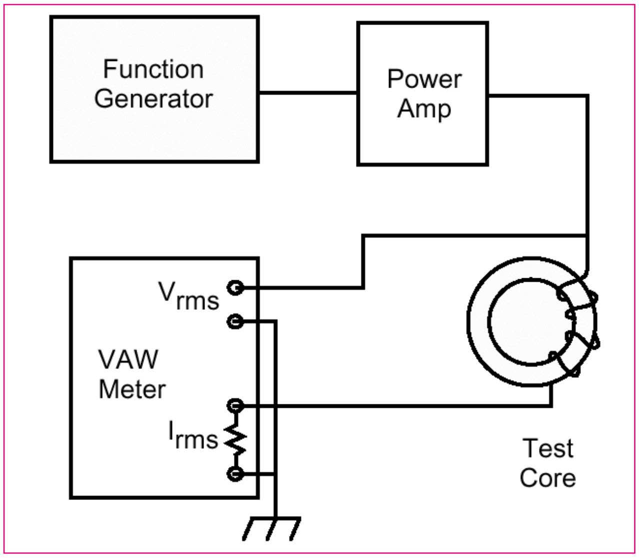
Frequency is set and voltage is adjusted to the desired flux density level, given by the relation

$$E_{[Vrms]} = 4.44 f n B_{[G]} A_{e[cm^2]} 10^{-8}$$

Power losses are indicated by the VAW meter in watts. Measurements are made as rapidly as possible to avoid temperature rise in the samples.

Material power loss density is determined by dividing the measured power loss by the effective volume of the ferrite core.

A VAW meter may also be used to measure magnetizing current, I_m. This value can be used to calculate the winding loss ($I_m^2 R_{ac}$), a part of the total measured power loss.



Test set up for measuring power loss.

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Ferrite Property Measurement

Measurement of Impedance Of Ferrite Components

The most common property referenced for soft magnetic materials is permeability. Permeability is a complex property comprised of real (reactive) and imaginary (resistive) components. At the lower end of the RF scale, impedance can be calculated from inductance as $Z = 2\pi fL = X_L$ and is dominated by the reactive component of permeability.

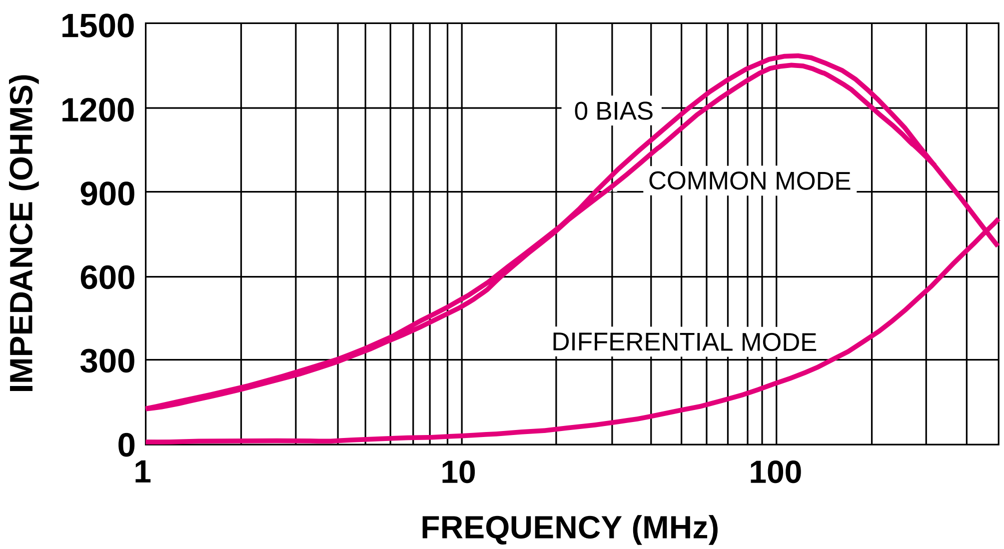
As frequency increases, impedance is driven by the resistive component and can be calculated as $Z = \sqrt{R^2 + (j\omega L)^2}$, where R represents the resistive component and $j\omega L$ represents the reactive component. At higher frequencies permeability will approach zero and impedance will reach a maximum value comprised of a purely resistive component. Impedance, like permeability, varies with temperature, frequency, signal current, DC bias, and the presence of any extraneous fields.

The useful impedance obtained from a ferrite component depends on its application, number of turns, and winding method. See below for an illustration of the effect of differential versus common mode winding techniques on the net impedance of a core.

Impedance measurements are made on an RF impedance analyzer. Measurements for this catalog were made on a Hewlett-Packard 4195A Network/Spectrum Analyzer with a 41951A Impedance Test Kit. All impedance curves represent gross measurements with number of turns and DC Bias current applied as shown (unless noted other-wise). In all cases the length of the conductive path between the part under test and the test fixture is kept to a minimum and in a fixed position to minimize parasitic capacitance.

All impedance measurements with DC Bias utilize the internal circuitry of the impedance analyzer. Measurements are also possible with an external source of DC current using an RF choke and a blocking capacitor to isolate the bias circuit from the RF circuit.

IMPEDANCE vs. DC BIAS
COMMON vs. DIFFERENTIAL MODE WINDING



28T0155-200, 10 AMP-TURNS

These curves show the effect of ten amp-turns of DC bias on the same core wound two different ways. In the differential mode, wherein there is a single winding carrying direct current, the core is pushed far into saturation (ten amp-turns on a T0155-200 corresponds to 13.7 Oersteds). In the common mode, wherein the direct current returns through a coil of the opposite winding direction and an equal number of turns, the only deviation from zero-bias arises from leakage inductance, which is inherently low in toroids.

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Terminology

The following glossary of terms is adapted from the Magnetic Materials Producers Association publication SFG-92 and other sources.

Air Core Inductance (L_0 [Henry]): The inductance that would be measured if the core had unity permeability and the flux distribution remained unaltered. See sction entitled "Magnetic Design Formulas" for this relation.

Circular Mils (c.m. [mils^2]): The cross sectional area of a circular conductor calculated as a square conductor, ie, area in c.m. is D^2, where D is the diameter of the wire. See also "Square Mils."

Coercive Force (H_c [Oe; Amp/m]): The magnetization field strength required to bring the magnetic flux density of a magnetized material to zero. See "Field Strength."

Common Mode Current: The component of signal current that induces electric and magnetic fields that do not tend to cancel one another. For example, in a circuit with one outgoing signal conductor and one return ("ground") conductor, the common mode current is the component of the total signal current that flows in the same direction on both conductors. Common mode current is the primary source of EMI in many electronic systems.

Common Mode Type I: On a single phase Wye bus, the conduction mode in which phase, neutral, and ground currents are in phase. The return current path is through the ground plane and the case.

Common Mode Type II: On a single phase Wye bus, the conduction mode in which phase and neutral currents are in phase, but the green wire currents are the return path, therefore 180° out of phase.

Common Mode Voltage: The voltage that drives directed common mode (noise) currents.

Core Constant (C_1 [cm^{-1}; mm^{-1}]): The summation of the magnetic path length of each section of the circuit divided by the corresponding area of the same section. See section entitled "Magnetic Design Formulas." C_1 is a frequently useful ratio in the analysis and prediction of core performance.

Core Constant (C_2 [cm^{-3}; mm^{-3}]): The summation of the magnetic path length of each section of the magnetic circuit divided by the square of the corresponding magnetic area of the same section. See section entitled "Magnetic Design Formulas."

Curie Temperature (T_c [°C]): The transition temperature above which a ferrite loses its ferromagnetic properties. Usually defined as the temperature at which μ_i falls to 10% of its room temperature value.

Dielectric Withstanding Voltage (DWV [V]): DWV is the voltage level at which the dielectric breaks down, allowing conduction between isolated conductors or between a conductor and the core. Isolation, or Hipot is the ability of a transformer to withstand a specific breakdown voltage between the primary and secondary windings.

Differential Mode: A current conduction mode in which currents, relative to two conductors, are flowing 180° out of phase, with equal magnitude within the conductors.

Differential Mode Current: The intended signal currents that are equal and oppositely directed on pairs of signal and return ("ground") conductors.

Differential Mode Voltage: The voltage that drives equal and oppositely directed currents to achieve an intended circuit function; the source of differential mode currents.

Disaccommodation (D): The proportional change of permeability after a disturbance of a magnetic material, measured at constant temperature, over a given time interval.

Disaccommodation Factor (DF): The disaccommodation factor is the disaccommodation after magnetic conditioning divided by the permeability of the first measurement times $\log_{10}$ of the ratio of time interval.

Effective Area (A_e [cm^2; mm^2]: For a magnetic core of a given geometry, the magnetic cross-sectional area that a hypothetical toroidal core of the same material properties would possess to be the magnetic equivalent to the given core. For a toroid, see the section entitled "Magnetic Design Formulas" for this relation.

Effective Length (l_e [cm; mm]): For a magnetic core of a given geometry, the magnetic length that a hypothetical toroidal core of the same material properties would possess to be the magnetic equivalent to the given core. For a toroid, see the section entitled "Magnetic Design Formulas" for this relation.

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Terminology

Effective Volume (V_e [cm^3; mm^3]): For a magnetic core of a given geometry, the magnetic volume that a hypothetical toroidal core of the same material properties would possess to be the magnetic equivalent to the given core. For a toroid, see the section entitled "Magnetic Design Formulas" for this relation.

Field Strength (H [Oe; Amp/m]): The parameter characterizing the amplitude of ac or dc field strength. Field strength is determined by the magnitude of current and geometry of the windings.

Flux Density (B [Gauss; Tesla]): The corresponding parameter for the induced magnetic field in an area perpendicular to the flux path. Flux density is determined by the field strength and permeability of the medium in which it is measured.

Impedance Z [Ohm]: The impedance of a ferrite may be expressed in terms of its complex permeability:

$$Z = j\omega L_S + R_S = j\omega L_O\,(\mu'_S - j\mu''_S)\ \text{(ohm)}$$

Incremental Permeability [μ_Δ]: The permeability of a magnetic material about a specified operating point and applied H (especially under DC bias). The incremental permeability is expressed as the slope of the B-H characteristic about the given operating point.

$$\mu_\Delta = \frac{\Delta B}{\Delta H}$$

Inductance Factor (A_L): A constant for a given geometrical shape that when multiplied by the square of the number of turns, gives the inductance in nano Henrys. Initial permeability (flux density of less than 10 Gauss) is assumed in the inductance factor.

Insulation Resistance [Ohm]: The insulation properties of the insulating material as measured in Ohms.

Leakage Flux: Leakage flux is the small fraction of the total magnetic flux in a transformer or common mode choke that does not contribute to the magnetic coupling of the windings of the device. In a transformer with a single set of primary and secondary windings, the leakage flux is that portion of flux that is produced by the primary that does not link the secondary. The presence of leakage flux in a transformer or common mode choke is modeled as a small "leakage" inductance in series with each winding. In a multi-winding choke or transformer, leakage inductance is the inductance measured at one winding with all other windings short circuited.

Leakage Inductance (L_λ [Henry]): That component of inductance that results from non-ideal coupling of flux to a core and/or other windings. As applied to the primary side of a transformer, the quotient of flux *not* coupled to the secondary winding and the current in the primary winding. As applied to an inductor, the quotient of flux outside the core and the current through the winding. In a multi-winding choke or transformer, leakage inductance is the inductance measured at one winding with all other windings short circuited.

Loss Factor ($\tan\delta/\mu_i$): The phase displacement between the fundamental components of the flux density and the field strength divided by the initial permeability. This term is essentially normalized loss. Note that $1/\tan\delta$ equals Q. This term is most useful as an indicator of the useful high Q bandwidth of a material. Above a specific frequency, depending on the material, loss factor normally undergoes a rapid increase due magnetic resonance. Note that a high Q is not de-sirable in all applications, especially EMI or filtering.

Loss Tangent: The measure of the loss of a magnetic material at high operating frequencies due to the oscillation of microscopic magnetic regions within the material. The loss tangent is expressed as the ratio of the imaginary permeability component μ" to the real permeability μ' of the material.

Magnetic Constant (μ_o [Henry/m]): The permeability of free space. The constant μ_o has a value of $4\pi \times 10^{-7}$.

Magnetic Field Intensity or Magnetizing Force (|H|): The mmf per unit length. H can be considered to be a measure of the strength or effort that the magnetomotive force applies to a magnetic circuit to establish a magnetic field. H may be expressed as $H = NI/\vartheta$, where ϑ = the mean length of the magnetic circuit in meters.

Magnetic Hysteresis: In a magnetic material, the irreversible variation of the flux density or magnetization which is associated with the change of magnetic field strength and is independent of the rate of change. Hysteresis results in the square or "open" characteristic of the B-H loop. Because it is irreversible, hysteresis results in lost energy. The amount of energy lost is related to the area within the B-H loop traversed.

Magnetically Soft Material: A magnetic material with a low coercivity.

Terminology

Magnetomotive Force (MMF [Amp]**):** The magnetic field which induces a magnetic flux in a magnetic circuit. The total magnetomotive force is the product of turns and current. Also, the product of Magnetic Field and coil length.

Mean Length Turn (MLT [cm; mm]**):** The average length of a single turn around the toroid. Values in this catalog are given for single layer coils. In multi-layer coils, the length of each successive layer is longer resulting in a longer average turn length.

Parasitic Capacitance (C_p [F]**):** Unintentional capacitance resulting from close physical proximity of two conductors. The copper comprising the wire is separated by its insulation from the core. The capacitance is proportional to area (wire diameter) and inversely proportional to separation.

Permeability (μ): The extent to or ease with which a material can be magnetized, often expressed as the parameter relating the magnetic flux density B induced by an applied magnetic field intensity H, as $B = \mu H$. The "absolute" permeability of a given material is expressed as the product of its relative permeability μ_r (a dimensionless constant) and the free space constant μ_o.

Permeability, amplitude (μ_a): The quotient of the peak value of flux density and peak value of applied field strength at a stated amplitude of either, with no static field present.

Permeability, incremental (μΔ): This is the permeability derived from the incremental difference of B and H (ΔB/ΔH), as given by a small ac signal with a static field, or bias, present. Also, minor loop permeability.

Permeability, effective (μ_e): For a magnetic circuit constructed with an air gap(s), the permeability of a hypothetical homogeneous material which would provide the same reluctance.

Permeability, Free Space (μ_o): The permeability of free space, a constant.

Permeability, initial (μ_i): This is the permeability of an initially de-gaussed core driven with a small signal ($2<B<10$ Gauss typical) such that the permeability of a minor loop centered on the origin is measured. The drive level is specified as < 10 Gauss, and is such that the minor loop is "inside" the major loop. Note that the (amplitude) permeability initially increases with increasing field strength.

Permeability, Pulse (μP): Under stated conditions, permeability obtained from the ratio of the rate of change in flux density to the rate of change in applied field strength of the pulse field.

Power Loss Density (P [mW/cm^3; kw/m^3]**):** The power absorbed by a body of ferromagnetic material and dissipated as heat when the body is subjected to an alternating field, which results in a measurable temperature rise. The total loss is divided by the volume of the body.

Quality Factor (Q): The ratio of energy stored to energy lost (reactance to resistance). For a series LR circuit, Q is $\omega L/R$. For a parallel LR circuit, Q is $R/\omega L$.

Remanence (Br [Gauss; Tesla]**):** The flux density remaining in a magnetic material when the applied field strength is reduced to zero.

Resistivity (ρ): The intrinsic property measured in ohm-cm that quantifies a material's opposition to free electron motion. Resistivity is the reciprocal property to conductivity. The resistance of a homogeneous material of uniform cross section A and length l can be found by:

$$R = \frac{\vartheta\, r}{A}$$

Rise Time (τ_r [sec]**):** Rise time of a square pulse is defined as the shortest time required for the voltage level to change from a "low" state to a high "state." Time is customarily measured between voltage levels 10% and 90% of the "high" amplitude.

Saturation: The point at which the flux density B in a magnetic material does not increase with further applications of greater magnetization force H. At saturation, the slope of a materials's B-H characteristic curve becomes extremely small, with the instantaneous permability approaching that of free space(relative permeability = 1.0)

Saturation Flux Density (B_s [Gauss; Tesla]**):** The maximum intrinsic induction possible in a material. This is the flux level at which additional H-field produces no additional B-field.

Single-Layer Winding: A winding for toroidal cores which will result in the full utilization of the inside circumference of the core without overlapping turns. Both the wire gauge and the thickness of the insulation will effect the number of turns which will fit on a single-layer winding.

Square Mils (mils^2): The cross sectional area of a circular conductor calculated as a circle, ie, area is πr^2, where r is in mils. See also "Circular Mils."

Terminology

Temperature Coefficient (T.C.): The normalized change of the quantity considered (inductance, for instance), divided by the difference in temperature producing it.

Turns Ratio: The ratio of the number of turns on the primary to the number of turns on the secondary.

Volt Second Product (ET [V_S]): The ET product is a parameter used to measure the transformer's ability to maintain and support a pulse signal without saturating the core. It is determined as the product of the voltage applied at the primary and the time required for the magnetizing current to reach 1.5 times its linear value. Values for ET are dependent on the core geometry, core material, and the number of turns on the winding.

Volume Resistivity (ρ [Ohm-cm]): The resistance measured by means of direct voltage of a body of ferromagnetic material having a constant cross-sectional area.

10th Edition!

Steward Toroid Catalog

10th Edition REV 2 - 04/2004

Steward produces an extensive line of ferrite products for Inductive and EMI Filtering Applications. Products include ferrite EMI cable cores, connector plates, unique common mode chokes, can-bus chokes, high current thru hole and surface mount components, impedance chip beads, surface mount inductors, toroid inductor cores and ferrite powders. Please consult our web site, Steward's EMI and Inductive Components full catalog, or contact your nearest Steward office or representative for additional information.

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