PHILIPS

DATA HANDBOOK

ELECTRONIC COMPONENTS AND MATERIALS DIVISION

COMPONENTS AND MATERIALS

PART 4 MARCH 1970

Magnetic materials

White ceramics

Properties of manganese zinc and nickel zinc ferrites

INTRODUCTION

The predominant feature of ferroxcube lies in its high resistivity that allows cores to be made of solid material without the eddy current losses becoming prohibitively high, even if the cores are used in the megacycle range.
Compared with powder-iron, the permeability of ferroxcube is high, whereas the losses remain comparatively low.

Ferroxcube cores are available in convenient shapes such as potcores, square cores* , E- and I-cores, X-cores, toroids, U-cores, aerial rods, yoke rings, screw cores, rods and tubes.
Potcores, E-I cores and X cores enable well-defined air gaps to be used without introducing appreciable stray fields. In this way the permeability of the material may be reduced to an effective value at which core and copper losses are matched. The dependence of the permeability on temperature and time is furthermore reduced to values that guarantee correct operation of the equipment.

This section contains comprehensive data on manganese zinc ferrites (ferroxcube 3) and nickel zinc ferrites (ferroxcube 4) and their various grades. The latter material in general shows higher specific resistance values, lower values of permeability and saturation flux density, higher coercivities and higher Curie points.

APPLICATION

grade	application
3B	potcores, cores for small coils
3B3	frames for i.f. transformers, potcores, rods, screw cores
3B5	potcores
3B7	potcores and square cores
3C1	erasing heads
3C2	yoke rings, L-cores, erasing heads
3C6	E- and U-cores
3C8	U- and I-cores
3D3	potcores, square cores, screw cores
3E1	E- and I-cores, toroids, potcores
3E2	H-cores and toroids
3E3	toroids
3H1	potcores, square cores, small toroids, cross cores, erasing heads

*) Square cores actually are square potcores.

grade	application
4A3	aerial rods
4A4	frames for i.f. transformers
4B1	aerial rods, frames for i.f. transformers
4C1	rods and tubes
4C6	potcores, square cores, toroids, frames for i.f. transformers
4C7	aerial rods
4D1, 4D2, 4E1	frames for i.f. transformers, screw cores, tubes and rods
4H1 $4L_1$ $4L_2$ 4MX	These are special-purpose NiZn ferrites developed for one type of application, namely resonant cavities for particle accelerators. In this field, usually a technical discussion is necessary before the correct material can be determined.

SYMBOLS

l_e — effective length of the magnetic path in cm

A_e — cross-section of a homogeneous part of a core in cm^2

μ_i — relative initial permeability, defined by:

$$\mu_i = \frac{1}{\mu_0} \lim_{H \to 0} \frac{B}{H}$$

μ_Δ — relative incremental permeability, defined by:

$$\mu_\Delta = \frac{1}{\mu_0} \frac{\Delta B}{\Delta H}$$

μ_a — relative amplitude permeability, defined by:

$$\mu_a = \frac{1}{\mu_0} \frac{B}{H}$$

μ_e — relative effective permeability, defined by:

$$\mu_e = \frac{\Sigma \frac{l_e}{A_e}}{\Sigma \frac{l_e}{\mu_i A_e}}$$

V_e — effective volume of a core in cm^3 = volume of an ideal toroid in the same material grade and with the same magnetic properties as the core. V_e is calculated from:

$$V_e = \frac{\left(\Sigma \frac{l_e}{A_e}\right)^3}{\left(\Sigma \frac{l_e}{A_e^2}\right)^2} \ cm^3$$

$T.F. = \frac{1}{\mu^2} \frac{d\mu}{dT}$ — temperature factor =

value for a certain ferroxcube material over a certain temperature range. In order to calculate the temperature coefficient per deg C of a coil the temperature factor has to be multiplied by the effective permeability.

So $t.c. = \frac{\Delta\mu}{\mu_i} \times \frac{\mu_e}{\mu_i} = \frac{\Delta\mu}{\mu_i^2} \times \mu_e$ per deg C

D.F. $= \dfrac{\mu_1 - \mu_2}{\mu_1^{\,2} \log \frac{t_2}{t_1}}$	disaccommodation factor, which gives the permeability variation, measured between 10 and 100 minutes after demagnetisation.
Curie point	critical temperature in °C above which the ferromagnetic body is paramagnetic.
$\dfrac{\tan\delta}{\mu_i}$	constant for eddy current and residual losses together at a certain frequency, determined at $\hat{B} \leq 1$ gauss through the coil. The resulting R/L value for eddy current and residual losses is: $\frac{R}{L} = \frac{\tan\delta}{\mu_i} \times \mu_e \times 2\pi f\ \Omega/H$ (f in Hz)
$q_{2\text{-}24\text{-}100}$	constant for hysteresis losses standardised for an effective volume of 24 cm^3, μ_e = 100 and measured between two currents, corresponding with two B_{max} values. At 800 Hz for a given volume V_e and for an effective permeability μ_e, we obtain: $q_{2\text{-}V\text{-}\mu} = q_{2\text{-}24\text{-}100} \times \left(\frac{\mu_e}{100}\right)^{3/2} \times \sqrt{\frac{24}{V_e}}\ \Omega/H^{3/2}\ mA$; $\frac{R_h}{L} = q_{2\text{-}V\text{-}\mu} \times \sqrt{L} \times i \times \frac{f}{800}\ \Omega/H$ (L in henry, f in Hz and i in mA)
ϱ	specific resistance in Ω cm measured with d.c. current
ϵ	dielectric constant

1 Gs $= 10^{-4}$T $= 10^{-4}$ Wb/m^2 $= 10^{-4}$ Vs/m^2

1 Oe $= \dfrac{10^3}{4\pi}$ A/m = 79.6 A/m = 0.796 A/cm

μ_0 = 1 Gs/Oe = 4 .10^{-7} H/m

TECHNICAL DATA

	(approximate values)
Specific heat	0.17 (cal/g)/deg C
Thermal conductivity	8×10^{-3} (cal/cm.s)/deg C
Coefficient of linear expansion	10^{-5}/deg C
Modulus of elasticity	15 000 kg/mm^2 (15×10^4 N/mm^2)
Tensile strength	1.8 kg/mm^2 (18 N/mm^2)
Crushing strength	7.3 kg/mm^2 (73 N/mm^2)

	3B	3B3	3B5	3B7	3C1
μ_i	900 ± 20%	900 ± 20%	1400 ± 25%	2300 ± 20%	~900
B (Gs), ballistically measured, at H = 10 Oe, T = 20 °C T = 100 °C	~ 3450 ~ 2300			~ 3400	
$10^6 \times \frac{\tan \delta}{\mu_i}$ at 4 kHz at 100 kHz at 250 kHz at 450 kHz	 ≤ 50	≤ 7 ≤ 15 ≤ 27 ≤ 50	≤ 2.5 ≤ 10	≤ 1 ≤ 5	
► $q_{2-24-100}$ (in $\Omega/H^{3/2}mA$) at 15-30 Gs and 4 kHz		≤ 12	≤ 2.5	≤ 1.8	
ϱ (in Ω.cm), measured with d.c. current	≥ 20	≥ 100	≥ 20	≥ 100	
10^6 x D.F. between 10 and 100 min after demagnetisation at 23 ± 1 °C	≤ 10	≤ 11	≤ 7.5	≤ 4.3	

Continued

	3B	3B3	3B5	3B7	3C1
T.F. (in 10^{-6}/deg C) at +23 to +55 °C	between 0 and +3	between 0 and +2	between +0.5 and +2.3		
at +23 to +70 °C				between −0.6 and +0.6 [1])	
Curie point (in °C)	≥ 150	≥ 150	≥ 150	≥ 170	≥ 150
Specific weight	4.7 - 4.9	4.7 - 4.9	4.7 - 4.9	4.7 - 4.9	4.7 - 4.9

The figures mentioned are valid for toroids of not too small dimensions. For cores of small dimensions and of different shapes translation of these figures in a straightforward way is not always possible.

[1]) Measured 10 min after demagnetisation.

	3C2	3C6	3C8	3D3	3E1	3E2	3E3	3H1
μ_i	900 ± 25%			750 ± 20%	2700 ± 20% 1)	≥ 5000 2)	≥ 10^4 3)	2300 ± 20%
B (in Gs), ballistically measured, at H = 10 Oe, T = 23 °C	~ 3500			~ 3500	~ 3500	~ 4200	~ 4000	~ 3400
T = 70 °C						~ 3400	~ 3000	
T = 100 °C	~ 2450							
at H = 2.5 A/cm, T = 100 °C		≥ 2900	≥ 3300					
$10^6 \times \frac{\tan\delta}{\mu_i}$ at 4 kHz					≤ 2.5	≤ 2.5	≤ 2.5	≤ 1
at 50 kHz							≤ 20	
at 100 kHz				≤ 8	≤ 15	≤ 15	≤ 50	≤ 5
at 500 kHz				≤ 14	≤ 90	≤ 90		
at 1000 kHz				≤ 30				
Core losses (in mW/cm^3), measured with a.c. current of 16 kHz, at B = 1000 Gs, at B = 2000 Gs, T = 25 °C		≤ 170	≤ 110					
T = 50 °C		≤ 160						
T = 100 °C		≤ 140	≤ 100					

Continued

	3C2	3C6	3C8	3D3	3E1	3E2	3E3	3H1
$q_{2-24-100}$ (in $\Omega/H^{3/2}mA$) at 15-30 Gs and 4 kHz ►at 3-12 Gs and 100 kHz				≤ 3	≤ 4	≤ 1.8	≤ 1.8	≤ 1.8
ρ (in Ω.cm), measured with d.c. current	≥ 10			≥ 150	≥ 30	≥ 10	≥ 5	≥ 100
10^6 x D.F., between 10 and 100 min after demagnetisation at 23 ± 1 °C				≤ 12	≤ 6	≤ 1.9	≤ 1.9	≤ 4.3
T.F. (in 10^{-6}/deg C) at +5 to +23 °C								between +0.5 and +1.5 4)
at +23 to +55 °C	between 0 and +4.5				between 0 and +4			between +0.5 and +1.5 4)
at +23 to +70 °C				between 0 and +2 4)				between +0.5 and +1.5 4)5)
Curie point (in °C)	≥ 150	≥ 190	≥ 200	≥ 150	≥ 125	≥ 130	≥ 125	≥ 130
Specific weight	4.7-4.9	4.8-4.9	4.8-4.9	4.5-4.9	4.7-4.9	4.7-4.9	4.8-4.95	4.7-4.9

The figures mentioned are valid for toroids of not too small dimensions. For cores of small dimensions and of different shapes translation of these figures in a straight forward way is not always possible.

1) For data on an improved 3E1 grade see page A16.
2) At +23 to +70 °C.
3) At +10 to +70 °C.
4) Measured 24 hours after demagnetisation.
5) Only for orientation.

		4A3	4A4	4B1	4C1
μ_i		450 ± 20%	500 ± 20%	250 ± 20%	125 ± 20%
B (in Gs), ballistically measured,					
H = 10 Oe, T = 20 °C			approx. 2700		
T = 70 °C			approx. 2100		
H = 20 Oe, T = 20 °C				approx. 3250	
T = 100 °C				approx. 2600	
H = 25 Oe, T = 20 °C					
T = 70 °C					
H = 30 Oe, T = 20 °C					approx. 2750
T = 70 °C					
T = 100 °C					approx. 2450
$\frac{\tan\delta}{\mu_i}$ at 500 kHz			≤ 30x10^{-6}		
at 700 kHz				≤ 70x10^{-6}	
at 1 MHz				≤ 90x10^{-6}	
at 1.5 MHz		≤ 40x10^{-6}	≤ 40x10^{-6}	≤ 140x10^{-6}	
at 2 MHz		≤ 70x10^{-6}	≤ 70x10^{-6}		≤ 120x10^{-6}
at 3 MHz					≤ 160x10^{-6}
at 5 MHz					≤ 300x10^{-6}

Continued

		4A3	4A4	4B1	4C1
$q_{2\text{-}24\text{-}100}$ (in $\Omega/H^{3/2}mA$) at 100 kHz, B = 3-12 Gs			≤ 3		
ϱ (in Ω.cm), measured with d.c. current		$\geq 10^5$	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$
ϵ at 11 MHz at 10 and 20 MHz			15-20		
→ D.F. between 10 and 100 min. after demagnetisation at 23 $\pm$ 1			$\leq 5 \times 10^{-6}$		
T.F. between +23 and +55 °C				between 0 and $+8 \times 10^{-6}/°C$	between 0 and $+12 \times 10^{-6}/°C$
+23 and +70 °C			between +5 and $+15 \times 10^{-6}/°C$ *		
Curie point in °C		≥ 125	≥ 125	≥ 250	≥ 350
Specific weight		4.7 - 5.1	4.7 - 5.1	4.4 - 4.8	4.2 - 4.6

The figures mentioned are valid for toroids of not too small dimensions. For cores of small dimensions and of different shapes translation of these figures in a straight forward way is not always possible.

* Measured 24 hours after demagnetisation

	4C6	4C7	4D1	4D2	4E1
μ_i	120 ± 20%	100 ± 20%	50 ± 20%	60 ± 5%	15 ± 20%
B (in Gs), ballistically measured, H = 30 Oe, T = 20 °C	~ 3800				
T = 70 °C	~ 3500				
H = 40 Oe, T = 20 °C			~ 2400		
T = 100 °C			~ 2200		
H = 60 Oe, T = 20 °C					~ 1750
T = 100 °C					~ 1650
$10^6 \times \frac{\tan\delta}{\mu_i}$ at 1.5 MHz		≤ 50			
at 2 MHz	≤ 40				
at 3 MHz			≤ 180		
at 5 MHz		≤ 60	≤ 210		
at 10 MHz	≤ 100	≤ 150	≤ 300	≤ 100	≤ 300
at 20 MHz		≤ 300			≤ 300
at 25 MHz				≤ 200	
at 40 MHz				≤ 600	≤ 360
$q_{2-24-100}$ (in $\Omega/H^{3/2}mA$) at 100 kHz, B = 3-12 Gs	≤ 10				
ρ (in Ω.cm), measured with d.c. current	≥ 10^5		≥ 10^5		≥ 10^5
ε at 1 MHz	10-15				
10^6 x D.F. between 10 and 100 min after demagnetisation at 23 and 70 °C	≤ 10				

Continued

	4C6	4C7	4D1	4D2	4E1
T.F. (in 10^{-6}/deg C)					
+5 and +55 °C					
+5 and +23 °C	between −2 and +4 *	≤ 10			
+23 and +55 °C	between 0 and +6 *		between 0 and +15		between 0 and +15
+23 and +70 °C				between 0 and +15	
Curie point (in °C)	≥ 350	≥ 350	≥ 400		≥ 500
Specific weight	4-5	3.5-5	4-4.4		3.5-4

The figures mentioned are valid for toroids of not too small dimensions. For cores of small dimensions and of different shapes translation of these figures in a straight forward way is not always possible.

* Measured 24 hours after thermal demagnetisation.

→ Improved grade 3E1

μ_i	3800 ± 20%
μ_i (T within 23 to +70 °C)	≥ 3040
B (in Gs), ballistically measured,	
at H = 10 Oe, T = 23 °C	~ 3800
at H = 10 Oe, T = 70 °C	~ 2800
$\frac{\tan\delta}{\mu_i} \times 10^6$ at 4 kHz	≤ 2.5
at 100 kHz	≤ 20
at 500 kHz	≤ 200
$q_{2-24-100}$ (in $\Omega/H^{3/2}mA$) at 4 kHz, measured between 15 and 30 Gs	≤ 3
ϱ (in Ω.cm), measured with d.c. current	≥ 30
Curie point (in °C)	≥ 130
Specific weight	4.7-4.9

The figures are valid for toroids with dimensions 30 x 15 x 7.5 mm.

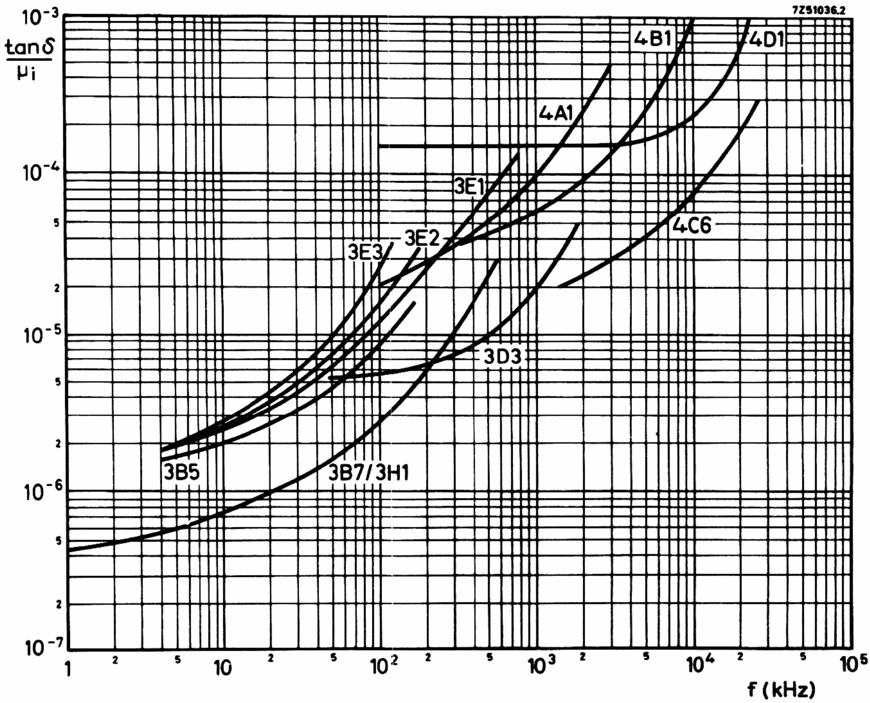
NiZn ferrites for resonant cavities

	4H1	4L1	4L2	4MX
Q80/Q~	0.9	0.7	0.7	0.8
μ_{rem}/μ_i	0.6-0.7	0.7-0.8	0.8-0.9	0.8-0.9
μ in remanent state (μ_{rem}) approx.	170	150	190	130
μQ in remanent state at 1.5 MHz, 50 Gs	21400	17800	21400	21800
at 1.5 MHz, 100 Gs	16000	14000	17000	20500
at 1.5 MHz, 150 Gs	12800	11200	14000	18800
at 1.5 MHz, 200 Gs	8600	9200	9700	14000
at 2.5 MHz, 50 Gs	15000	13000	17000	
at 2.5 MHz, 100 Gs	6000	7200	14500	
at 2.5 MHz, 150 Gs		5000	11000	
at 2.5 MHz, 200 Gs			8200	
at 5 MHz, 50 Gs	5000	10600	12000	19200
at 5 MHz, 100 Gs		4600	9700	16000
at 5 MHz, 150 Gs			6700	12500
at 5 MHz, 200 Gs			4500	5600
at 10 MHz, 50 Gs		4200		11200
at 10 MHz, 100 Gs				8200
at 10 MHz, 150 Gs				5600

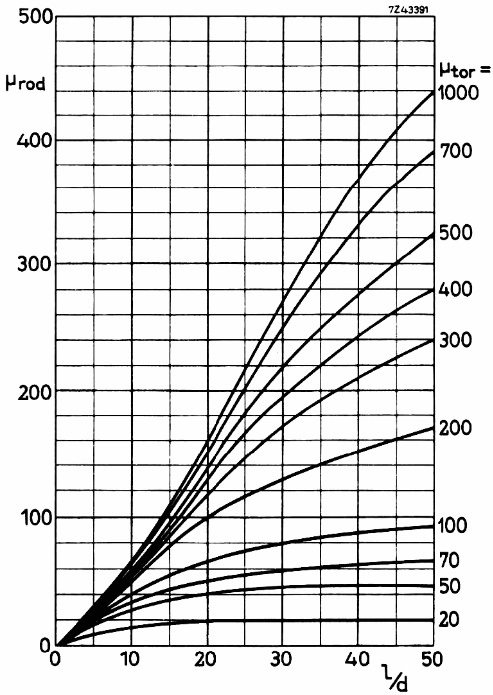
Q80/Q~ indicates the properties under pulse conditions.
Q80 is the quality factor 80 milliseconds after application of a continuous bias of approx. 50 oerstedts.
Q~ is the quality factor in the static state.
μ_{rem}/μ_i indicates the squareness of the hysteresis loop.

CHARACTERISTIC CURVES

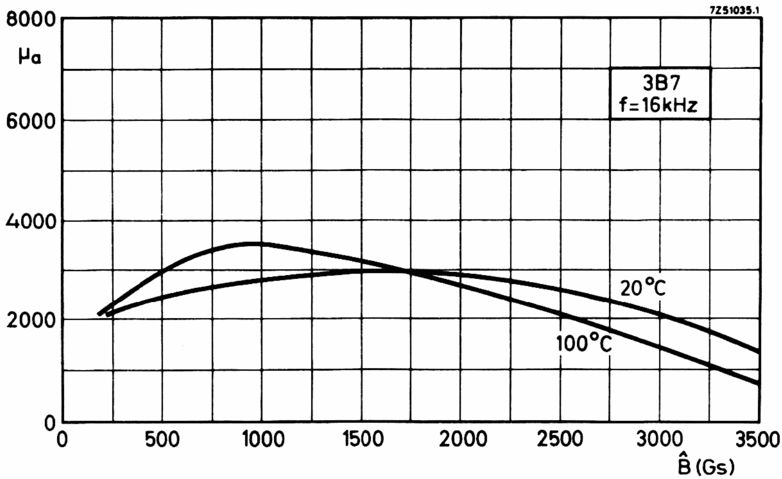
EDDY CURRENT LOSSES AND RESIDUAL LOSSES AS A FUNCTION OF THE FREQUENCY AT LOW INDUCTION LEVEL

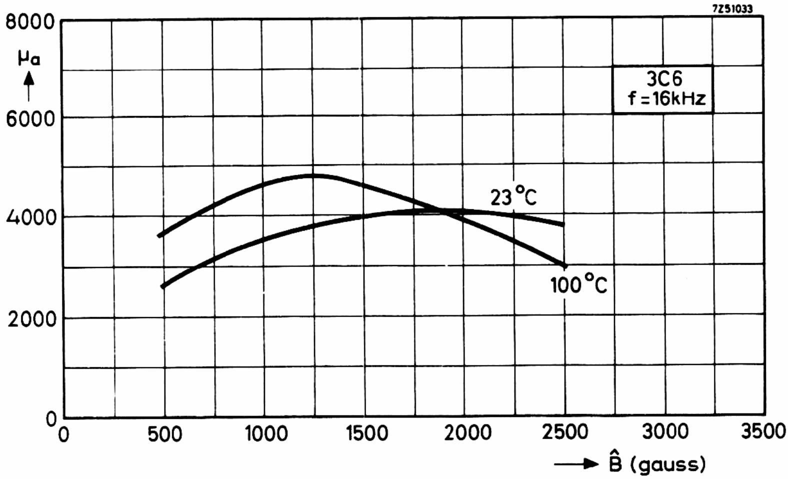


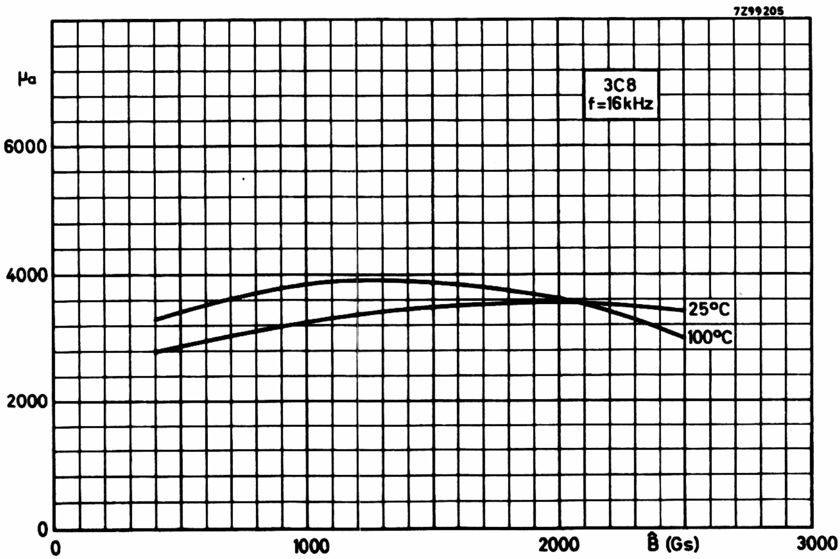
ROD PERMEABILITY AS A FUNCTION OF THE RATIO l/d WITH THE RELATIVE INITIAL PERMEABILITY OF A TOROIDAL CORE AS PARAMETER

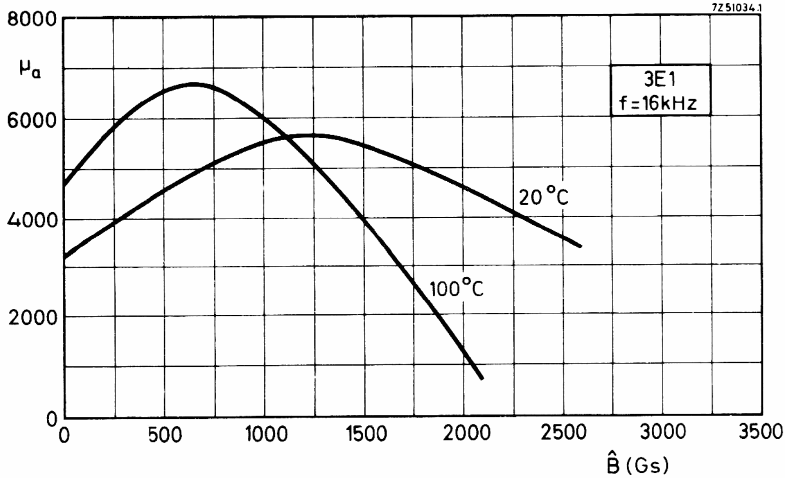


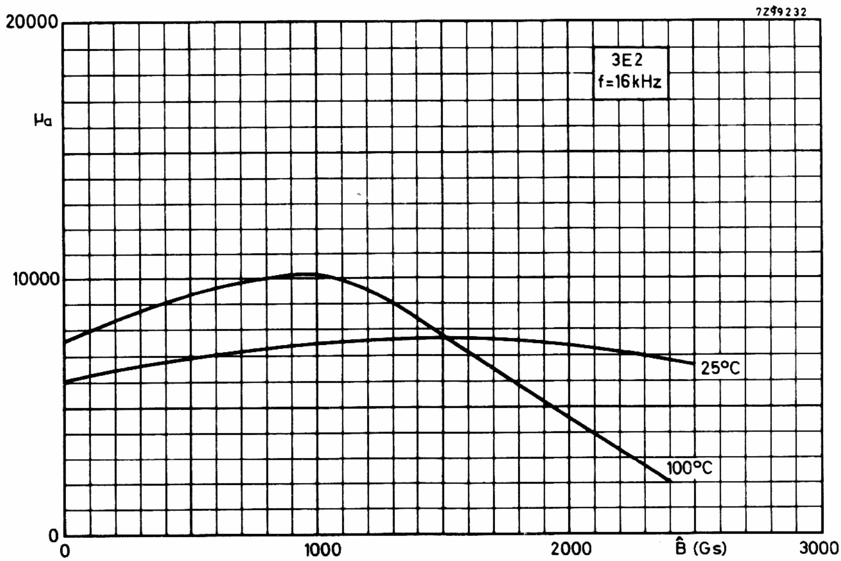
AMPLITUDE PERMEABILITY AS A FUNCTION OF THE INDUCTION

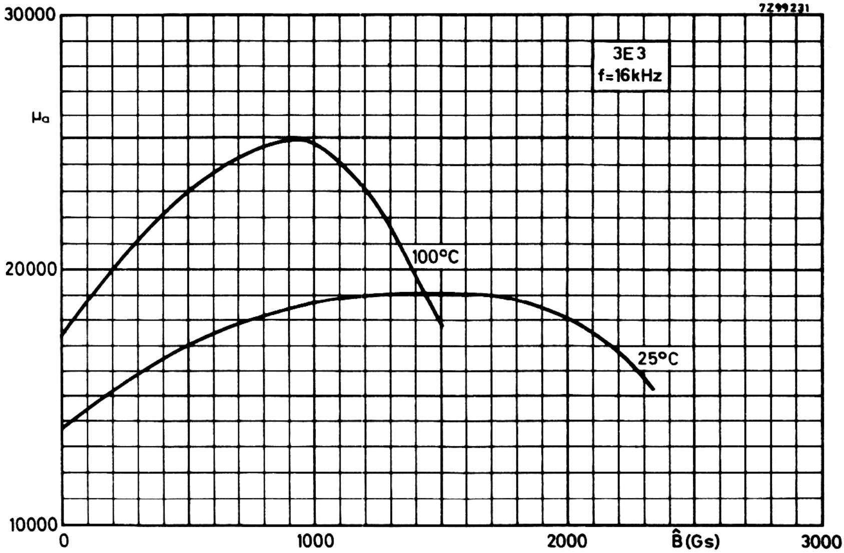


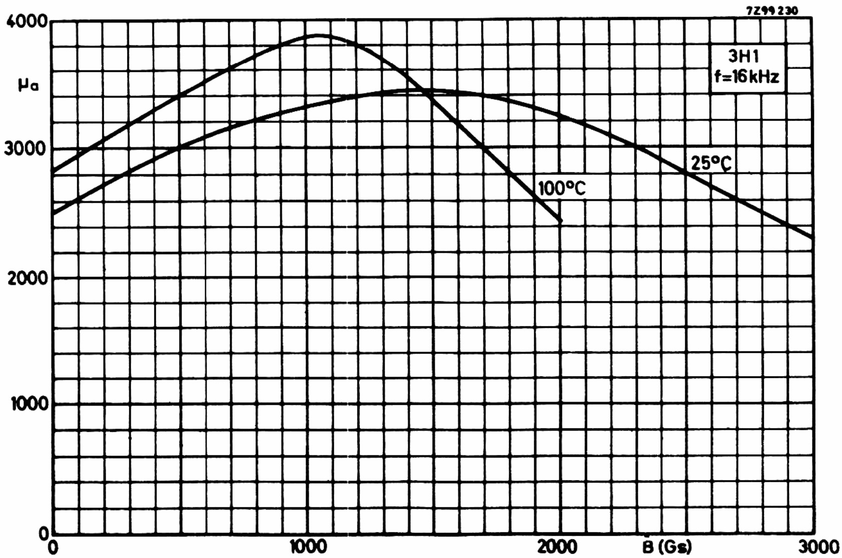

7Z51033
8000
μ_a
6000
4000
2000
0
3C6
f = 16kHz
23 °C
100 °C
0
500
1000
1500
2000
2500
3000
3500
B̂ (gauss)


7Z99205
μ_a
6000
4000
2000
0
3C8
f=16kHz
25°C
100°C
0
1000
2000
B̂ (Gs)
3000

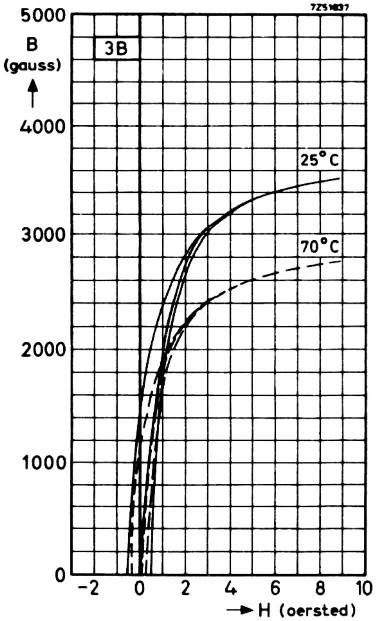

7Z51034.1
8000
μa
6000
4000
2000
0
3E1
f=16kHz
20°C
100°C
0
500
1000
1500
2000
2500
3000
3500
B̂ (Gs)

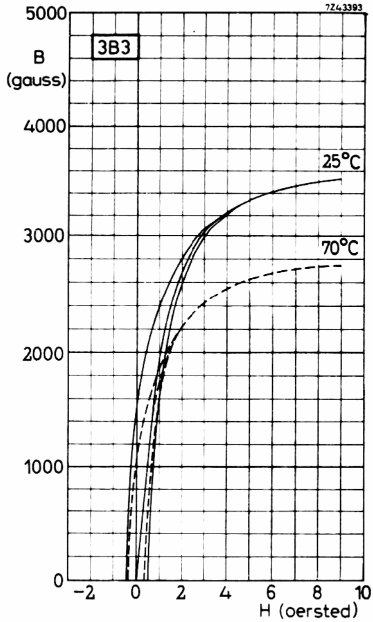

7Z49232
20000
μa
10000
0
3E2
f=16kHz
25°C
100°C
0
1000
2000
B̂ (Gs)
3000

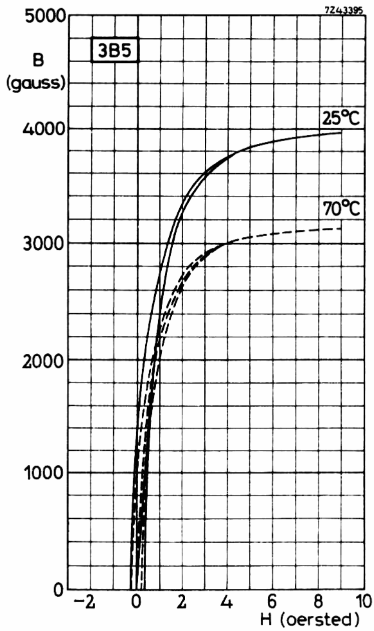

7Z99231
3E3
f=16kHz
μa
30000
20000
10000
100°C
25°C
0
1000
2000
B̂ (Gs)
3000

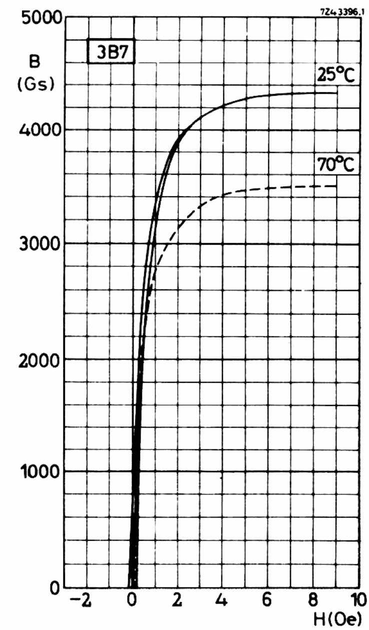

7Z99230
3H1
f=16kHz
μa
4000
3000
2000
1000
0
100°C
25°C
0
1000
2000
B̂ (Gs)
3000

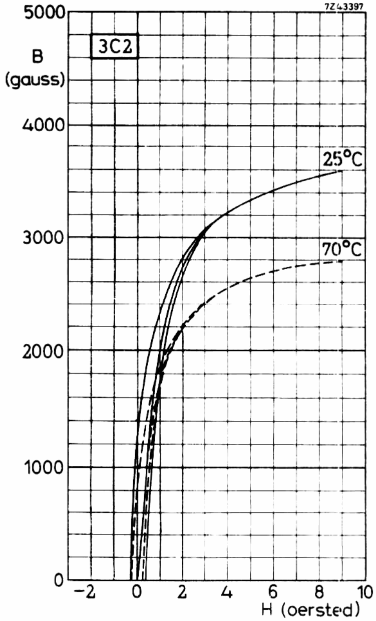
TYPICAL BH-CURVES (ballistically measured)

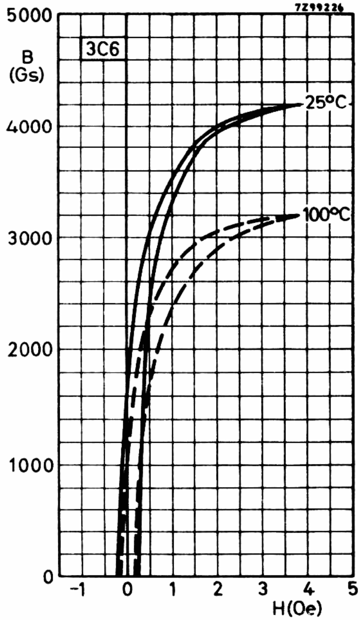


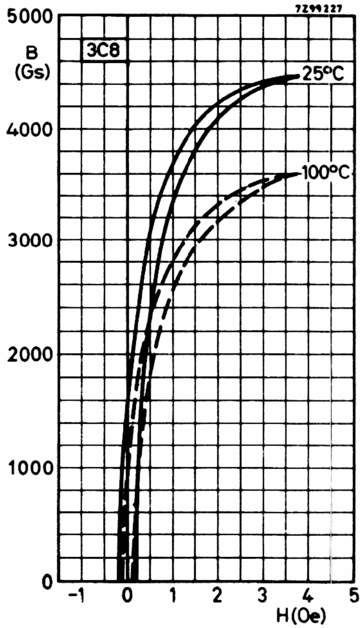


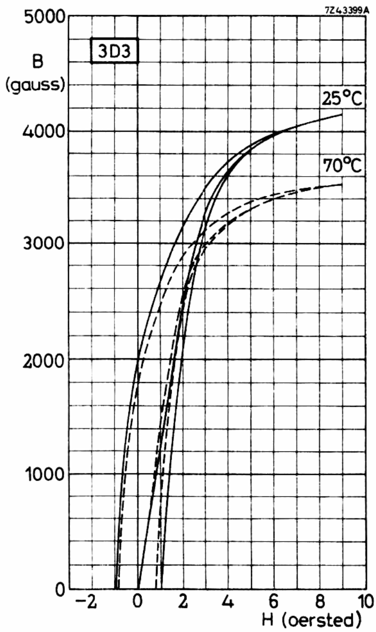


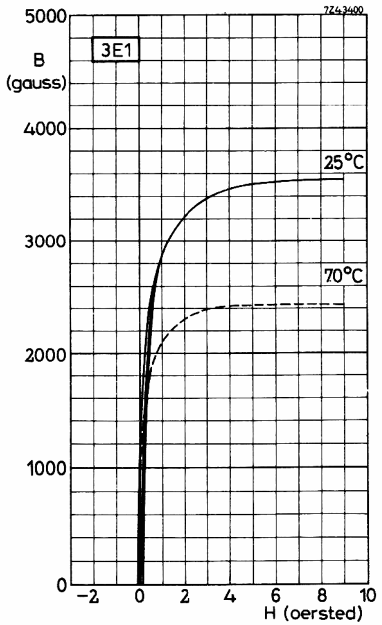


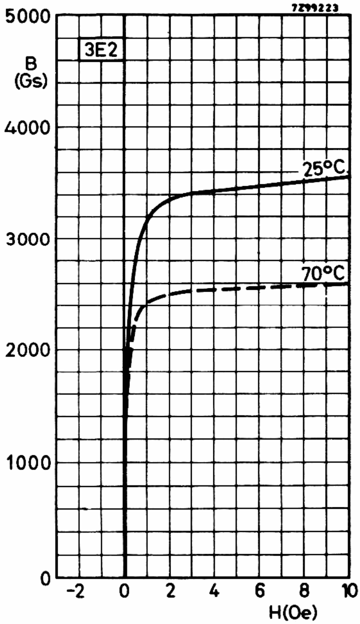

7Z43397
3C2
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

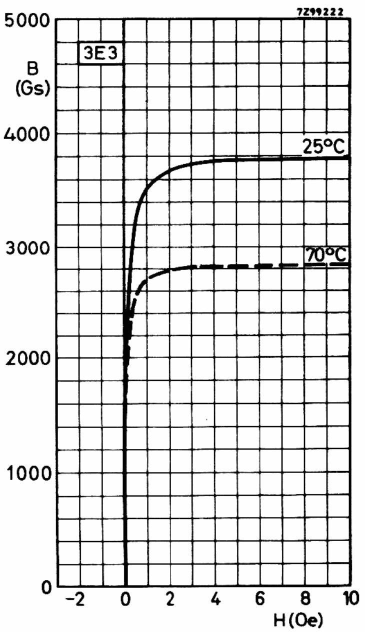

7Z99226
3C6
5000
B
(Gs)
4000
3000
2000
1000
0
25°C
100°C
−1
0
1
2
3
4
5
H(Oe)

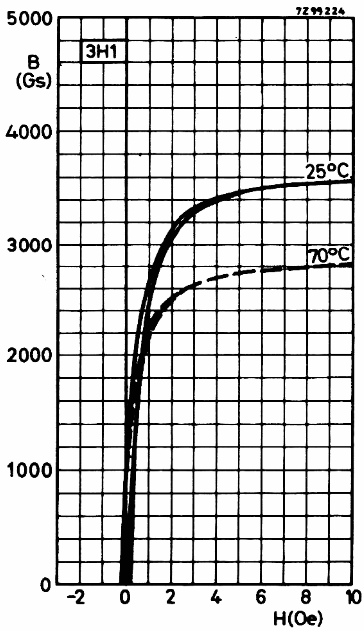

7Z99227
3C8
5000
B
(Gs)
4000
3000
2000
1000
0
25°C
100°C
−1
0
1
2
3
4
5
H(Oe)

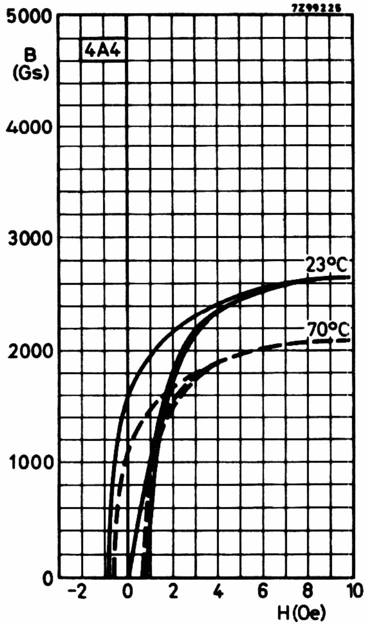

7Z43399A
3D3
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

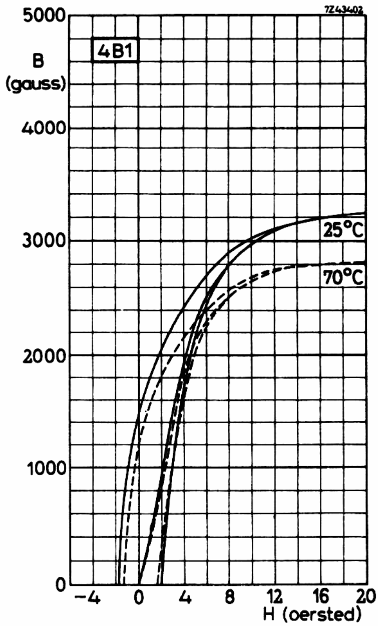

7Z43400
3E1
B (gauss)
25°C
70°C
H (oersted)

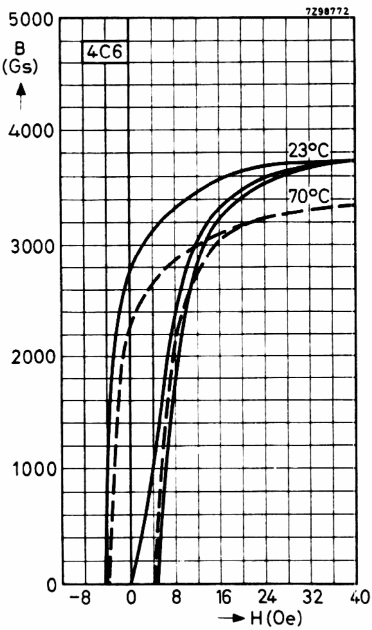

7Z99223
3E2
B (Gs)
25°C
70°C
H(Oe)

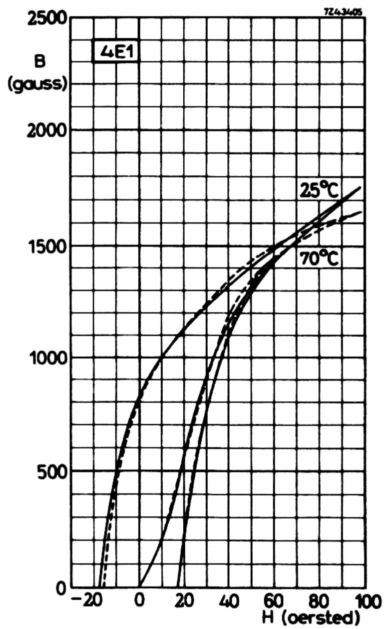

7Z99222
3E3
B (Gs)
25°C
70°C
H(Oe)


7Z99224
3H1
B (Gs)
25°C
70°C
H(Oe)

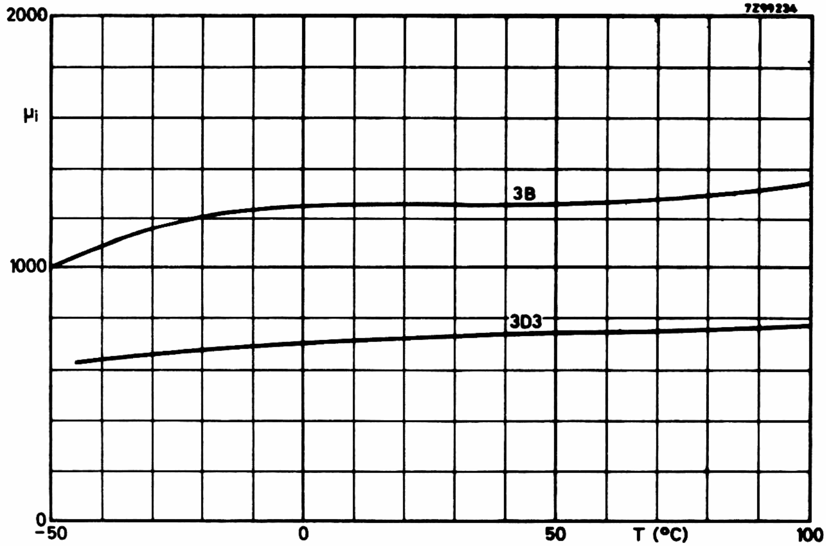

7Z99225
4A4
B (Gs)
5000
4000
3000
2000
1000
0
23°C
70°C
−2
0
2
4
6
8
10
H(Oe)

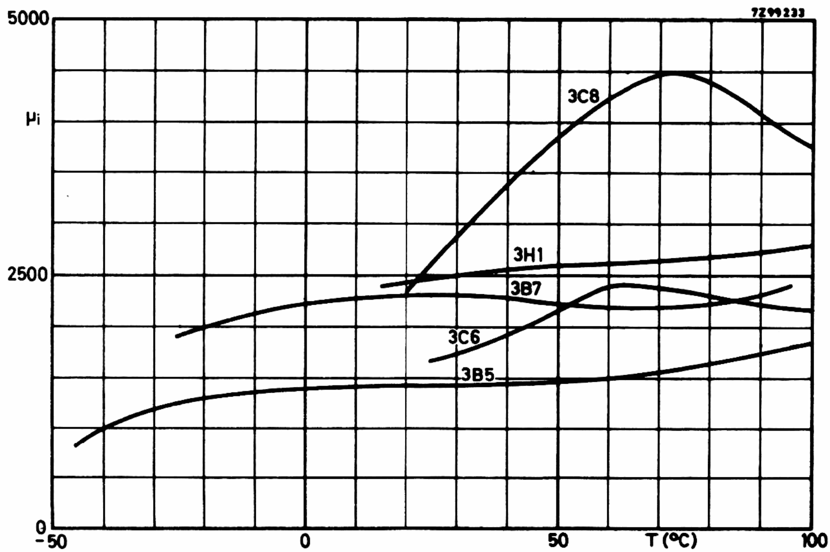

7Z43402
4B1
B (gauss)
5000
4000
3000
2000
1000
0
25°C
70°C
−4
0
4
8
12
16
20
H (oersted)

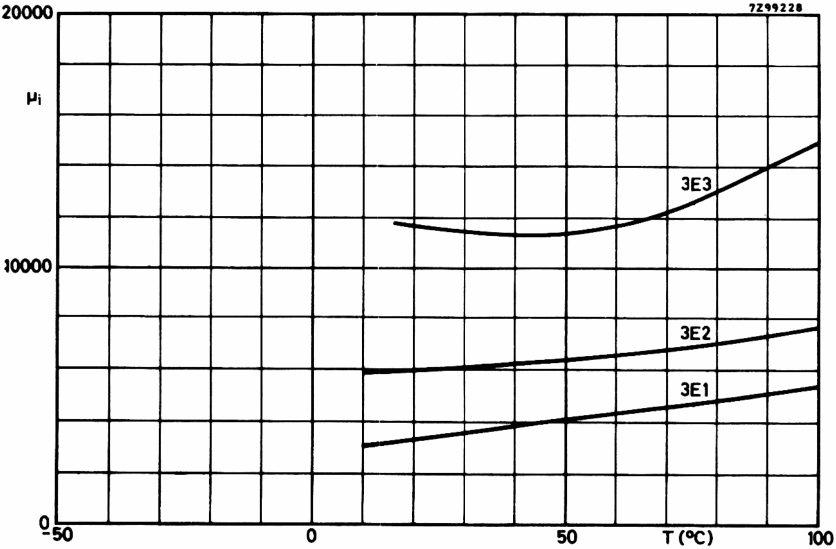

7Z98772
4C6
B (Gs)
5000
4000
3000
2000
1000
0
23°C
70°C
−8
0
8
16
24
32
40
H (Oe)

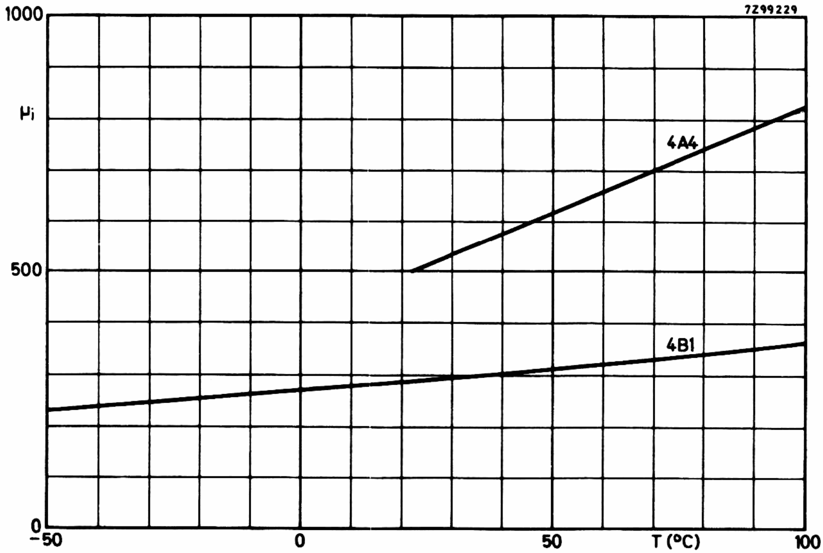

7Z43405
4E1
B (gauss)
2500
2000
1500
1000
500
0
25°C
70°C
−20
0
20
40
60
80
100
H (oersted)

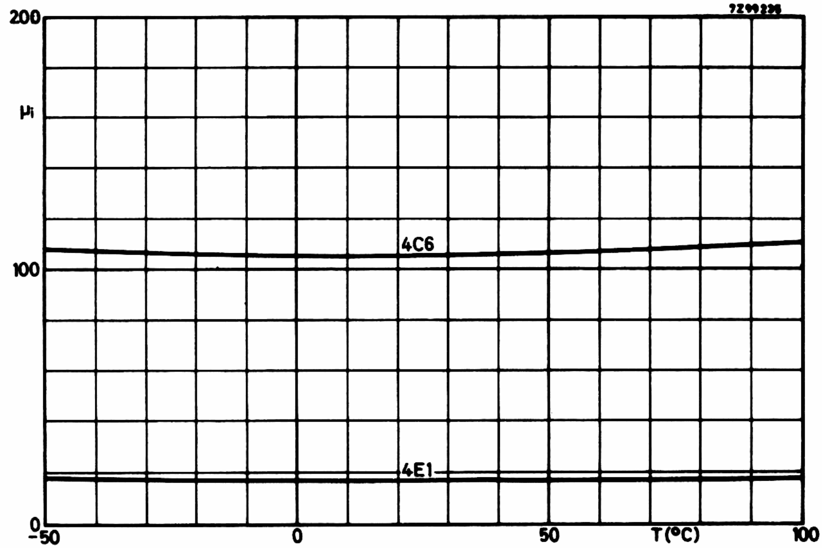
RELATIVE INITIAL PERMEABILITY AS A FUNCTION OF THE TEMPERATURE



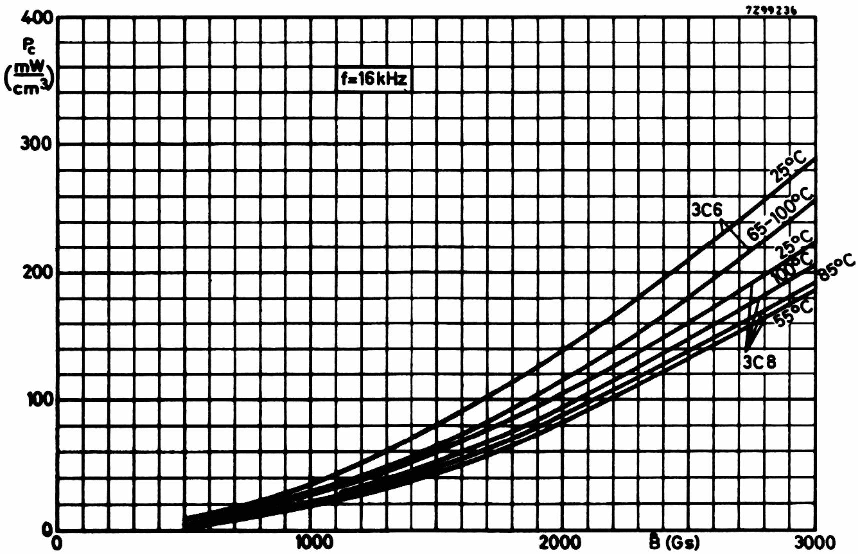


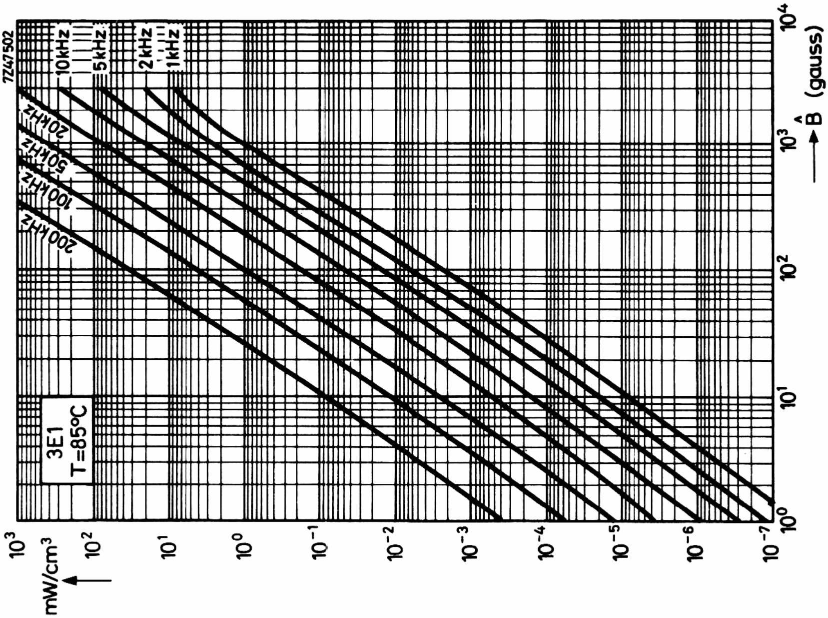

7Z99228
20000
μ_i
10000
0
-50
0
50
T (°C)
100
3E3
3E2
3E1

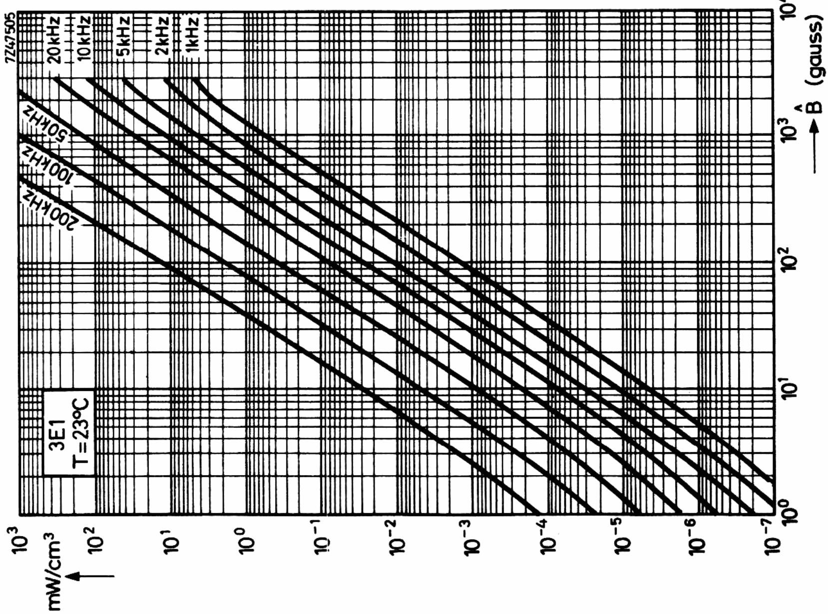

7Z99229
1000
μ_i
500
0
-50
0
50
T (°C)
100
4A4
4B1

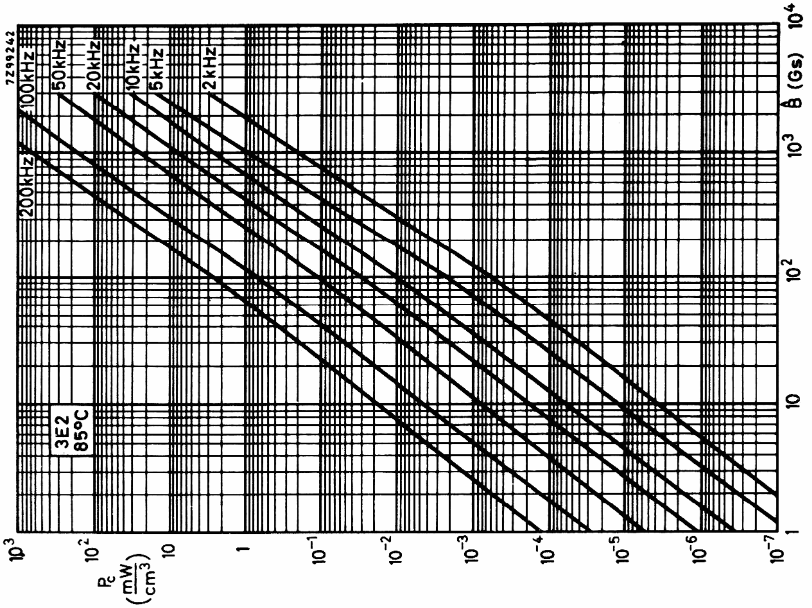


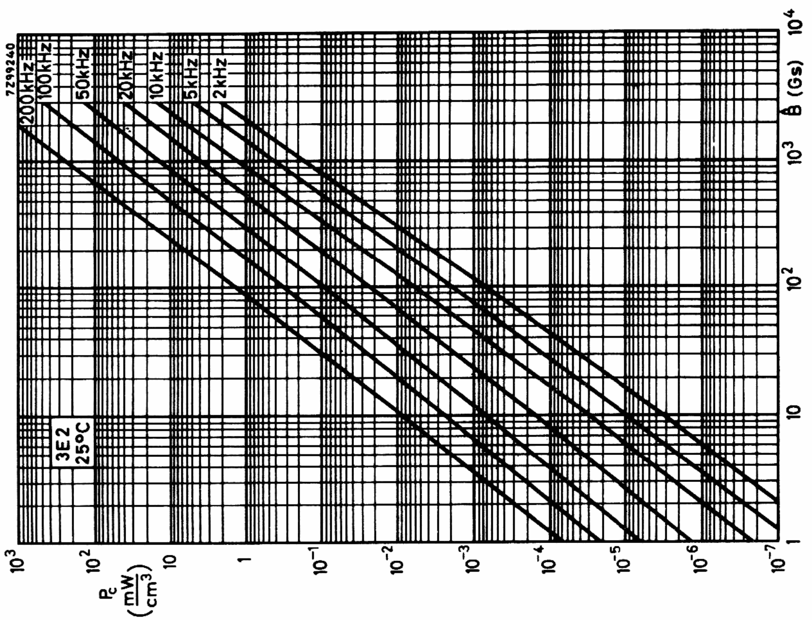
CORE LOSSES AS A FUNCTION OF THE INDUCTION

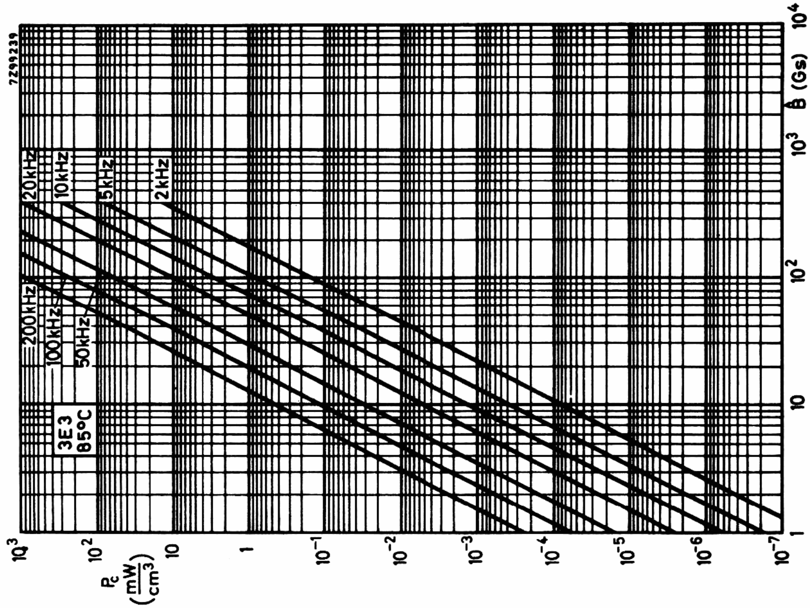


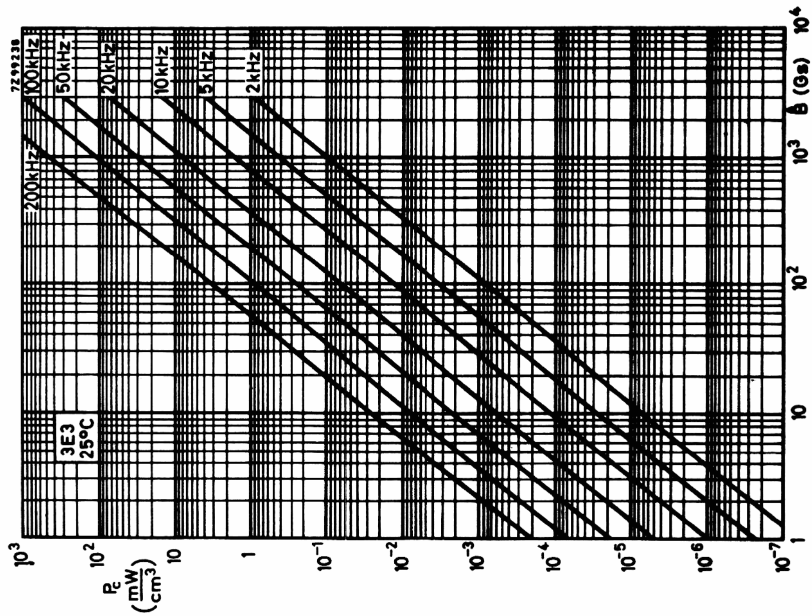

7Z47502
3E1
T=85°C
10kHz
5kHz
2kHz
1kHz
20kHz
50kHz
100kHz
200kHz
mW/cm³
B̂ (gauss)

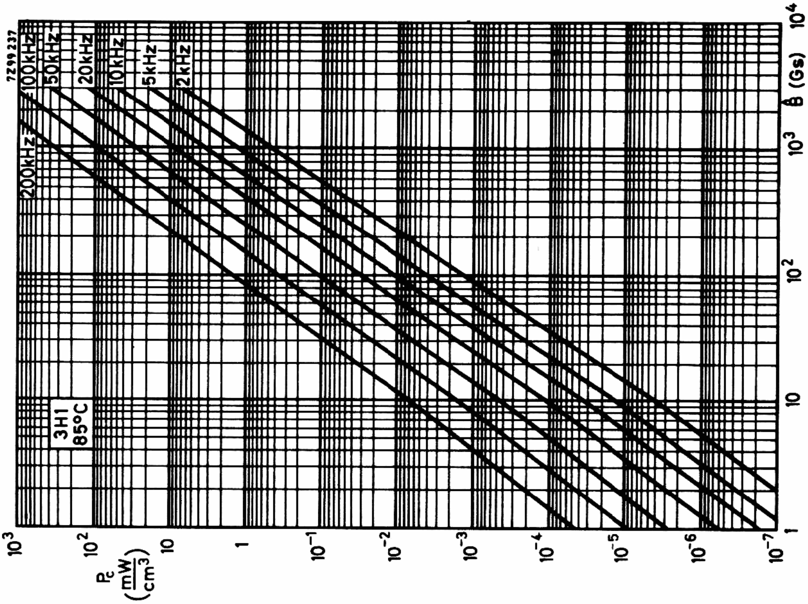

7Z47505
3E1
T=23°C
20kHz
10kHz
5kHz
2kHz
1kHz
50kHz
100kHz
200kHz
mW/cm³
B̂ (gauss)

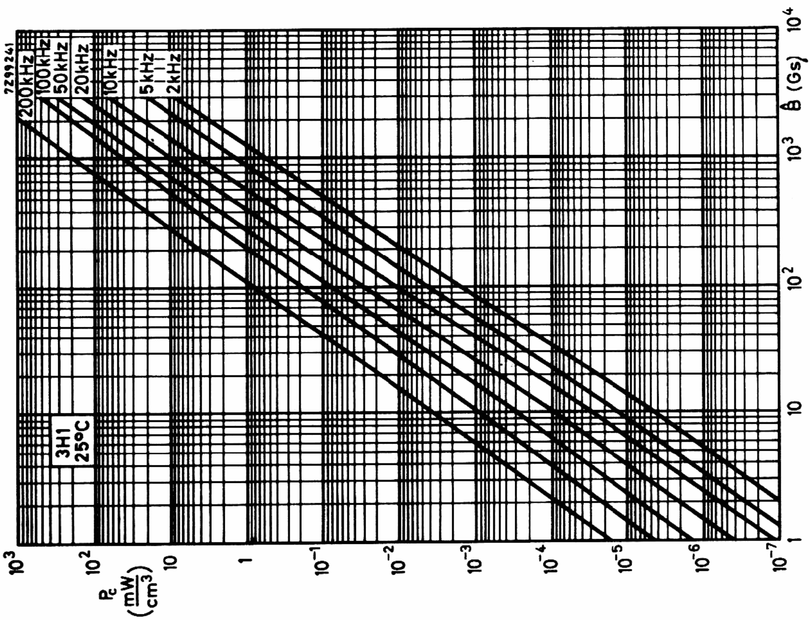

7Z99242
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3E2
85°C
B̂ (Gs)
Pc (mW/cm3)
1
10
10^2
10^3
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7


7Z99240
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3E2
25°C
B̂ (Gs)
Pc (mW/cm3)
1
10
10^2
10^3
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7

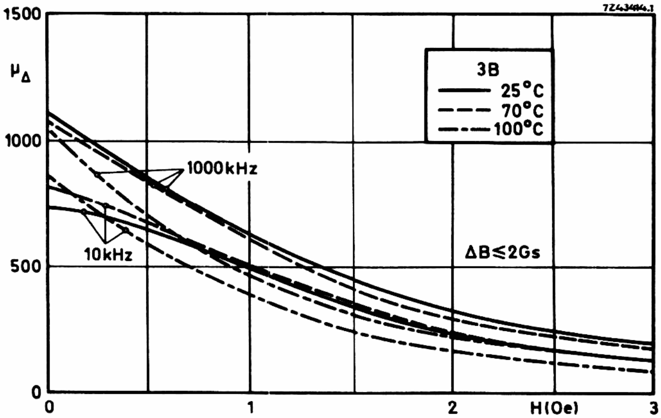

7Z99239
3E3
85°C
20kHz
10kHz
5kHz
2kHz
200kHz
100kHz
50kHz
P_c $\left(\frac{mW}{cm^3}\right)$
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
10
10^2
10^3
$\hat{B}$ (Gs)
10^4

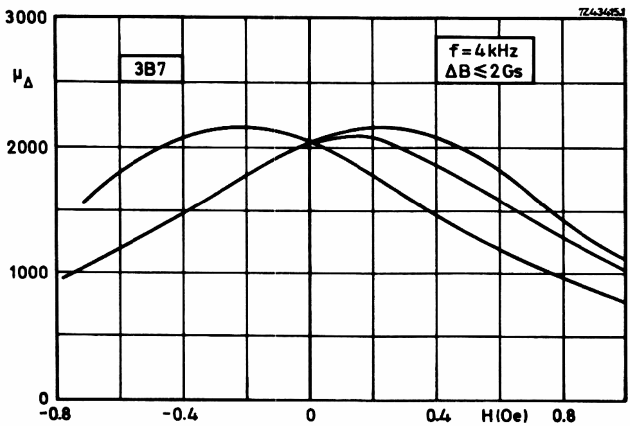

7Z99238
3E3
25°C
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
200kHz
P_c $\left(\frac{mW}{cm^3}\right)$
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
10
10^2
10^3
$\hat{B}$ (Gs)
10^4

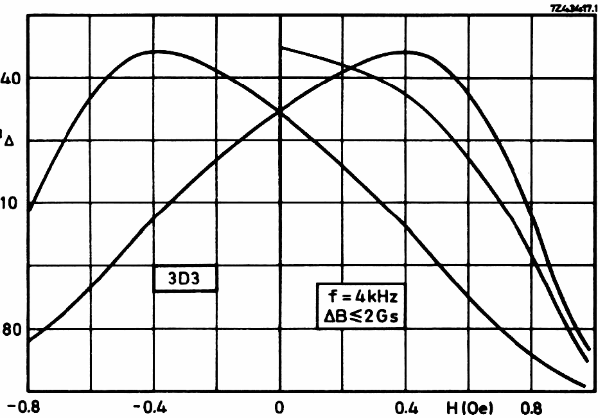

7299237
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3H1
85°C
P_c $\left(\frac{mW}{cm^3}\right)$
$\hat{B}$ (Gs)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^4

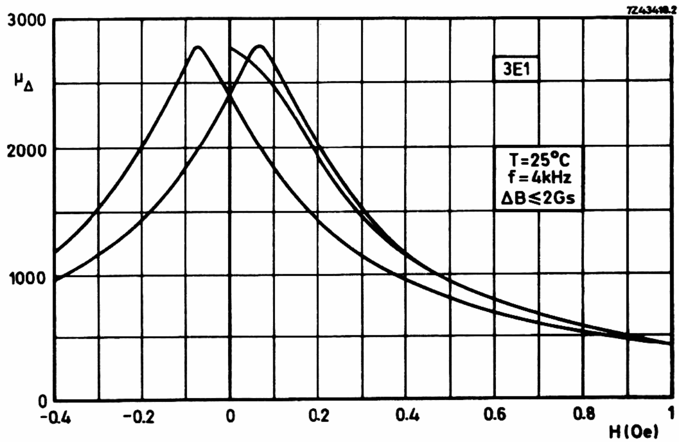

7299241
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3H1
25°C
P_c $\left(\frac{mW}{cm^3}\right)$
$\hat{B}$ (Gs)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^4

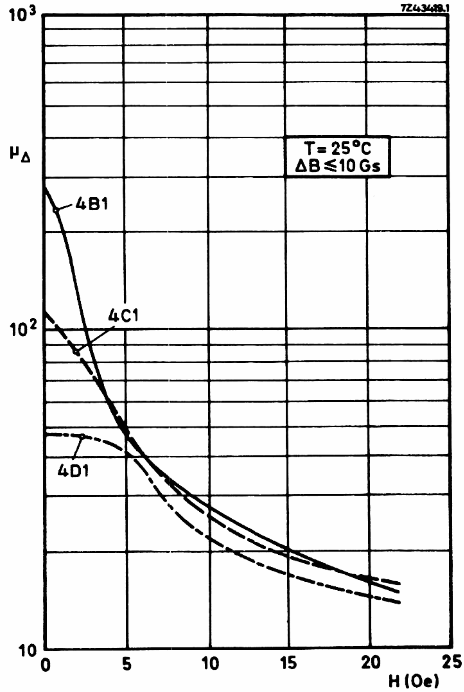
INCREMENTAL PERMEABILITY AS A FUNCTION OF THE FIELD STRENGTH






7Z43417.1
740
μΔ
710
680
3D3
f = 4kHz
ΔB≤2Gs
-0.8
-0.4
0
0.4
H (Oe)
0.8


7Z43418.2
3000
μΔ
2000
1000
0
3E1
T=25°C
f=4kHz
ΔB≤2Gs
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
H (Oe)


7Z43419.1
10^3
μ_Δ
T = 25°C
ΔB ≤ 10 Gs
4B1
4C1
10^2
4D1
10
0
5
10
15
20
25
H (Oe)

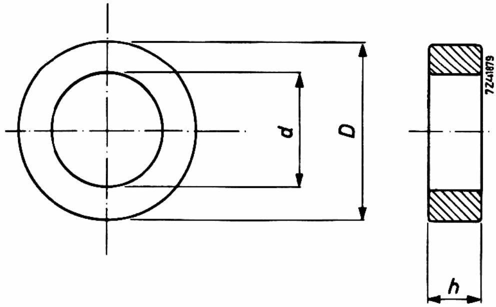
TOROIDS

INTRODUCTION

Toroids, having no air gap, posses a small magnetic stray field and a high permeability.
In spite of the closed magnetic circuit the losses are low due to the favourable properties of ferroxcube.

Toroids are mainly used in small broadband transformers, pulse transformers and chokes. If, however, the direct current through the transformer is relatively large, transformer cores with an air gap are to be preferred.
Toroids are not recommended for tuned circuits.

TOROIDS



Ferroxcube toroids are used in small broadband transformers, pulse transformers, etc.
Toroids are available in various sizes and ferroxcube grades. They are barrel-finished and coated with an insulating lacquer.

DIMENSIONAL QUANTITIES, TOLERANCES AND WEIGHTS (Table I)

D (mm)	d (mm)	h (mm)	l_e (cm)	$\Sigma \frac{l_e}{A_e}$ (cm^{-1})	V_e (cm^3)	weight (g)
2 ±0.1	1.3 ±0.1	0.7 ±0.1	0.511	208	0.00125	0.006
3.93 ±0.13	2.23 ±0.09	1.27 ±0.09	-	87.4	-	-
4 ±0.1	2.2 ±0.1	1.1 ±0.1	0.946	95.6	0.00937	0.045
4.83 ±0.25	2.28 ±0.25	1.27 ±0.25	-	66.3	-	-
5.84 ±0.13	3.05 ±0.2	1.52 ±0.13	-	63.4	-	-
6 ±0.15	4 ±0.15	2 ±0.1	1.55	77.5	0.0310	0.15
9 ±0.2	6 ±0.2	3 ±0.1	2.33	51.7	0.105	0.50
9.53 ±0.25	4.75 ±0.25	3.18 ±0.25	-	28.4	-	-
14 ±0.3	9 ±0.25	5 ±0.15	3.55	28.5	0.445	2.14
23 ±0.5	14 ±0.35	7 ±0.2	5.70	18.1	1.79	8.6
29 ±0.5	19 ±0.4	7.5 ±0.2	7.50	20.1	2.58	13
36 ±0.7	23 ±0.5	10 ±0.2	9.20	14.2	5.60	29
36 ±0.7	23 ±0.5	15 ±0.2	9.20	9.42	8.50	44

Notes

1. All dimensions apply to non-lacquered toroids.
2. All μ-values in the following are determined with the $\Sigma \frac{l_e}{A_e}$ values of Table I at 25 °C.
   The relevant A_L values can be calculated with the formula $A_L = \frac{4\pi\mu}{\Sigma \frac{l_e}{A_e}}$
3. The smaller a toroid, the more its properties deviate from the material properties. Therefore a straight-forward translation of the material figures is not always possible.

GRADES AND SIZES

Toroids of ferroxcube 3E1

→ μ_{tor} = 2700 ±20% at 23 ± 1 °C
Lacquered green

dimensions (mm)	catalog number
29 x 19 x 7.5	4322 020 36550
36 x 23 x 10	4322 020 36560
36 x 23 x 15	4322 020 36570

Toroids of ferroxcube 3E2

μ_{tor} > 5000 at +23 to +70 °C
Lacquered blue

dimensions (mm)	catalog number
4 x 2.2 x 1.1	4322 020 36650
6 x 4 x 2	4322 020 36660
9 x 6 x 3	4322 020 36670
14 x 9 x 5	4322 020 36680
23 x 14 x 7	4322 020 36690

Toroids of ferroxcube 3E3

μ_{tor} > 10 000 at +10 to +70 °C
Lacquered brown
* Not lacquered

dimensions (mm)	catalog number
*2 x 1.3 x 0.7	8222 293 03230
4 x 2.2 x 1.1	4322 020 36700
6 x 4 x 2	4322 020 36710
9 x 6 x 3	4322 020 36720

Toroids of ferroxcube 3E3

μ_{tor} is between 10 000 and 15 000
at +10 to +60 °C
Not lacquered

dimensions (mm)	catalog number
3.93 x 2.23 x 1.27	4322 020 90780
4.83 x 2.28 x 1.27	4322 020 90790
5.84 x 3.05 x 1.52	4322 020 90800
9.53 x 4.75 x 3.18	4322 020 90810

Toroids of ferroxcube 3H1

Sorted into μ groups.
Lacquered orange
D.F. $\leq 4.3 \times 10^{-6}$ at 23 ± 1 °C

dimensions (mm)	catalog number
4 x 2.2 x 1.1	4322 020 36590
6 x 4 x 2	4322 020 36600
9 x 6 x 3	4322 020 36610
14 x 9 x 5	4322 020 36620
23 x 14 x 7	4322 020 36630

For the convenience of the user the toroids of ferroxcube 3H1 are delivered sorted into groups of approximately equal μ-value. The μ-value is indicated by the colour of the circumference of the toroids, see Table II. Groups are not separately available.

Table II (for toroids of the 3H1 series)

group	colour of circum-ference	μ_{tor} at 23 ± 1 °C	4322 020 36590	36600	36610	36620	36630
			α-factor				
1	brown	2000-2200	60.2	54.1	44.3	32.9	26.2
2	red	2140-2360	58.3	52.3	42.8	31.8	25.3
3	orange	2300-2540	56.0	50.3	41.2	30.6	24.4
4	yellow	2480-2740	54.0	48.6	39.8	29.5	23.5
5	green	2680-2960	51.8	46.6	38.2	28.3	22.6
6	blue	2900-3210	49.9	44.8	36.7	27.3	21.7
7	violet	3150-3480	48.0	43.2	35.4	26.2	20.9
8	grey	3420-3780	46.2	41.4	34.0	25.2	20.1
9	white	3720-4110	44.2	39.7	32.5	24.1	19.2
10	black	> 4050	< 43.3	< 38.9	< 31.8	< 23.7	< 18.8

Number of turns for L mH : $N = \alpha\sqrt{L}$

The α factors are mean values, except those of the last group.

Between +23 and +70 °C the min μ_{tor} of the product is higher than the min μ_{tor} of the group.

Toroids of ferroxcube 4C6

μ_{tor} > 100 at +5 to +55 °C
Lacquered violet

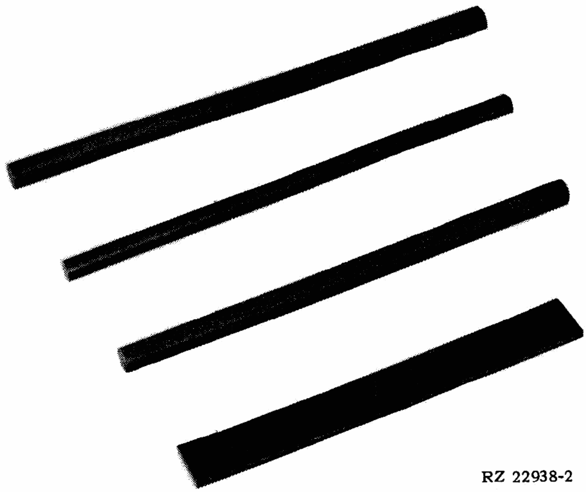
dimensions (mm)	catalog number
6 x 4 x 2	4322 020 91000
9 x 6 x 3	4322 020 91010
14 x 9 x 5	4322 020 91020
23 x 14 x 7	4322 020 91070
36 x 23 x 15	4322 020 91090

Toroids of ferroxcube 3B7

Between 0 and +60 °C the deviation in A_L is max. +10/−6% with regard to A_L at the reference temperature +23 °C.
Not lacquered.

dimensions (mm)	A_L ± 20% at 23 ± 1 °C	catalog number
3.93 x 2.23 x 1.27	360	4322 020 90820
4.83 x 2.28 x 1.27	475	4322 020 90830
5.84 x 3.05 x 1.52	495	4322 020 90840
9.53 x 4.75 x 3.18	1100	4322 020 90850

ANTENNA RODS AND PLATES



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RODS (standard types)

Grade 4A3 (for long wave and medium wave reception)

dimensions (mm)		catal. No.
(ϕ 10 - 0.5)	x (240 - 7)	3122 104 93440
	(230 - 7)	4311 020 53120
	(220 - 6)	4311 020 52740
	(210 - 6)	3122 104 93700
	(200 - 6)	3122 104 93420
	(190 - 6)	4311 020 53230
	(180 - 6)	3122 104 93450
	(170 - 6)	4311 020 52760
	(160 - 5)	4311 020 52610
	(150 - 5)	4311 020 52770
	(140 - 5)	3122 104 93460
	(130 - 5)	4311 020 52780
	(120 - 4)	4311 020 53300
	(100 - 4)	4311 020 52590

Grade 4A3 (continued)

dimensions (mm)	catal. No.
(ϕ 7.8 ± 0.2) x (190 $^{+1}_{-6}$)	4311 020 52700
(140 $^{+1}_{-5}$)	4311 020 52690
(130 $^{+1}_{-3}$)	4311 020 52680
(100 $^{+1}_{-3}$)	4311 020 52790
(ϕ 6.35 ± 0.2) x (130 $^{+1}_{-3}$)	4311 020 52800
(100 $^{+1}_{-3}$)	4311 020 52810

Grade 4B1 (for long wave and medium wave reception)

(dimensions (mm)	catal. No.
→ (ϕ 10 - 0.5) x (207 -8)	3122 104 91250
(180 -10)	4311 020 52240
(143 -6)	3122 104 91240
(132 -4)	4311 020 52230
(ϕ 9.8 - 0.6) x (207 -8)	4311 020 52220
(164 -8)	4311 020 52210
→ (103 -6)	4311 020 52200
(ϕ8 - 0.4) x (207 -8)	4311 020 52190
(204 -8)	4311 020 50040
(143 -6)	4311 020 50250
(102 -4)	4311 020 52170
ϕ (6.55 - 0.4) x (168.5 -7)	4311 020 52160

Grade 4C7 (for short wave and medium wave reception)

dimensions (mm)	catal. No.
ϕ(10 - 0.5) x (240 -8)	4311 020 53510
(220 -6)	4311 020 53560
(210 -6)	4311 020 53550
(200 -6)	4311 020 53540
(180 -6)	4311 020 53450
(160 -5)	4311 020 53490
(140 -5)	4311 020 53530

Measurements on typical antenna rods of 10 mm ϕ x 200 mm

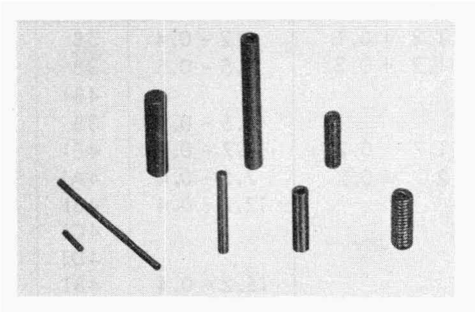
Material grade	4A3	4B1	4C7	
Frequency	1	1	10	MHz
Inductance	200	200	2.5	μH
Number of turns	40	44	5	
Rod quality Q_o'	135	128	120	
Effective height h	7.6×10^{-3}	6.6×10^{-3}	6.7×10^{-3}	m
h^2	58×10^{-6}	44×10^{-6}	45×10^{-3}	m^2
Sensitivity hQ_o	1.02	0.86	0.8	m
Signal output h^2Q_o	7.8×10^{-3}	5.63×10^{-3}	5.4×10^{-3}	m^2

PLATES (standard types)

Grade 4B1 (for long wave and medium wave reception)

dimensions (mm)	catal. No.
(19 - 1) x (3.8 - 0.3) x (150 - 6)	4311 020 52410
x (125 - 5)	4311 020 52400
x (100 - 4)	4311 020 52390
x (75 - 3)	4311 020 52380
(13.4 - 0.8) x (4.15 - 0.3) x (120 - 2)	3122 104 92140
x (94 - 1)	3122 104 92120
x (62 - 1)	3122 104 92150

CORES FOR SMALL COILS



A 52810-1

Ferroxcube rods, tubes and screws to be used as cores in r.f. and h.f. coils with an open magnetic circuit such as in i.f. transformers. Only preferred types are listed.

RODS

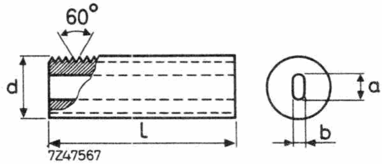
dia. (mm)	length (mm)	grade	catal. No.
0.95 - 0.15	10 - 2.5	3 B	3522 200 03750
1.25 - 0.04	6.2 - 0.4	3 B	4322 020 32080
1.65 - 0.05	9.2 - 0.4	3 B	3122 104 91070
	9.2 - 0.4	4 B1	3122 104 91060
	11.5 - 0.4	3 B	4322 020 32100
	11.5 - 0.4	4 E1	4322 020 32110
	12.2 - 0.4	3 B	3122 104 91100
	12.2 - 0.4	4 B1	3122 104 91110
	19.2 - 0.4	3 B	3122 104 91230
	25.2 - 0.4	3 B	3122 104 91170
	25.2 - 0.4	4 B	3122 104 91180
	28.2 - 0.4	3 B	3122 104 91090
	28.2 - 0.4	4 B1	4322 020 32090
1.7 - 0.15	15.2 - 0.4	4 D1	4322 020 32170
1.7 - 0.1	28.2 - 0.4	4 C1	4322 020 32120
	28.2 - 0.4	4 D1	4322 020 32130
	28.2 - 0.4	4 E1	4322 020 32140
1.7 - 0.15	30.5 - 1	3 B	3122 104 91200
1.75 - 0.2	10.2 - 0.4	3 B	3122 104 91130
	18.5 - 1	3 B	3122 104 91140
	18.5 - 1	4 B1	3122 104 91150
6 - 0.075	46.2 - 0.4	3 C1	3122 104 91310
6.65 - 0.3	40.4 - 0.8	3 B	4322 020 32160

TUBES

outside dia. (mm)	inside dia. (mm)	length (mm)	grade	catal. No.
2.8 - 0.03	1.2 + 0.1	8.2 - 0.4	3B	4322 020 34340
3.7 - 0.4	1.2 + 0.2	3.5 - 0.5	3B	4322 020 34400
			4B1	4322 020 34420
		6.5 - 0.5	3B	4022 101 80010
3.7 - 0.3	1.7 + 0.2	13.7 - 0.4	4E1	4322 020 34330
4.15 - 0.05	2 + 0.2	7.2 - 0.4	4A1	4322 020 34440
		12.2 - 0.4	4B1	4322 020 34450
			4C1	4322 020 34460
			4D1	4322 020 34470
		15.2 - 0.4	4B1	4322 020 34380
			4C1	4322 020 34370
		21.2 - 0.4	4A1	4322 020 34390
			4B1	4322 020 34480
4.3 - 0.2	2 + 0.2	7.2 - 0.4	3B	3122 104 92900
		12.5 - 1	3B	4322 020 34490
		15.2 - 0.4	4D1	4322 020 36760
		15.4 - 0.8	3B	4322 020 36750
		18.5 - 1	3B	4322 020 36770
		25.5 - 1	3B	4322 020 36780
			4B1	3122 104 90810
			4C1	3522 200 10950
			4D1	3522 200 10960
		30.2 - 0.4	3B	4322 020 36790
		40.5 - 1	3B	3122 104 90800
		55.5 - 1	3B	4322 020 36800
4.95 - 0.1	1.3 + 0.2	40.5 - 1	3C3	3122 104 93110
5.3 - 0.2	3 + 0.2	22.4 - 0.8	3B	4322 020 36810
6.2 - 0.4	2.85 + 0.3	30.2 - 0.4	4C1	4322 020 36820
8 - 0.4	4.2 + 0.6	51.4 - 2.8	3B	4322 020 34310
			4B1	4322 020 34320

SCREW CORES

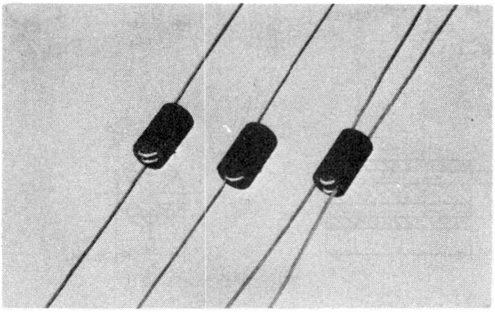
The standard cores are available in grade 3D3 with an initial permeability of 750 ± 20%.



screw thread	l (mm)	d (mm)	a (mm)	b (mm)	catalog number
M4 x 0.50	12 ± 0.3	3.65 + 0.05	1.6 ± 0.1	0.7 ± 0.1	4312 020 32040
M5 x 0.75	12 ± 0.3	4.55 + 0.05	2.15 ± 0.15	0.8 ± 0.1	4312 020 32050
M5 x 1	20 ± 0.3	5.0 - 0.1	2.35 ± 0.15	1.1 ± 0.1	4312 020 32130
M6 x 0.5 [1)]	12 ± 0.2	5.9 - 0.04	2.45 + 0.3	1.2 + 0.2	4312 020 32010
M6 x 0.75	25 ± 0.5	5.55 + 0.05	2.65 ± 0.15	1.1 ± 0.1	4312 020 32070
M6 x 0.75	13 ± 0.3	5.55 + 0.05	2.65 ± 0.5	1.1 ± 0.1	4312 020 32060
M6 x 1	25 ± 0.5	5.5 ± 0.02	2.75 ± 0.25	1.3 ± 0.1	4312 020 32030
M8 x 1.25	25 + 0.5	7.35 + 0.05	3.65 ± 0.15	1.3 ± 0.1	4312 020 32120
M8 x 1.25	16 ± 0.5	7.35 + 0.05	3.65 ± 0.15	1.3 ± 0.1	4312 020 32110

1) Grade 3B

BEADS FOR SCREENING AND DAMPING, AND WIDE-BAND H.F. CHOKES



RZ 22959-1

APPLICATION

Beads and chokes are available in ferroxcube grades 3B and 4B. They are used in v.h.f. radio and TV receivers and in electric motors, ignition systems etc. to reduce in- or outgoing interference, and also in v.h.f. circuits to avoid troublesome coupling. The supply leads in radio, TV and other electronic equipment often transfer unwanted r.f. and v.h.f. energy from one circuit or stage to another. Capacitive decoupling of the leads will not always be effective by reason of possible resonances. On the same grounds the addition of a series inductance will not always have the required results. In these cases a number of beads (the total length of which is small compared with the wavelength) simply threaded on the supply leads, or a single wideband choke may be used successfully. For the same volume chokes are more effective than beads.

In "damping circuits" either beads or chokes may be used in conjunction with small capacitors, to provide additional filtering of the self-resonant frequency of that capacitor and its leads.

Ferroxcube beads and ferroxcube-cored chokes have the following advantages over air-cored chokes:

- small volume;
- wide band;
- no sharp fall-off;
- insensitive to stray circuit capacitance;
- no parasitic resonances;
- no additional resistor required for damping;
- low price.

BEADS (without wire)

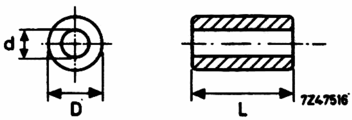


Fig.1

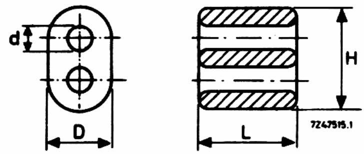


Fig.2

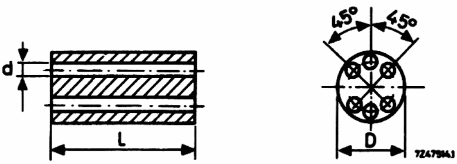


Fig.3

Fig.	grade	L (mm)	D (mm)	H (mm)	d (mm)	catalog number
1	3B	3	3.5 ± 0.2	-	1.3 ± 0.2	4322 020 34400
1	4B	3	3.5 ± 0.2	-	1.3 ± 0.2	4322 020 34420
1	3B	5	3.5 ± 0.2	-	1.3 ± 0.2	4312 020 31060
2	4B1	8 ± 0.3	8.5 - 0.5	14 ± 0.5	3.5 + 0.5	4312 020 31570
2	4B1	14 ± 0.4	8.5 - 0.5	14 ± 0.5	3.5 + 0.5	4312 020 31520
3	3B	10 ± 0.5	6 ± 0.3	-	0.7 + 0.2	4312 020 31500
3	4B1	10 ± 0.5	6 ± 0.3	-	0.7 + 0.2	4312 020 31550

The beads may be threaded with insulated or bare wire, but if grade 3B is used on bare wire a maximum fall-off in resistance of 8 % can be expected, as a result of its lower resistivity.

Fig.4 shows some performance details of the 3 mm long tube beads in the two material grades. It will be noted that above about 60 MHz the impedance of the 3B type is substantially resistive.

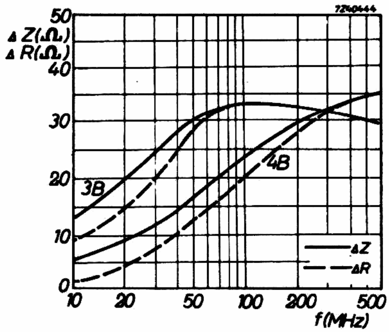


Fig.4

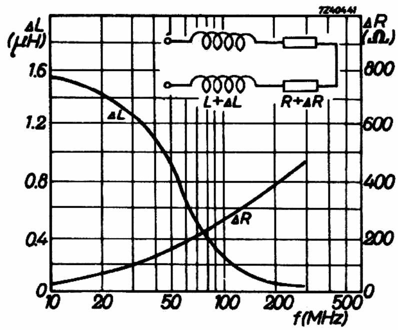


Fig.5

With twin beads the advantages of mutual inductance can be utilized. Fig.5 gives the increase of the inductance L and loss resistance R caused by a twin bead 4312 020 31520 on two straight wires.
Grade 4B provides ample insulation between the two wires even if bare.

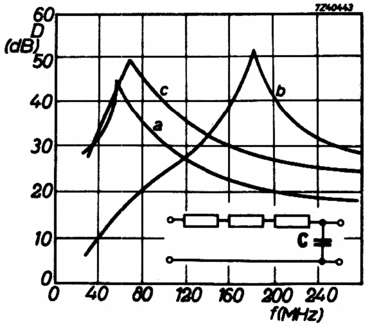


Fig.6. Damping in an LC circuit consisting of a string of three beads 4322 020 34400 and a ceramic capacitor.

a. C = 1500 pF tubular
b. C = 190 pF tubular
c. C = 1500 pF disc.

H.F. CHOKES

The chokes are supplied with six axial holes through which 1.5, 2.5 or 2 x 1.5 turns of tinned copper wire are threaded.
The table gives the types of choke that are currently available.

Dimensions in mm

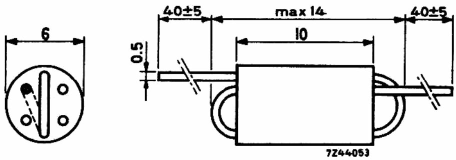


Fig.7

number of turns	Z_{max} (kΩ)	f at Z_{max} (MHz)	decrease of impedance in the freq. range (MHz)	dB	grade	catalog number
1.5	0.35 ± 20%	120	10-300	≤7	3B	4312 020 36630
1.5	0.45 ± 20%	250	80-300	≤3	4B1	4312 020 36690
2.5	0.75 ± 20%	50	10-220, 30-100	≤7, ≤3	3B	4312 020 36640
2.5	0.85 ± 20%	180	50-300, 80-220	≤6, ≤3	4B1	4312 020 36700
2 x 1.5	0.90 ± 20%	50	10-220, 30-100	≤7, ≤3	3B	4312 020 36650
2 x 1.5	1.00 ± 20%	110	50-300, 80-220	≤7, ≤3	4B1	4312 020 36710

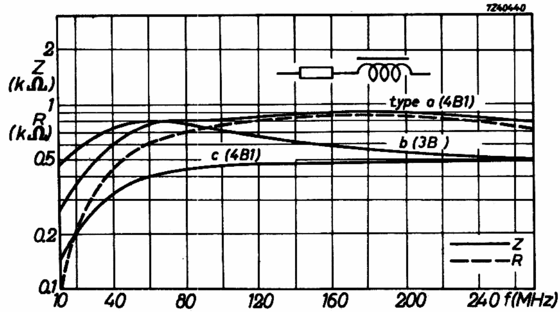


Fig.8. Performance of three single chokes

Type a = 4312 020 36700
b = 4312 020 36640
c = 4312 020 36690

Fig.8 shows some performance details of three single chokes. It will be noted that above approx. 80 MHz the impedance is substantially resistive and tends to be constant. Double chokes are used for twin leads, in which case the advantages of mutual inductance can be utilized.
Fig.9 compares the typical obtainable performance.

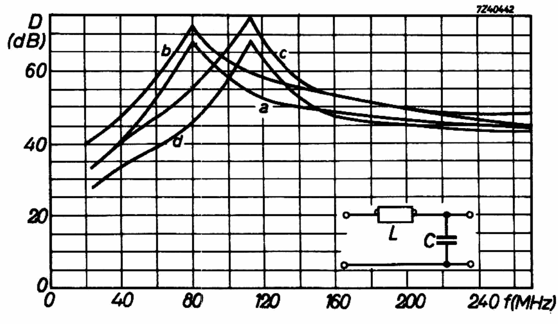


Fig.9. Damping in an LC circuit consisting of a ferroxcube choke and a ceramic disc capacitor.

a. L = 4312 020 36690, C = 1500 pF
b. L = 4312 020 36700, C = 1500 pF
c. L = 4312 020 36700, C = 550 pF
d. L = 4312 020 36690, C = 550 pF

For complete information reference is made to data handbook series "Components and Materials" Part 5.

STANDARD TYPES

minimum cycle times	core size	core type	nominal operating conditions					relevant typical output characteristics				
			T °C	I mA	DR	t_r μs	t_d μs	uV_1 mV	rV_1 mV	wV_z mV	t_p μs	t_s μs
40 μs	150 mil	6E1 1)	40	346	0.50	0.8	12	120	115	30	3.5	8
6 μs	50 mil	6D5 1)	40	365	0.50	0.2	1.5	64	60	7	0.54	1.15
5 μs	50 mil	6D9 1)	40	450	0.50	0.2	1.5	60	58	8	0.55	1.20
5 μs	50 mil	6C1 1)	40	500	0.50	0.2	1.1	63	60	8	0.48	0.93
5 μs	50 mil	6C2 2)	70	755	0.50	0.25	1.2	105	103	7	0.45	0.88
1.5 μs	30 mil	6F8	40	655	0.50	0.1	0.5	55	53	6	0.20	0.39
1.5 μs	30 mil	6F3 2)	70	740	0.50	0.15	0.6	60	58	5	0.25	0.50
1.0 μs	20 mil	6H3	40	835	0.50	0.05	0.45	55	53	5	0.095	0.19
1.0 μs	20 mil	6H2 2)	70	900	0.50	0.05	0.28	48	45	4	0.110	0.22
0.65 μs	20 mil	6H5	60	800	0.50	0.05	0.25	72	69	7.5	0.105	0.195
0.5 μs	20 mil	6H4	45	665	0.50	0.05	0.30	54	52	5	0.108	0.220
0.5 μs	18 mil	6H6	60	770	0.50	0.05	0.20	59	57	5	0.095	0.175
0.3 μs	14 mil	6V1	40	1100	0.50	0.025	0.15	34	33	5	0.06	0.11

1) Maintenance type.

2) With this core a memory system can be operated over a wide temperature range without temperature compensation, air conditioning, or other alternatives.

Note: Offers for cores differing from those of our range may be made on request.