COMPONENTS AND MATERIALS

PART 4

Magnetic materials and white ceramics

PHILIPS

ELECTRONIC COMPONENTS AND MATERIALS DIVISION

March, 1967

Information and data on other Components, Subassemblies and on Materials will be subsequently issued in the following parts. The parts, which will issued periodically, are listed in the order in which they will become available.

COMPONENTS AND SUBASSEMBLIES FOR DATA PROCESSING AND CONTROL

(last issue March, 1966)

Digital circuit blocks
- 100 kHz-Series
- 1-Series
- 10-Series
- 20-Series
- Norbits

Circuit blocks for ferrite core memory drive

Accessories for digital circuit blocks
- Power supplies
- Mounting chassis
- Printed-wiring boards

Ferrite memory cores

Matrix planes, matrix stacks

Complete memories

Quartz crystals

ELECTRICAL COMPONENTS AND ASSEMBLIES

(last issue October, 1966)

Ceramic capacitors, RC combinations

Polyester, paper, mica, polystyrene capacitors

Electrolytic capacitors

Variable capacitors

Fixed resistors

Variable resistors

Non-linear resistors

Fixed and variable mains transformers

Electro-mechanical components

RADIO, AUDIO AND TELEVISION

(last issue November, 1966)

F.M. tuners

Intermediate frequency coils

Audio transformers

Loudspeakers

Television tuners

Deflection components for black and white television

Components for colour television

Deflection assemblies for camera tubes

Contents

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COMPONENTS AND MATERIALS

PART 4

MAGNETIC MATERIALS
AND
WHITE CERAMICS

March, 1967

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 (e.g. potcores, E- and I-cores, X-cores, toroids, U-cores, aerial rods, yoke rings, screw cores, rods and tubes), which 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 in the course of time.

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

APPLICATION

grade	application
3B	potcores
3B2, 3B3	frames for i.f. transformers, potcores, rods, screw cores
3B5, 3B7	potcores
3C1	erasing heads
3C2	yoke rings
3C4	U-cores
3C6	E- and U-cores
3D3	aerial rods, potcores, screw cores
3E1	E- and I-cores, toroids, potcores
3E2	H-cores and toroids
3H1	potcores, small toroids, cross cores
4A1	potcores, E-cores
4A3	aerial rods
4A4	frames for i.f. transformers
4B1	aerial rods, frames for i.f. transformers
4C1	rods and tubes
4C3	aerial rods
4C4	small potcores and small toroids
4C5	frames for i.f. transformers
4C6	potcores and small toroids
4D1, 4D2, 4E1	frames for i.f. transformers, screw cores

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:

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

μ_Δ — relative incremental permeability, defined by:

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

μ_a — relative amplitude permeability, defined by:

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

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 by:

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

$T.F. = \frac{1}{\mu^2} \cdot \frac{du}{dT}$ — 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 $\quad t.c. = \frac{\Delta\mu}{\mu_i} \times \frac{\mu_e}{\mu_i} = \frac{\Delta\mu}{\mu_i^2} \times \mu_e$ 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 ^{o}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:

$$\frac{R}{L} = \frac{\tan\delta}{\mu_i} \times \mu_e \times 2\pi f \ \Omega/H \ \text{(f in Hz)}$$

$q_{2\text{-}24\text{-}100}$ — 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 equivalent 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)

specific resistance in Ω cm measured with d.c. current

dielectric constant

TECHNICAL DATA

Specific heat	approx. 0.17 (cal/g)/deg C
Thermal conductivity	approx. 8.10^{-3} (cal/cm.sec)/deg C
Coefficient of linear expansion	approx. 10^{-5}/deg C
Modulus of elasticity	approx. 15 000 kg/mm^2
Tensile strength	approx. 1.8 kg/mm^2
Crushing strength	approx. 7.3 kg/mm^2

	3B	3B2	3B3	3B5	3B7	3C1
μ_i	900 ± 20%	900 ± 20%	900 ± 20%	1400 ± 25%	2300 ± 20%	approx. 900
μ_a at B = 1000 Gs, T = 25 ± 5 °C						
T = 85 °C						
at B = 2000 Gs, T = 85 °C						
B (in Gs), ballistically measured, at H = 10 Oe, T = 20 °C	approx. 3450	approx. 4500			approx. 3400	
T = 100 °C	approx. 2300					
at H = 2.5 A/cm, T = 100 °C						
$\frac{\tan \delta}{\mu_i}$ at 4 kHz		≤ 7×10^{-6}		≤ 2.5×10^{-6}	≤ 1×10^{-6}	
at 100 kHz		≤ 18×10^{-6}	≤ 15×10^{-6}	≤ 10×10^{-6}	≤ 5×10^{-6}	
at 250 kHz			≤ 27×10^{-6}			
at 450 kHz	≤ 50×10^{-6}		≤ 50×10^{-6}			
at 500 kHz						
at 1000 kHz						
Core losses (in mW/cm^3), measured with a.c. current of 16 kHz, at B = 1000 Gs, T = 25 ± 5 °C						
T = 85 °C						
at B = 2000 Gs, T = 85 °C						
at B = 4000 Gs, T = 25 °C						
T = 50 °C						
T = 100 °C						

Continued

	3B	3B2	3B3	3B5	3B7	3C1
$q_{2\text{-}24\text{-}100}$ (in $\Omega/H^{3/2}mA$) at 4 kHz at 100 kHz		≤ 12	≤ 12	≤ 2.5	≤ 1.8	
ϱ (in Ω.cm), measured with d.c. current	≥ 20	≥ 80	≥ 120	≥ 20	≥ 100	
D.F. between 10 and 100 min after demagnetisation at 23 ± 1 °C	≤ 11×10^{-6}	≤ 11×10^{-6}	≤ 11×10^{-6}	≤ 7.5×10^{-6}	≤ 4.3×10^{-6}	
T.F. between +23 and +55 °C +23 and +70 °C	between 0 and $+3 \times 10^{-6}/°C$	between 0 and $+2 \times 10^{-6}/°C$	between 0 and $+2 \times 10^{-6}/°C$	between +0.5 and $+2.3 \times 10^{-6}/°C$	between −0.6 and $+0.6 \times 10^{-6}/°C$ **	
Curie point in °C	≥ 150	≥ 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	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.

** Measured 10 min after demagnetisation.

	3C2	3C4	3C6	3D3	3E1	3E2	3H1
μ_i	900 ± 25%			750 ± 20%	2700 ± 20% *	≥ 5000	2300 ± 20%
μ_a at B = 1000 Gs,							
T = 25 ± 5 °C		≥ 3000					
T = 85 °C		≥ 3000					
at B = 2000 Gs,							
T = 85 °C		≥ 2000					
B (in Gs), ballistically measured,							
at H = 10 Oe, T = 20 °C	approx. 3500			approx. 3500	approx. 3500	approx. 4200	approx. 3400
T = 100 °C	approx. 2450						
at H = 2.5 A/cm, T = 100 °C			≥ 2900				
$\frac{\tan \delta}{\mu_i}$ at 4 kHz					≤ 2.5×10^{-6}	≤ 2.5×10^{-6}	≤ 1×10^{-6}
at 100 kHz				≤ 8×10^{-6}	≤ 15×10^{-6}	≤ 15×10^{-6}	≤ 5×10^{-6}
at 250 kHz							
at 450 kHz							
at 500 kHz				≤ 14×10^{-6}	≤ 90×10^{-6}	≤ 90×10^{-6}	
at 1000 kHz				≤ 30×10^{-6}			
Core losses (in mW/cm^3), measured with a.c. current of 16 kHz, at B = 1000 Gs,							
T = 25 ± 5 °C		≤ 65					
T = 85 °C		≤ 65					
at B = 2000 Gs,							
T = 85 °C		≤ 230					
at B = 4000 Gs,							
T = 25 °C			≤ 170				
T = 50 °C			≤ 160				
T = 100 °C			≤ 140				

Continued

	3C2	3C4	3C6	3D3	3E1	3E2	3H1
$q_{2\text{-}24\text{-}100}$ (in $\Omega/H^{3/2}mA$) at 4 kHz	≥ 10				≤ 4	≤ 1.8	≤ 1.8
at 100 kHz				≤ 3			
ϱ (in Ω.cm), measured with d.c. current				≥ 150	≥ 30	≥ 30	≥ 100
D.F., between 10 and 100 min after demagnetisation at 23 ± 1 °C				≤ 12×10^{-6}		≤ 1.9×10^{-6}	≤ 4.3×10^{-6}
T.F. between +23 and +55 °C	between 0 and $+4.5 \times 10^{-6}$/°C				between 0 and $+4 \times 10^{-6}$/°C		
+23 and +70 °C				between 0 and $+2 \times 10^{-6}$/°C***			between +0.6 and $+1.8 \times 10^{-6}$/°C **
Curie point in °C	≥ 150	≥ 150	≥ 190	≥ 150	≥ 125	≥ 140	≥ 170
Specific weight	4.7 - 4.9	4.7 - 4.9	4.8 - 4.9	4.5 - 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 straight forward way is not always possible.

* A version with a higher relative initial permeability (μ_i = 3800 ± 20%) is available in limited quantities.
** Measured 10 min after demagnetisation.
*** Measured 24 hours after demagnetisation.

	4A1	4A3	4A4	4B1	4C1	4C3
μ_i	600 ± 20%	450 ± 20%	500 ± 20%	250 ± 20%	125 ± 20%	80 ± 20%
B (in Gs), ballistically measured,						
H = 10 Oe, T = 20 °C	approx. 2900		approx. 2700			
T = 70 °C			approx. 2100			
T = 100 °C	approx. 1750					
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	approx. 3900
T = 70 °C						approx. 3600
T = 100 °C					approx. 2450	
H = 40 Oe, T = 20 °C						
T = 100 °C						
H = 60 Oe, T = 20 °C						
T = 100 °C						
$\frac{\tan\delta}{\mu_i}$ at 450 kHz	$\leq 65 \times 10^{-6}$					
at 500 kHz			$\leq 30 \times 10^{-6}$			
at 700 kHz	$\leq 100 \times 10^{-6}$			$\leq 70 \times 10^{-6}$		
at 1 MHz	$\leq 150 \times 10^{-6}$			$\leq 90 \times 10^{-6}$		
at 1.5 MHz		$\leq 140 \times 10^{-6}$	$\leq 40 \times 10^{-6}$	$\leq 140 \times 10^{-6}$		
at 2 MHz			$\leq 70 \times 10^{-6}$		$\leq 120 \times 10^{-6}$	
at 3 MHz					$\leq 160 \times 10^{-6}$	
at 5 MHz					$\leq 300 \times 10^{-6}$	
at 10 MHz						$\leq 100 \times 10^{-6}$
at 15 MHz						$\leq 150 \times 10^{-6}$
at 20 MHz						$\leq 200 \times 10^{-6}$
at 25 MHz						
at 40 MHz						

Continued

	4A1	4A3	4A4	4B1	4C1	4C3
$q_{2\text{-}24\text{-}100}$ (in $\Omega/H^{3/2}mA$) at 100 kHz, B = 3-12 Gs			≤ 3			
ϱ (in Ω.cm), measured with d.c. current	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$
ϵ at 11 MHz at 10 and 20 MHz			15-20			
D.F. between 10 and 100 min. after demagnetisation at 23 and 70 °C			$\leq 5x10^{-6}$			
T.F. between +5 and +55 °C	between 0 and $+6x10^{-6}$/°C					between 0 and $+10x10^{-6}$/°C
+5 and +23 °C						
+23 and +55 °C				between 0 and $+8x10^{-6}$/°C	between 0 and $+12x10^{-6}$/°C	
+23 and +70 °C			between +5 and $+15x10^{-6}$/°C *			
Curie point in °C	≥ 125	≥ 125	≥ 125	≥ 250	≥ 350	≥ 350
Specific weight	4.6 - 5.0	4.7 - 5.1	4.7 - 5.1	4.4 - 4.8	4.2 - 4.6	3.5 - 5

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

	4C4	4C5	4C6	4D1	4D2	4E1
μ_i	120 ± 20%	100 ± 20%	100 ± 20%	50 ± 20%	60 ± 5%	15 ± 20%
B (in Gs), ballistically measured,						
H = 10 Oe, T = 20 °C						
T = 70 °C						
T = 100 °C						
H = 20 Oe, T = 20 °C						
T = 100 °C						
H = 25 Oe, T = 20 °C		approx. 3400				
T = 70 °C		approx. 3000				
H = 30 Oe, T = 20 °C	approx. 3300		approx. 3500			
T = 70 °C	approx. 3100		approx. 3200			
T = 100 °C						
H = 40 Oe, T = 20 °C				approx. 2400		
T = 100 °C				approx. 2200		
H = 60 Oe, T = 20 °C						approx. 1750
T = 100 °C						approx. 1650
$\frac{\tan\delta}{\mu_i}$ at 450 kHz						
at 500 kHz						
at 700 kHz						
at 1 MHz						
at 1.5 MHz						
at 2 MHz	$\leq 40 \times 10^{-6}$		$\leq 45 \times 10^{-6}$			
at 3 MHz				$\leq 180 \times 10^{-6}$		
at 5 MHz	$\leq 60 \times 10^{-6}$		$\leq 60 \times 10^{-6}$	$\leq 210 \times 10^{-6}$		
at 10 MHz	$\leq 100 \times 10^{-6}$	$\leq 150 \times 10^{-6}$	$\leq 100 \times 10^{-6}$	$\leq 300 \times 10^{-6}$	$\leq 100 \times 10^{-6}$	$\leq 300 \times 10^{-6}$
at 15 MHz						
at 20 MHz		$\leq 230 \times 10^{-6}$				$\leq 300 \times 10^{-6}$
at 25 MHz					$\leq 200 \times 10^{-6}$	
at 40 MHz					$\leq 600 \times 10^{-6}$	$\leq 360 \times 10^{-6}$

Continued

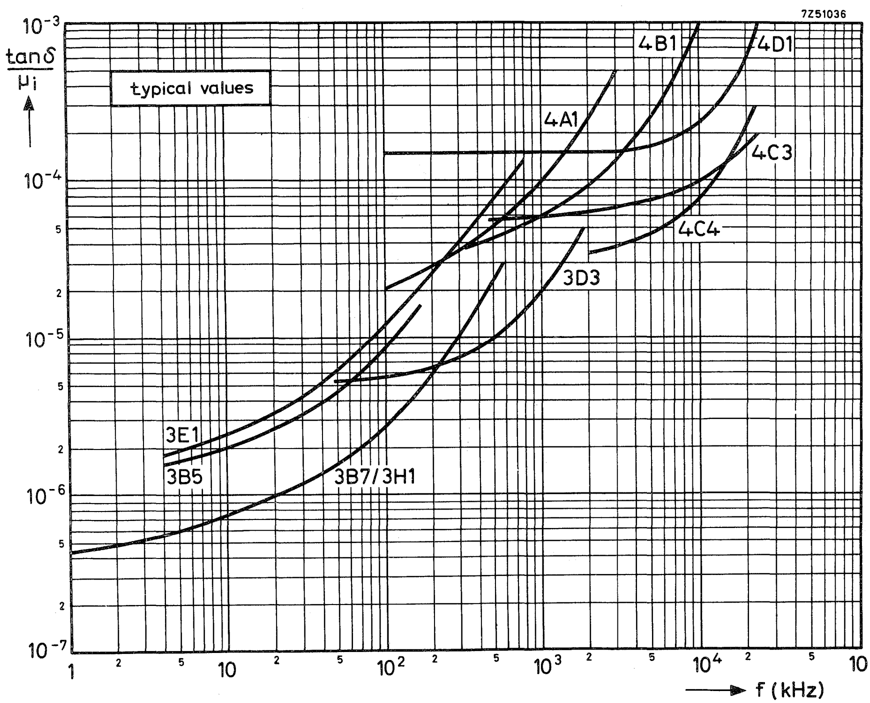
	4C4	4C5	4C6	4D1	4D2	4E1
$q_{2-24-100}$ (in $\Omega/H^{3/2}mA$) at 100 kHz, B = 3-12 Gs			≤ 40			
ϱ (in Ω.cm), measured with d.c. current	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$	$\geq 10^5$		$\geq 10^5$
ϵ at 11 MHz at 10 and 20 MHz		approx. 14				
D.F. between 10 and 100 min after demagnetisation at 23 and 70 °C	$\leq 33 \times 10^{-6}$	$\leq 10 \times 10^{-6}$	$\leq 10 \times 10^{-6}$			
T.F. between +5 and +55 °C	between −10 and $0 \times 10^{-6}/°C$					
+5 and +23 °C		between −20 and $+20 \times 10^{-6}/°C$ *	between −2 and $+4 \times 10^{-6}/°C$ *			
+23 and +55 °C		between −20 and $+20 \times 10^{-6}/°C$ *	between 0 and $+6 \times 10^{-6}/°C$ *	between 0 and $+15 \times 10^{-6}/°C$		between 0 and $+15 \times 10^{-6}/°C$
+23 and +70 °C					between 0 and $+15 \times 10^{-6}/°C$	
Curie point in °C	≥ 350		≥ 350	≥ 400		≥ 500
Specific weight	3.5 - 5		4.6 - 4.9	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.

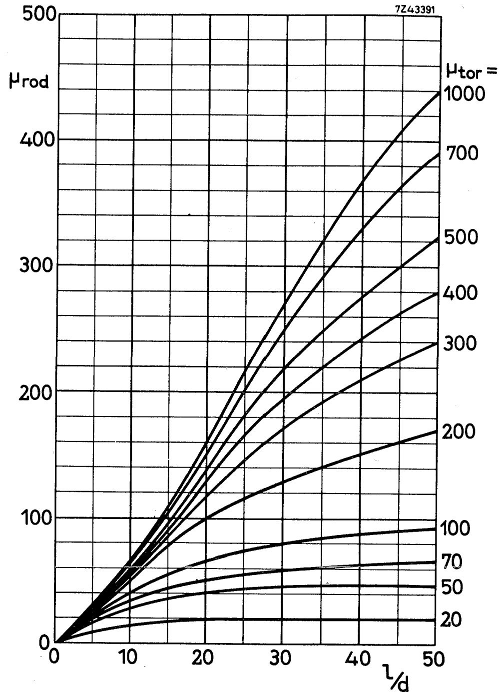
* Measured 24 hours after demagnetisation

CHARACTERISTIC CURVES

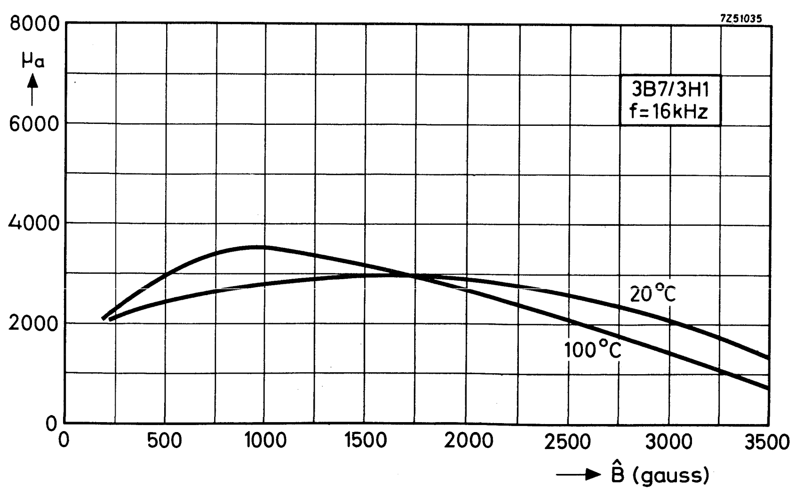
EDDY CURRENT LOSSES AND RESIDUAL LOSSES AS A FUNCTION OF THE FREQUENCY AT LOW INDUCTION LEVEL

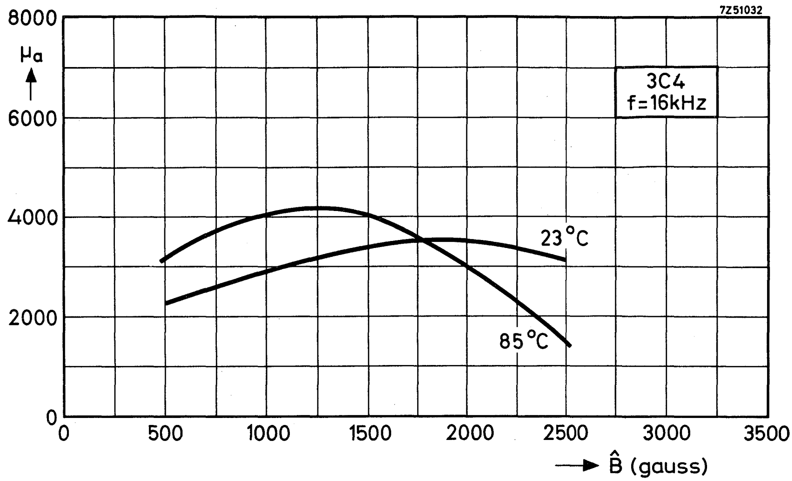


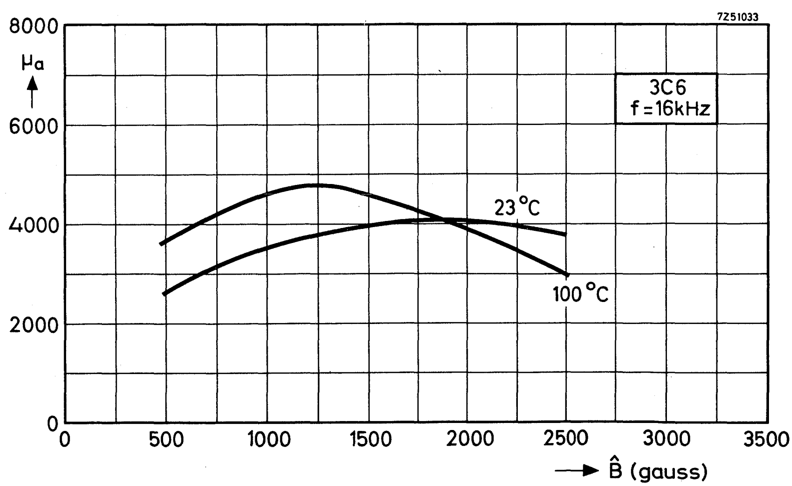
ROD PERMEABILITY AS A FUNCTION OF THE RATIO l/d WITH THE RELATIVE INITIAL PERMEABILITY OF A TOROIDAL CORE AS PARAMETER

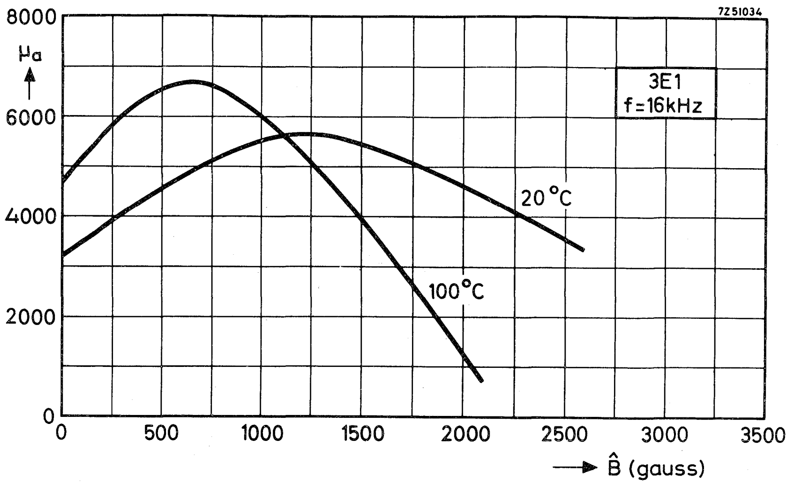


AMPLITUDE PERMEABILITY AS A FUNCTION OF THE INDUCTION

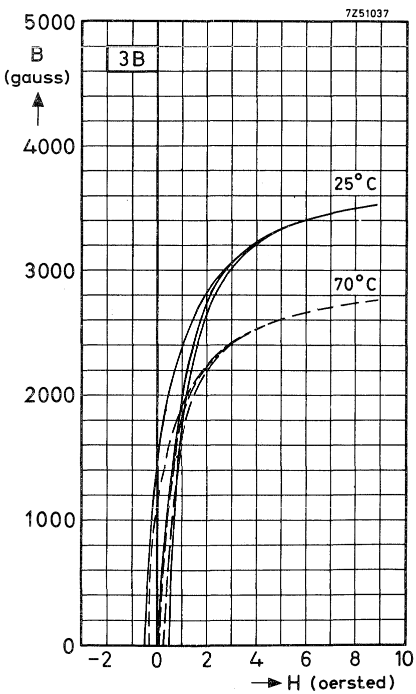


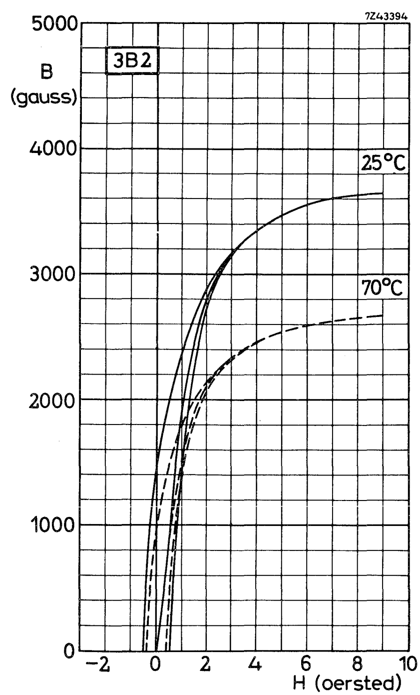

7Z51032
8000
6000
4000
2000
0
μ_a
3C4
f=16kHz
23°C
85°C
0
500
1000
1500
2000
2500
3000
3500
B̂ (gauss)

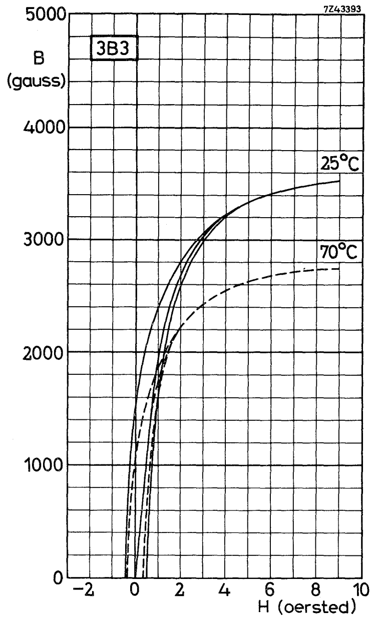

7Z51033
8000
6000
4000
2000
0
μ_a
3C6
f=16kHz
23°C
100°C
0
500
1000
1500
2000
2500
3000
3500
B̂ (gauss)

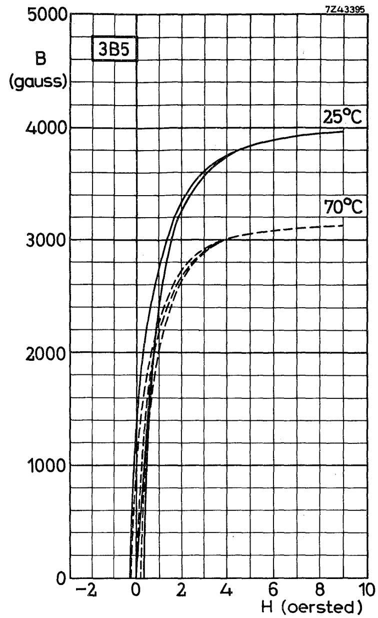


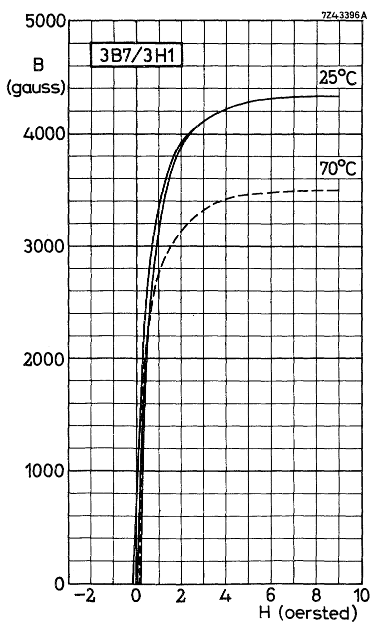
TYPICAL BH-CURVES (ballistically measured)

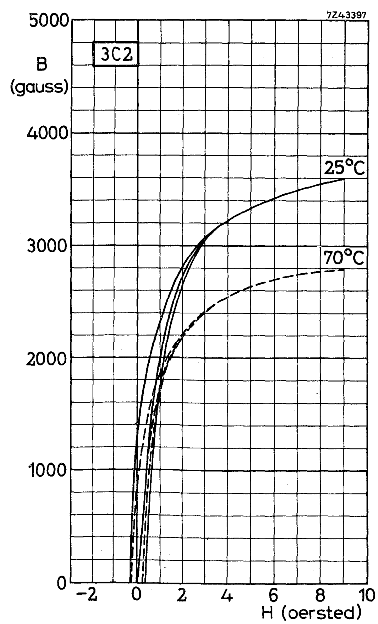


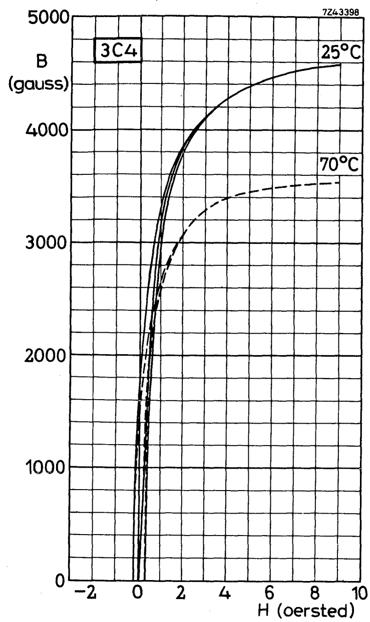


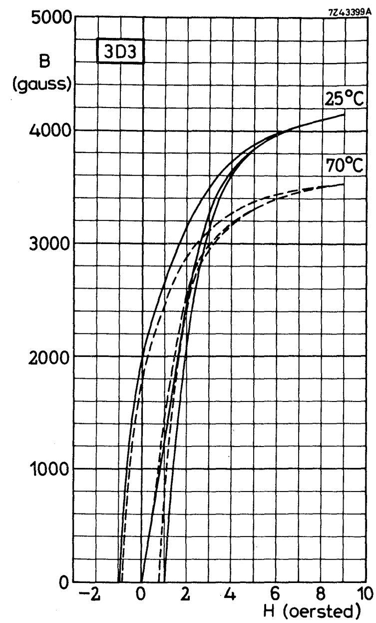

7Z43393
3B3
B
(gauss)
5000
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

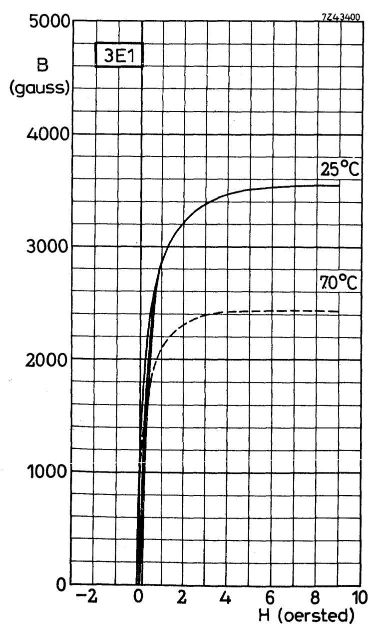

7Z43395
3B5
B
(gauss)
5000
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

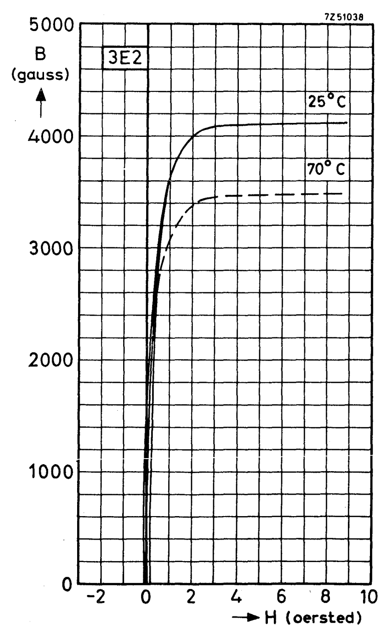

7Z43396A
3B7/3H1
B
(gauss)
5000
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

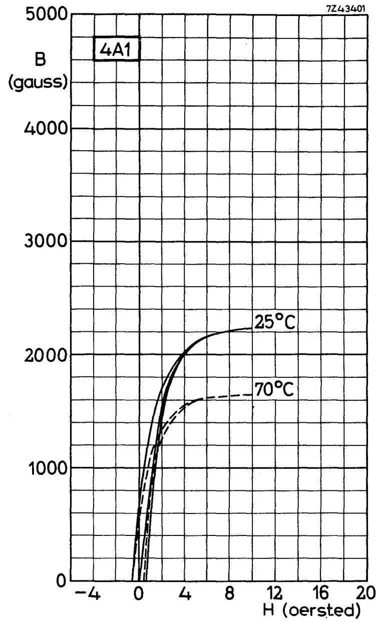

7Z43397
3C2
B
(gauss)
5000
4000
3000
2000
1000
0
25°C
70°C
−2
0
2
4
6
8
10
H (oersted)

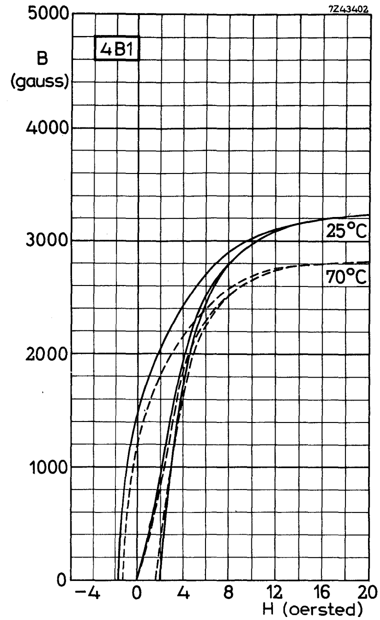

7Z43398
3C4
B (gauss)
25°C
70°C
5000
4000
3000
2000
1000
0
−2
0
2
4
6
8
10
H (oersted)

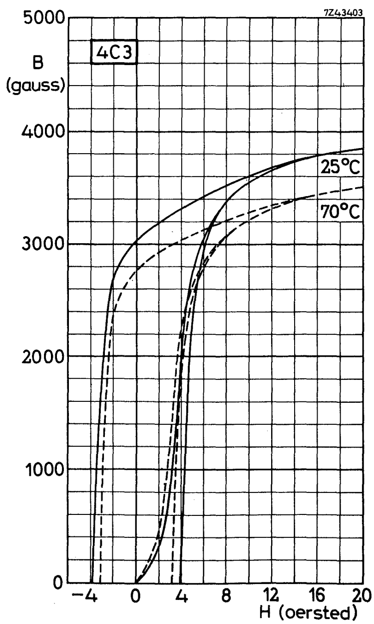

7Z43399A
3D3
B (gauss)
25°C
70°C
5000
4000
3000
2000
1000
0
−2
0
2
4
6
8
10
H (oersted)

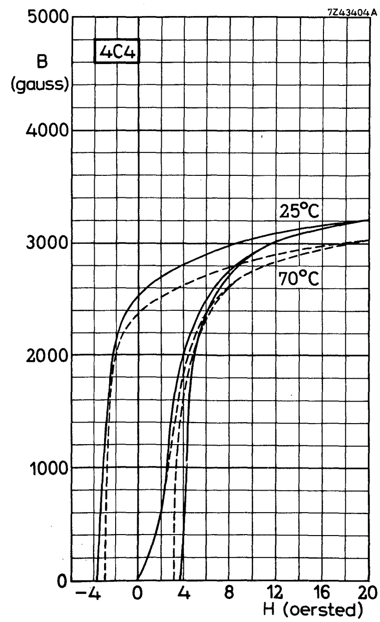

7Z43400
3E1
B (gauss)
25°C
70°C
5000
4000
3000
2000
1000
0
−2
0
2
4
6
8
10
H (oersted)

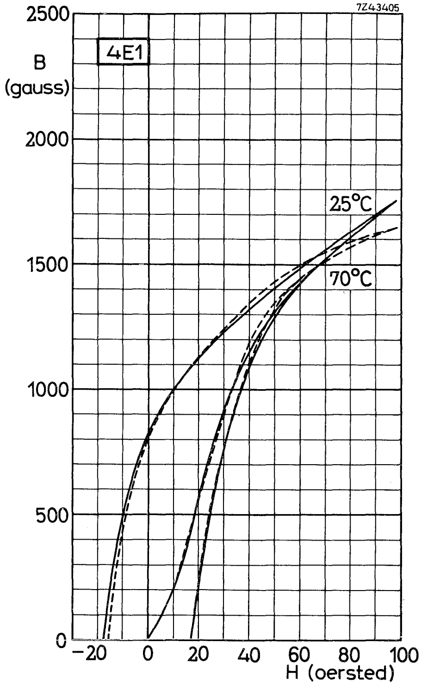

7Z51038
3E2
B (gauss)
25° C
70° C
5000
4000
3000
2000
1000
0
-2
0
2
4
6
8
10
H (oersted)


7Z43401
4A1
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−4
0
4
8
12
16
20
H (oersted)

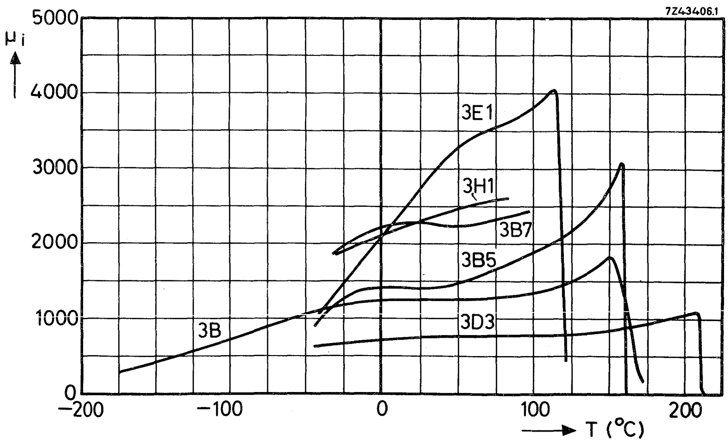

7Z43402
4B1
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−4
0
4
8
12
16
20
H (oersted)

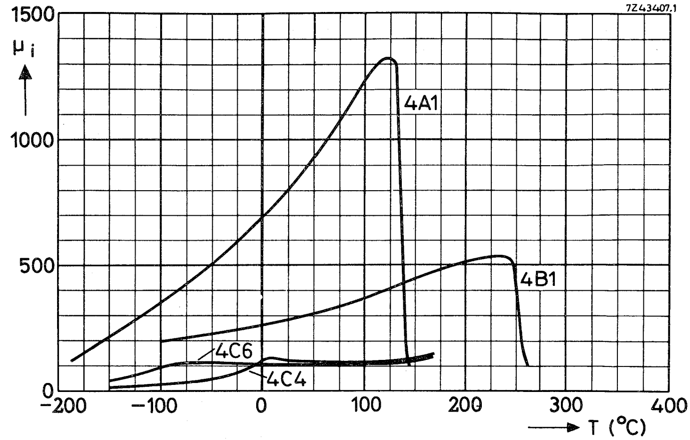

7Z43403
4C3
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−4
0
4
8
12
16
20
H (oersted)


7Z43404 A
4C4
5000
B
(gauss)
4000
3000
2000
1000
0
25°C
70°C
−4
0
4
8
12
16
20
H (oersted)

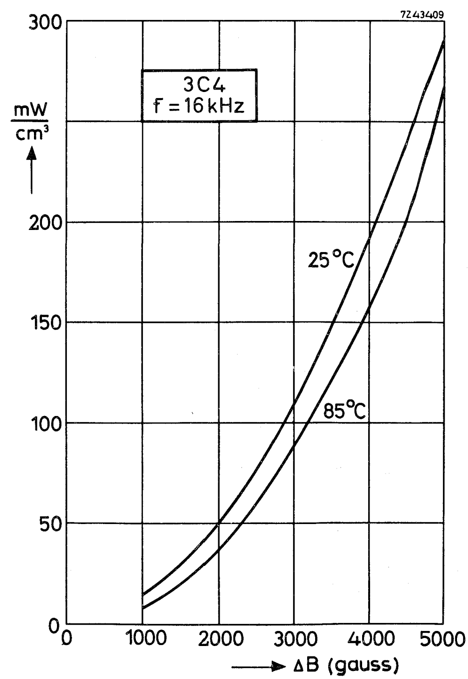


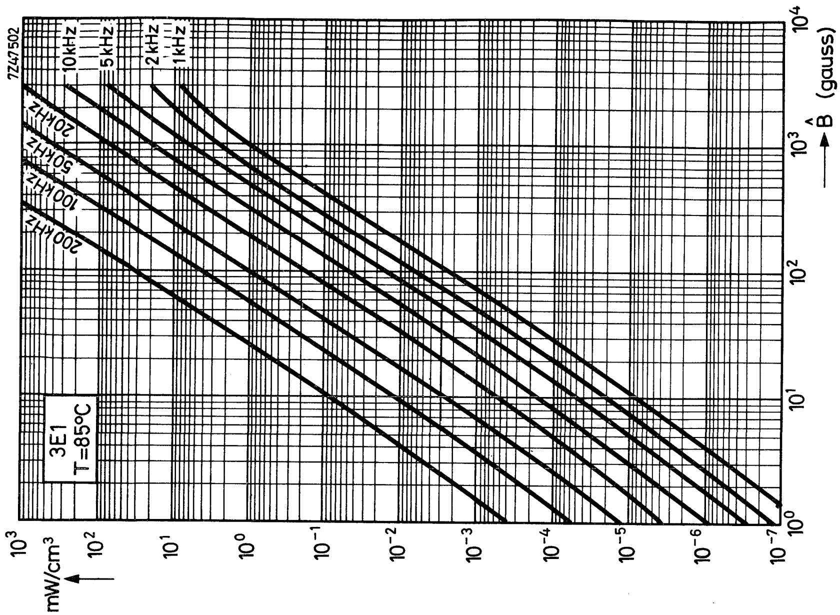
RELATIVE INITIAL PERMEABILITY AS A FUNCTION OF THE TEMPERATURE

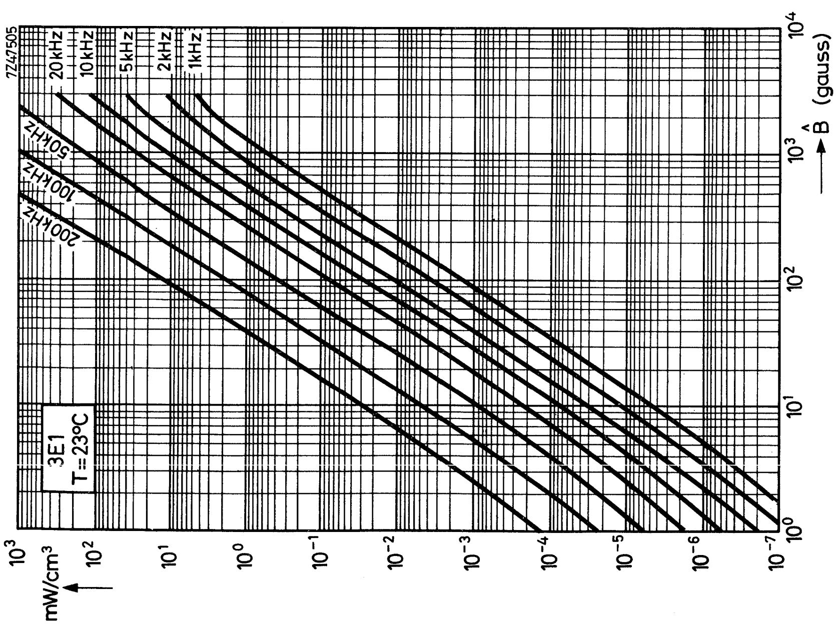


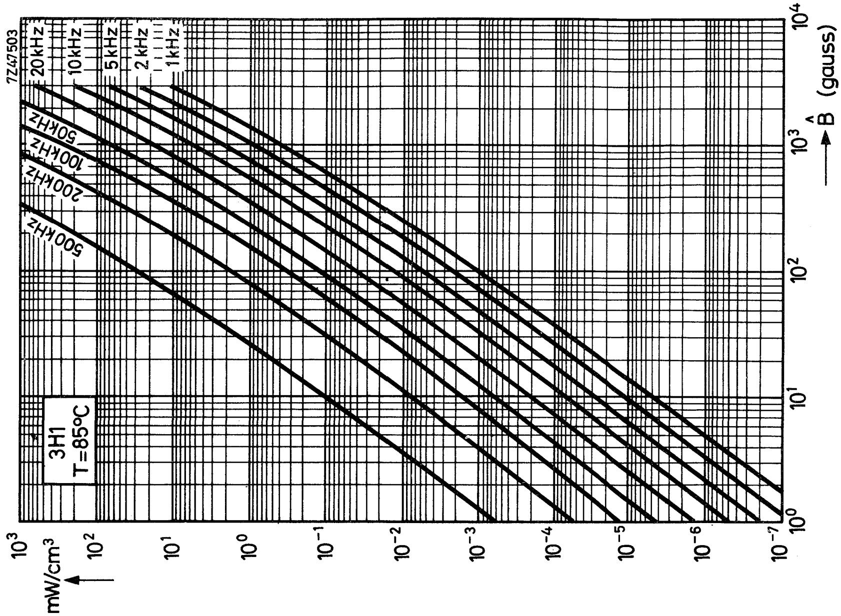


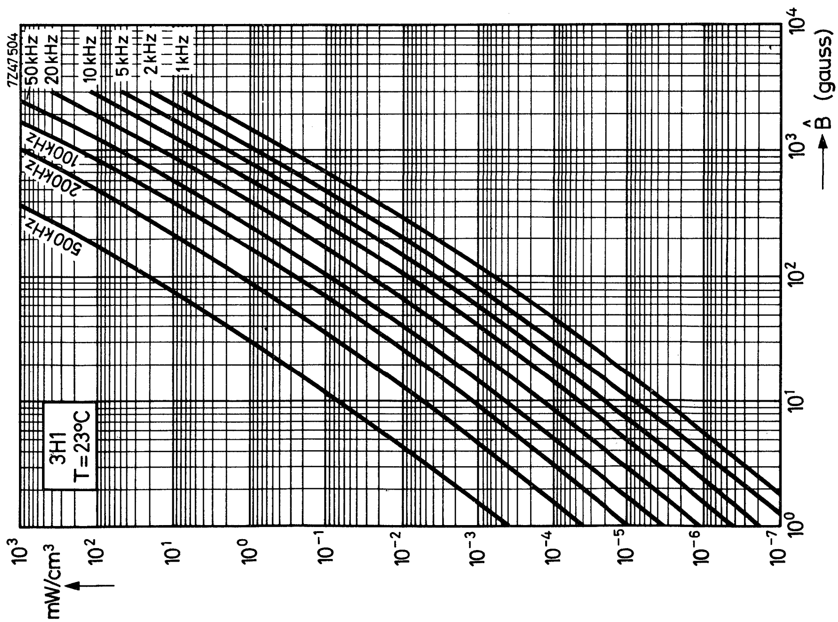
CORE LOSSES AS A FUNCTION OF THE INDUCTION



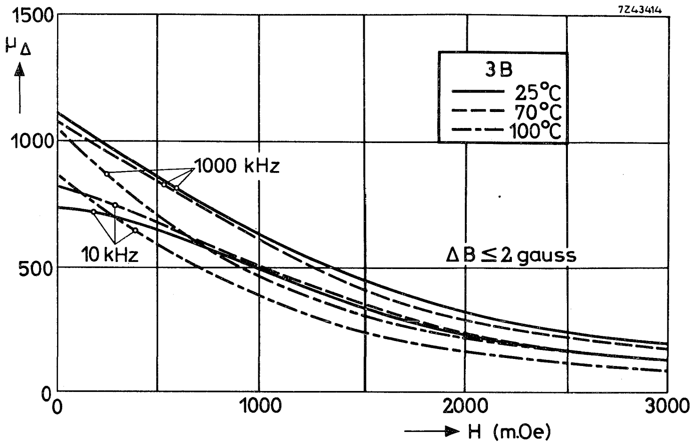

7Z47502
3E1
T=85°C
10kHz
5kHz
2kHz
1kHz
20kHz
50kHz
100kHz
200kHz
mW/cm³
→ B̂ (gauss)

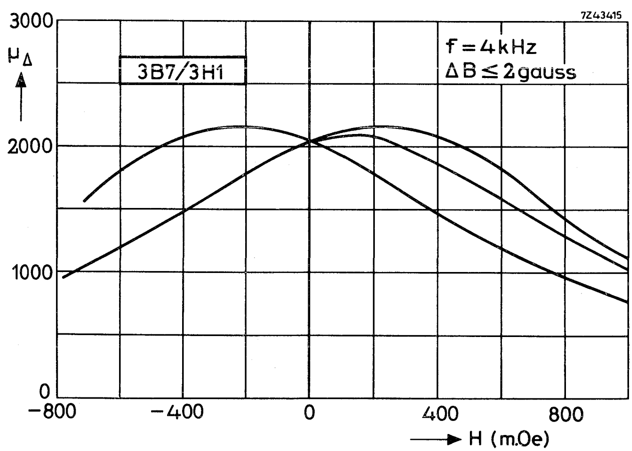

7Z47505
3E1
T=23°C
20kHz
10kHz
5kHz
2kHz
1kHz
50kHz
100kHz
200kHz
mW/cm³
→ B̂ (gauss)

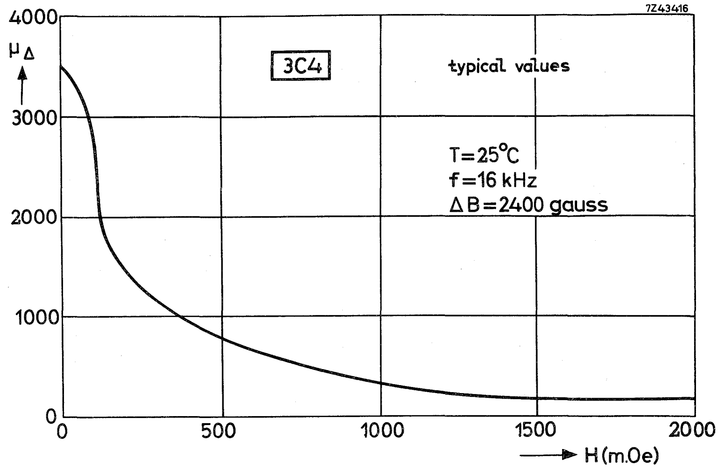

7Z47503
3H1
T=85°C
1kHz
2kHz
5kHz
10kHz
20kHz
50kHz
100kHz
200kHz
500kHz
mW/cm³
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁰
10¹
10²
10³
10⁴
B̂ (gauss)

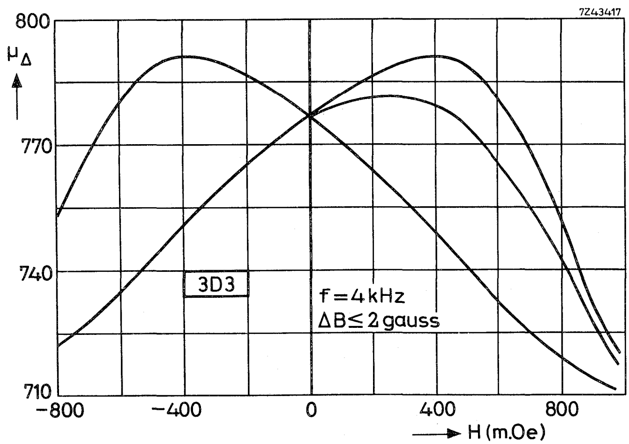

7Z47504
3H1
T=23°C
1kHz
2kHz
5kHz
10kHz
20kHz
50kHz
100kHz
200kHz
500kHz
mW/cm³
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁰
10¹
10²
10³
10⁴
B̂ (gauss)

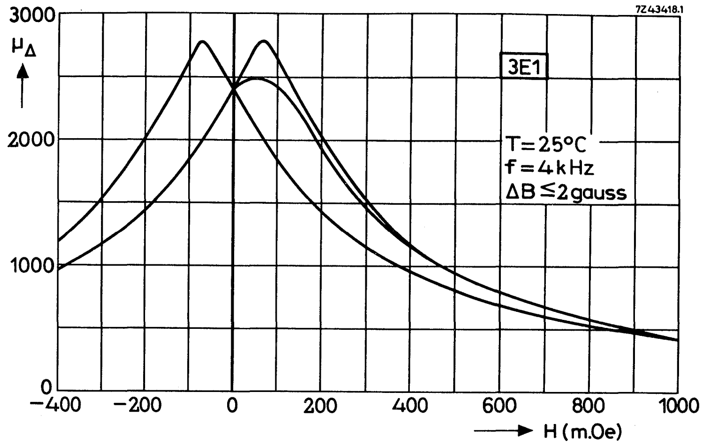
INCREMENTAL PERMEABILITY AS A FUNCTION OF THE FIELD STRENGTH

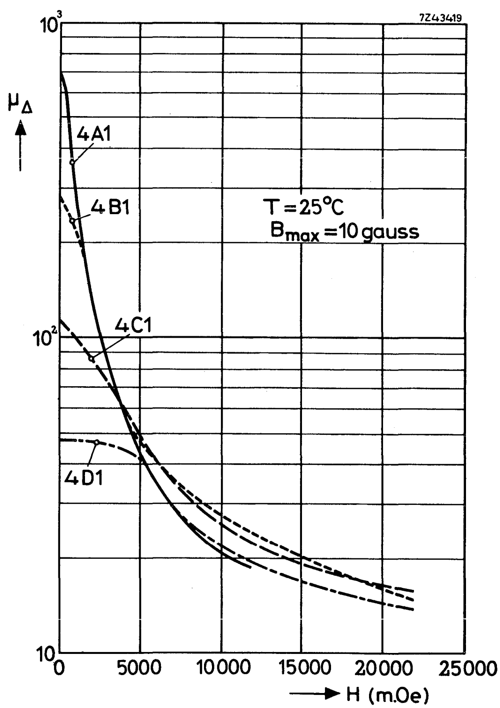





7Z43416
4000
μ_Δ
3000
2000
1000
0
3C4
typical values
T=25°C
f=16 kHz
ΔB=2400 gauss
0
500
1000
1500
2000
H (m.Oe)

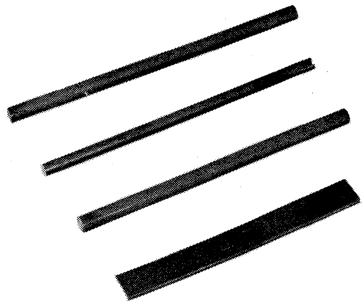

7Z43417
800
μ_Δ
770
740
710
3D3
f=4 kHz
ΔB≤2 gauss
−800
−400
0
400
800
H (m.Oe)


7Z43418.1
3000
2000
1000
0
μ_Δ
3E1
T=25°C
f=4kHz
ΔB≤2gauss
−400
−200
0
200
400
600
800
1000
H (m.Oe)


7Z43419
10^3
10^2
10
μ_Δ
4A1
4B1
4C1
4D1
T=25°C
B_{max}=10 gauss
0
5000
10000
15000
20000
25000
H (m.Oe)

Ferrites for radio, audio and television

ANTENNA RODS AND PLATES



RZ 22938-2

RODS [1)]

	dimensions (mm)		catalog number
Grade 4A3	(φ 10 - 0.5)	× (240 - 7)	3122 104 43442
		(230 - 7)	4311 020 53122
		× (220 - 6)	4311 020 52742
		(210 - 6)	3122 104 93701
		× (200 - 6)	3122 104 93422
		(190 - 6)	4311 020 53231
		× (180 - 6)	3122 104 93452
		(170 - 6)	4311 020 52762
		× (160 - 5)	4311 020 52612
		× (150 - 5)	4311 020 52772
		× (140 - 5)	3122 104 93462
		× (130 - 5)	4311 020 52782
		× (100 - 4)	4311 020 52592
	(φ 7.8 ± 0.2)	× (190^{+1}_{-6})	4311 020 52701
		× (140^{+1}_{-5})	4311 020 52691
		× (130^{+1}_{-3})	4311 020 52681
		× (100^{+1}_{-3})	4311 020 52791
	(φ 6.35 ± 0.2)	× (130^{+1}_{-3})	4311 020 52801
		× (100^{+1}_{-3})	4311 020 52811

1) Preferred types

Grade 4B1

dimensions (mm)	catalog number
(φ 9.7 ± 0.3) × (240 ± 8)	4311 020 52331
× (200^{+9}_{-3})	3122 104 91251
× (175 ± 5)	4311 020 52241
× (140 ± 5)	3122 104 91241
× (130 ± 2)	4311 020 52231
(φ 7.8 ± 0.2) × (190 ± 4)	4311 020 52551
× (140 ± 3)	4311 020 50251
× (100 ± 2)	4311 020 52171
(φ 6.5 − 0.3) × (130 ± 05)	3122 104 91801

Grade 4C3 (for short-wave reception)

dimensions (mm)	catalog number
(φ 9.8 ± 0.3) × (200^{+10}_{-2})	4311 020 52351
× (155 − 4)	4311 020 52341

PLATES [1]

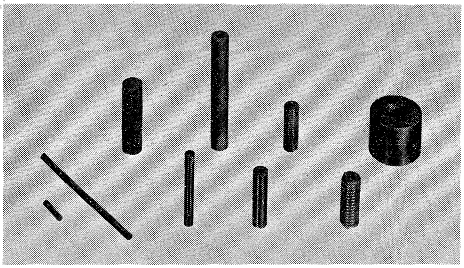
Grade 4B1

dimensions (mm)	catalog number
(19 − 1) × (3.8 − 0.3) × (150 − 6)	4311 020 52411
× (125 − 5)	4311 020 52401
× (100 − 4)	4311 020 52391
× (75 − 3)	4311 020 52381
(13.4 − 0.8) × (4.15 − 0.3) × (120 − 2)	3122 104 92141
× (94 − 1)	3122 104 92121
× (62 − 1)	3122 104 92151

[1] Preferred types

CORES FOR SMALL COILS

e.g. I.F. transformers



RZ 22938-6

Ferroxcube rods, tubes screws and caps 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

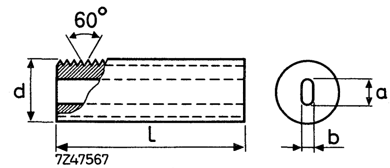
dia. (mm)	length (mm)	grade	catalog number
0.95 - 0.15	10 - 2.5	3B	3522 200 03751
1.25 - 0.04	6.2 - 0.4	3B	4322 020 32081
1.65 - 0.05	9.2 - 0.4	3B	3122 104 91071
	9.2 - 0.4	4B	3122 104 91061
	11.5 - 0.4	3B	4322 020 32101
	11.5 - 0.4	4E	4322 020 32111
	12.2 - 0.4	3B	3122 104 91101
	12.2 - 0.4	4B	3122 104 91111
	19.2 - 0.4	3B	3122 104 91231
	25.2 - 0.4	3B	3122 104 91171
	25.2 - 0.4	4B	3122 104 91181
	28.2 - 0.4	3B	3122 104 91091
	28.2 - 0.4	4B	4322 020 32091
1.7 - 0.15	15.2 - 0.4	4D	4322 020 32171
1.7 - 0.1	28.2 - 0.4	4C	4322 020 32121
	28.2 - 0.4	4D	4322 020 32131
	28.2 - 0.4	4E	4322 020 32141
1.7 - 0.15	30.5 - 1	3B	3122 104 91201
1.75 - 0.2	10.2 - 0.4	3B	3122 104 91131
	18.5 - 1	3B	3122 104 91141
	18.5 - 1	4B	3122 104 91151
6 - 0.075	46.2 - 0.4	3C	3122 104 91311
6.65 - 0.3	40.4 - 0.8	3B	4322 020 32161

TUBES

outer dia. (mm)	inner dia. (mm)	length (mm)	grade	catalog number
2.8 - 0.03	1.2 + 0.1	8.2 - 0.4	3B	4322 020 34341
3.7 - 0.4	1.2 + 0.2	3.5 - 0.5	3B	4322 020 34401
			4B	4322 020 34421
		6.5 - 0.5	3B	4022 101 80011
3.7 - 0.3	1.7 + 0.2	13.7 - 0.4	4E	4322 020 34331
4.15 - 0.05	2 + 0.2	7.2 - 0.4	4A	4322 020 34441
		12.2 - 0.4	4B	4322 020 34451
			4C	4322 020 34461
			4D	4322 020 34471
		15.2 - 0.4	4B	4322 020 34381
			4C	4322 020 34371
		21.2 - 0.4	4A	4322 020 34391
			4B	4322 020 34481
4.3 - 0.2	2 + 0.2	7.2 - 0.4	3B	3122 104 92901
		12.5 - 1	3B	4322 020 34491
		15.2 - 0.2	4D	4322 020 36761
		15.4 - 0.8	3B	4322 020 36751
		18.5 - 1	3B	4322 020 36771
		25.5 - 1	3B	4322 020 36781
			4B	3122 104 90811
			4C	3522 200 10951
			4D	3522 200 10961
			4E	3522 200 10971
		30.2 - 0.4	3B	4322 020 36791
		40.5 - 1	3B	3122 104 90801
		55.5 - 1	3B	4322 020 36801
4.95 - 0.1	1.3 + 0.2	40.5 - 1	3C3	3122 104 93111
5.3 - 0.2	3 + 0.2	22.4 - 0.8	3B	4322 020 36811
6.2 - 0.4	2.85 + 0.3	30.2 - 0.4	4C	4322 020 36821
8 - 0.4	4.2 + 0.6	51.4 - 2.8	3B	4322 020 34311
			4B	4322 020 34321

SCREW CORES

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

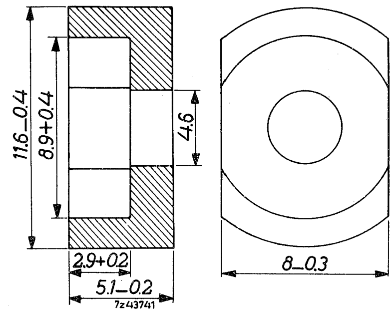


screw thread	l (mm)	d (mm)	a (mm)	b (mm)	catalog number
M4 × 0.50	12 ± 0.3	3.65 + 0.05	1.6 ± 0.1	0.7 ± 0.1	4312 020 32041
M4 × 0.50	7 ± 0.2	3.65 + 0.05	1.6 ± 0.1	0.7 ± 0.1	4312 020 32141
M5 × 0.75	12 ± 0.3	4.55 + 0.05	2.15 ± 0.15	0.8 ± 0.1	4312 020 32051
M5 × 1	20 ± 0.3	5.0 − 0.1	2.35 ± 0.15	1.1 ± 0.1	4312 020 32131
M6 × 0.5 1)	12 ± 0.2	5.9 − 0.04	2.45 + 0.3	1.2 + 0.2	4312 020 32011
M6 × 0.75	25 ± 0.5	5.55 + 0.05	2.65 ± 0.15	1.1 ± 0.1	4312 020 32071
M6 × 0.75	13 ± 0.3	5.55 + 0.05	2.65 ± 0.5	1.1 ± 0.1	4312 020 32061
M6 × 1	25 ± 0.5	5.5 ± 0.02	2.75 ± 0.25	1.3 ± 0.1	4312 020 32031
M6 × 1	12 ± 0.3	5.5 ± 0.02	2.75 ± 0.25	1.3 ± 0.1	4312 020 32021
M7 × 1	18 ± 0.5	6.45 + 0.05	3.15 ± 0.15	1.3 ± 0.1	4312 020 32091
M7 × 1	12 ± 0.3	6.45 ± 0.05	3.15 ± 0.15	1.3 ± 0.1	4312 020 32081
M8 × 0.75	16 ± 0.5	7.55 + 0.05	3.65 ± 0.15	1.3 ± 0.1	4312 020 32101
M8 × 1.25	25 ± 0.5	7.35 + 0.05	3.65 ± 0.15	1.3 ± 0.1	4312 020 32121
M8 × 1.25	16 ± 0.5	7.35 ± 0.05	3.65 ± 0.15	1.3 ± 0.1	4312 020 32111

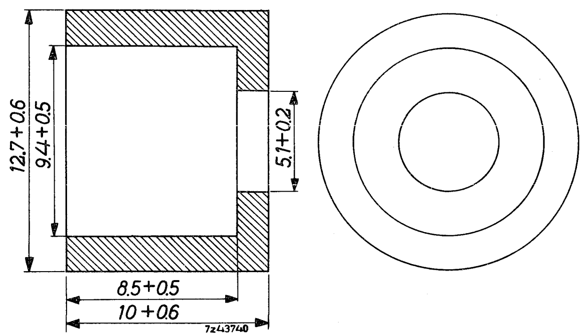
1) Grade 3B

CUP CORES (Grade 3B1)

Dimensions in mm



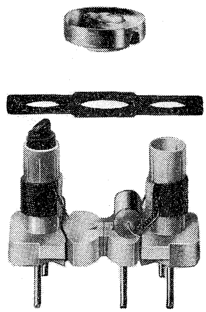
Catalog number 3122 104 92221



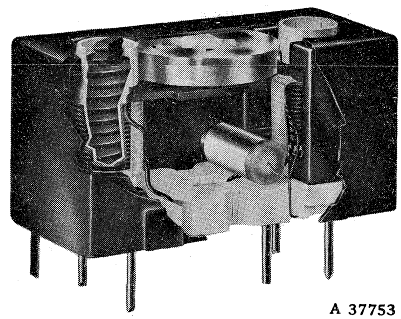
Catalog number 4322 020 20954

PIECE PARTS AND MOUNTING PARTS

for small I.F. coils (lilliput type)



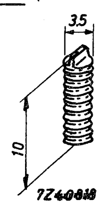
A 37755



A 37753

The complete range of piece parts comprises:

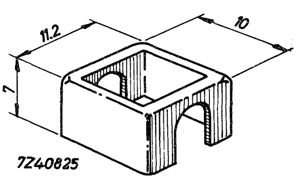
Screw core (ferroxcube)



max. frequency (MHz)	grade	catalog number
0.6	3B1	3122 104 93011
2	4B1	3122 104 93021
12	4D1	3122 104 93041
40	powder iron	3122 104 91631

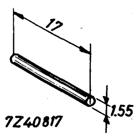
A version with a trimming grip on both sides is also available

Ferroxcube frame (lacquered)



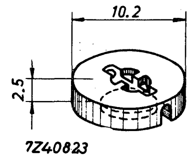
max. frequency (MHz)	colour	type number
0.6	black	AP3014/00/3B1
2	green	AP3014/01/4B1
12	light blue	AP3014/02/4D1
ratio detector	light blue	AP3014/03/4D1

Coupling rod (3B1)



For coupling between primary and secondary windings, to be inserted in disc AP 3018.
Catalog number :
3122 104 91131

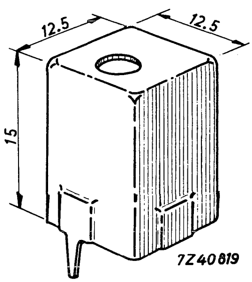
Coupling disc



Type number AP 3018

Can

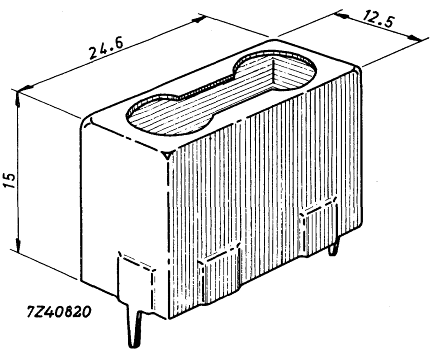
For one coil



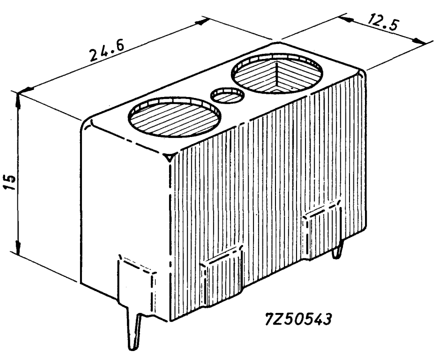
Polystyrene can for mechanical shielding, to be used when screening is not required. The Q-factor is not affected.
Type number AP 3015/00.

Copper can for mechanical and electrical shielding.
Symmetric hole : type number AP 3015/01
Asymmetric hole: type number AP 3015/02

For two coils

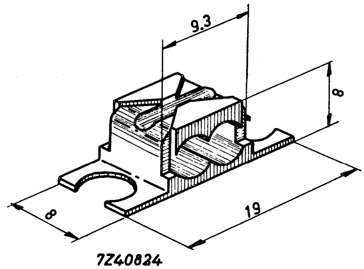


Tinned copper can
Type number AP 3015/03



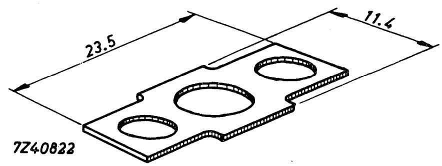
Tinned copper can
Type number AP 3015/04

Block



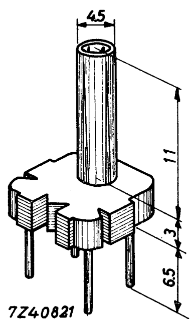
Type number AP 3019
(for ratio detector only)

Spacer plate

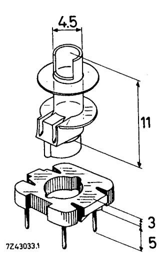


Type number AP 3017

Coil formers (polyethylene)



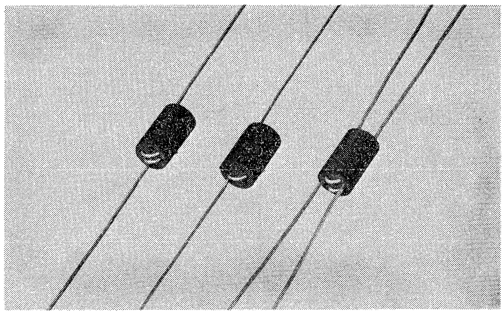
with base	version	type number
symmetric:		
for use without	4 pins	AP 3016/00
ferroxcube frame	5 pins	AP 3016/01
assymmetric:		
for use with	4 pins	AP 3016/02
ferroxcube frame	5 pins	AP 3016/03



Coil former (without base), asymmetric, for use with frame AP 3014, type number AP 3016/05.

Base with 4 pins for above coil former, type number AP 3016/07.

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 ofter 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)

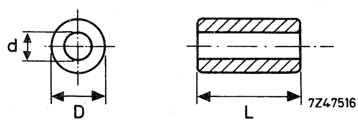


Fig.1

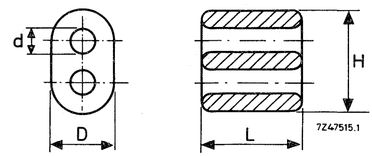


Fig.2

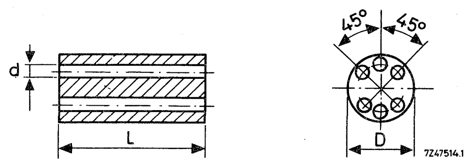


Fig.3

Fig.	grade	L (mm)	D (mm)	H (mm)	d (mm)	catalog number
1	3B1	3	3.5 ± 0.2	-	1.3 ± 0.2	4322 020 34401
1	4B1	3	3.5 ± 0.2	-	1.3 ± 0.2	4322 020 34421
1	3B1	5	3.5 ± 0.2	-	1.3 ± 0.2	4312 020 31061
2	4B1	8 ± 0.3	8.5 - 0.5	14 ± 0.5	3.5 + 0.5	4312 020 31571
2	4B1	14 ± 0.4	8.5 - 0.5	14 ± 0.5	3.5 + 0.5	4312 020 31521
3	3B1	7.5 ± 0.5	6 ± 0.3	-	0.7 + 0.2	VK 211 18
3	3B1	10 ± 0.5	6 ± 0.3	-	0.7 + 0.2	4312 020 31501
3	4B1	10 ± 0.5	6 ± 0.3	-	0.7 + 0.2	4312 020 31551

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.

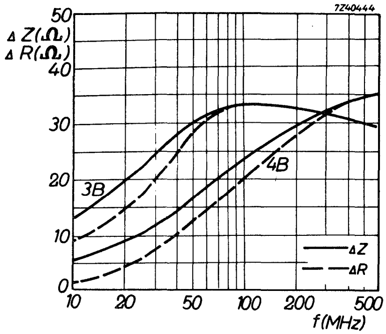


Fig.4

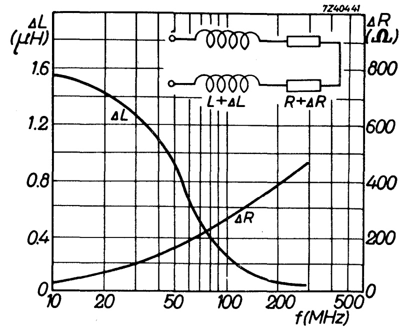


Fig.5

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 31521 on two straight wires.
Grade 4B provides ample insulation between the two wires even if bare.

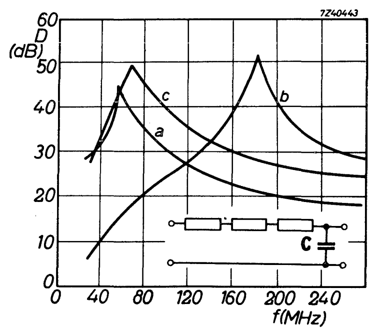


Fig.6. Damping in an LC circuit consisting of a string of three beads 4322 020 34401 and a ceramic capacitor.

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

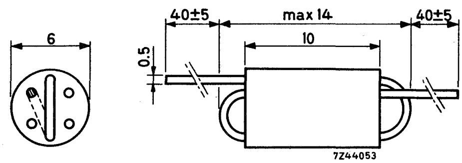


Fig.7

number of turns	Z_{max} (kΩ)	f at Z_{max} (MHz)	decrease of impedance		grade	catalog number
			in the freq. range (MHz)	dB		
1.5	0.35 ± 20%	120	10-300	≤ 7	3B1	4312 020 36631
1.5	0.45 ± 20%	250	80-300	≤ 3	4B1	4312 020 36691
2.5	0.75 ± 20%	50	10-220, 30-100	≤ 7, ≤ 3	3B1	4312 020 36641
2.5	0.85 ± 20%	180	50-300, 80-220	≤ 6, ≤ 3	4B1	4312 020 36701
2 x 1.5	0.90 ± 20%	50	10-220, 30-100	≤ 7, ≤ 3	3B1	4312 020 36651
2 x 1.5	1.00 ± 20%	110	50-300, 80-220	≤ 7, ≤ 3	4B1	4312 020 36711

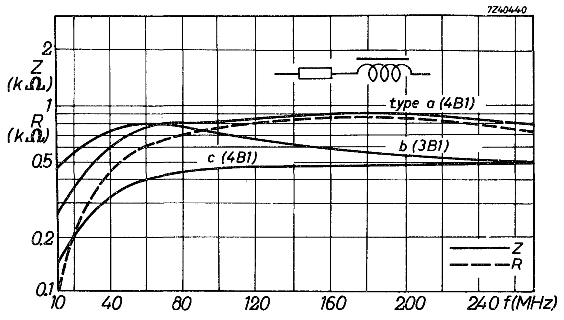


Fig.8. Performance of three single chokes

Type a = 4312 020 36701
b = 4312 020 36641
c = 4312 020 36691

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.

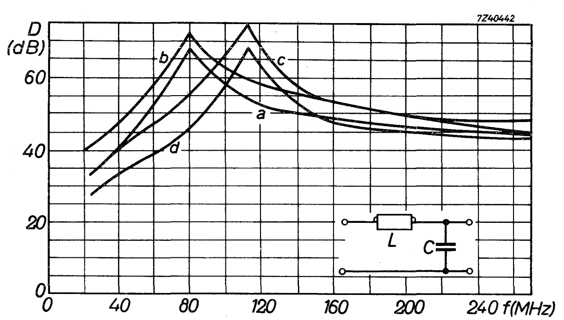
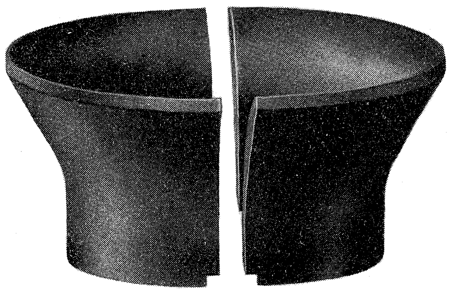


Fig.9. Damping in an LC circuit consisting of a ferroxcube choke and a ceramic disc capacitor.

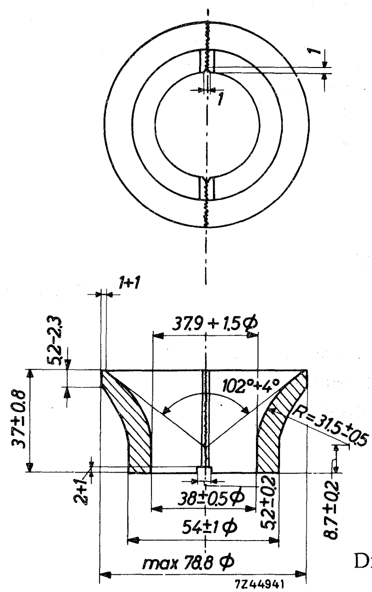
a. L = 4312 020 36691, C = 1500 pF
b. L = 4312 020 36701, C = 1500 pF
c. L = 4312 020 36701, C = 550 pF
d. L = 4312 020 36691, C = 550 pF

YOKE RINGS FOR USE IN DEFLECTION COILS FOR PICTURE TUBES

FOR 110° BLACK AND WHITE PICTURE TUBES



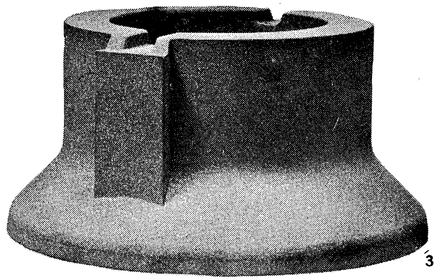
8032/6



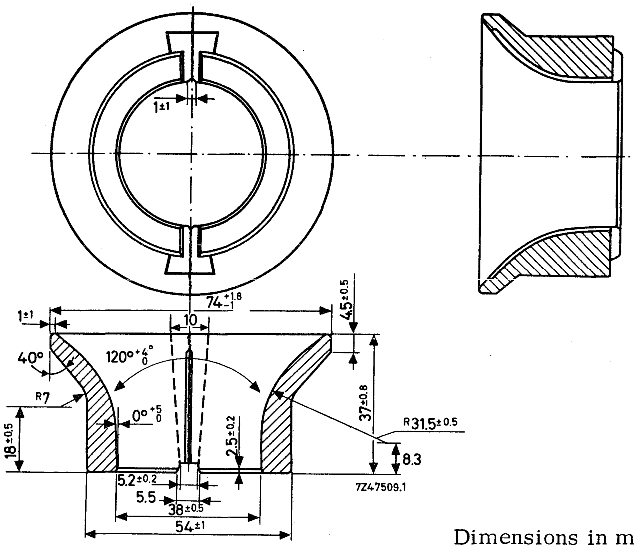
Dimensions in mm

European technique
Material : Ferroxcube 3C2
Catalog number: 3122 104 92181 (preferred type)

FOR 110° BLACK AND WHITE PICTURE TUBES (continued)



31172-1

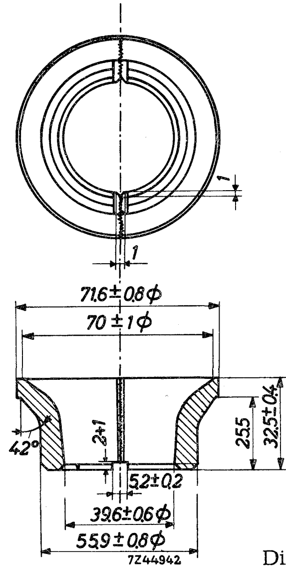


7Z47509.1

Dimensions in mm

European technique
Material : Ferroxcube 3C2
Catalog number: 4322 020 35071

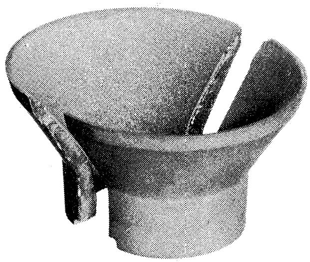
FOR 110° BLACK AND WHITE PICTURE TUBES (continued)



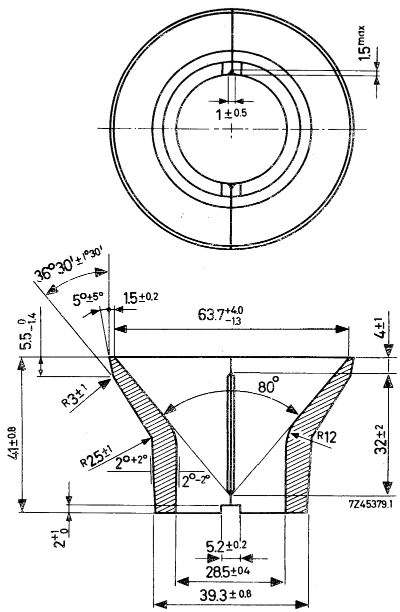
Dimensions in mm

American technique
Material : Ferroxcube 3C2
Catalog number: 4322 020 35011

FOR TINYVISION PICTURE TUBES (90°, 11 inch)



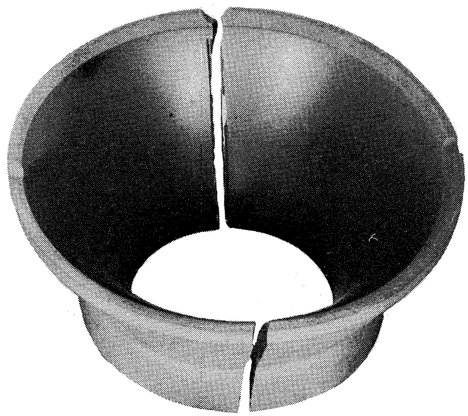
RZ 22938-4



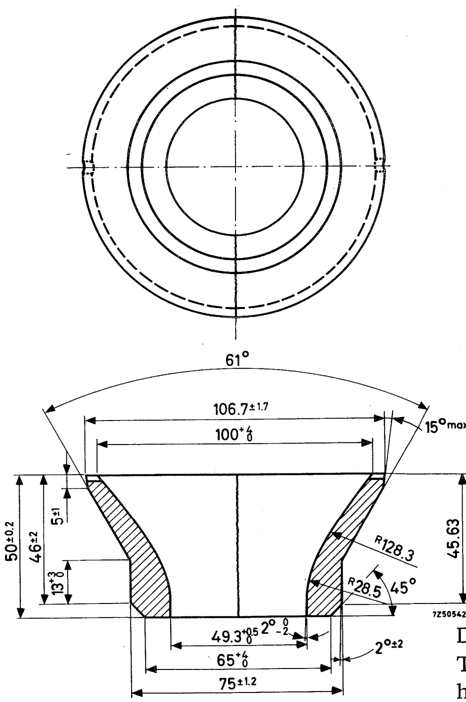
Dimensions in mm

Material : Ferroxcube 3C2
Catalog number: 3122 104 90514

FOR 90^{o} COLOUR PICTURE TUBES



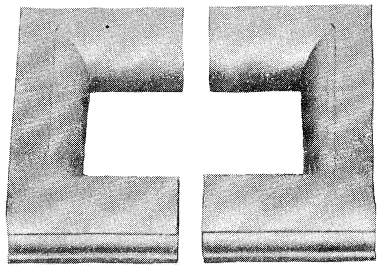
RZ 22938-1



Dimensions in mm
The inner surface
has been lacquered.

Material : Ferroxcube 3C2
Catalog number: 3122 108 12163

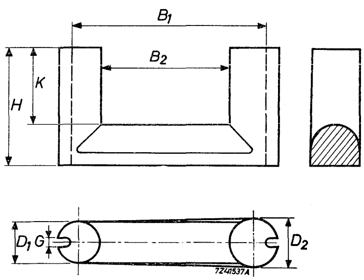
CORES FOR LINE-OUTPUT TRANSFORMERS

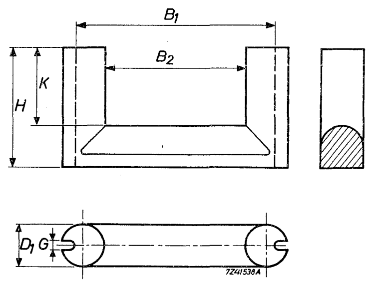


RZ 22938-3B

U-CORES (for black and white television)

All types of core are available in ferroxcube grades 3C4 and 3C6. The difference in splay between two U-cores taken at random from one packing will never exceed half the total tolerance on dimension B_1.





$D_2 = 15.9 \pm 0.2$

Available types

dimensions (mm)						grade	catalog number
B_1	B_2	D_1	G	H	K		Fig. 1
49.8 ± 0.8	26.9	15.5 ± 0.4	4.8 ± 0.2	28.4 ± 0.2	15.5 + 1	3C4	4312 020 33201
						3C6	4312 020 33301
							Fig. 2
56.7 ± 0.75	36.1	13.8 ± 0.2	3.6 ± 0.2	29.5 ± 0.2	17.6 + 1	3C4	4312 020 33221
						3C6	4312 020 33321
60.35 ± 0.9	37.05	15.9 ± 0.4	4.8 ± 0.2	28.75 ± 0.2	15.55 + 1	3C4	4312 020 33211
						3C6	4312 020 33311
60.35 ± 0.9	37.75	15.9 ± 0.4	4.8 ± 0.2	31.8 ± 0.2	18.55 + 1	3C4	4312 020 33231
						3C6	4312 020 33331

U- and I-CORES

Shapes

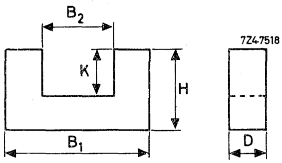


Fig.1

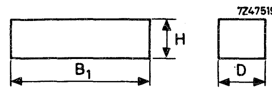


Fig.2

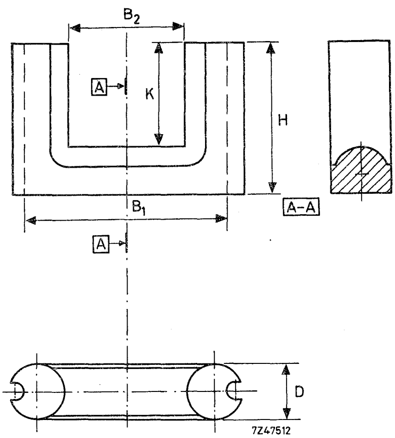


Fig.3

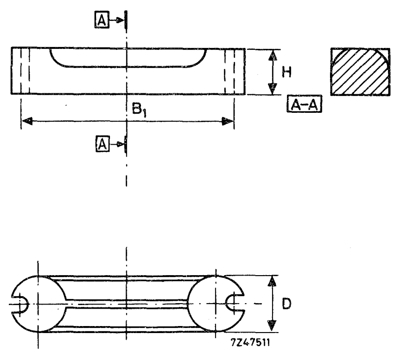


Fig.4

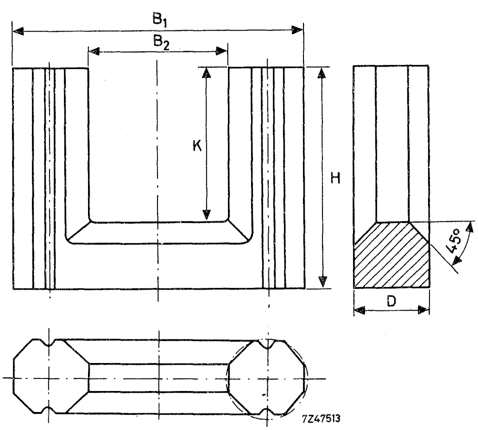


Fig.5

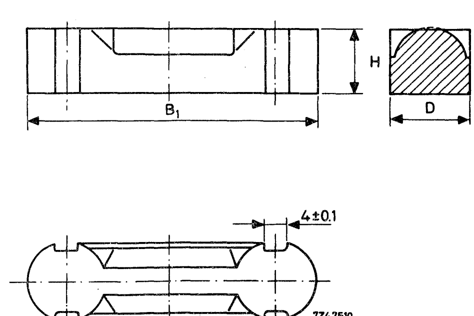


Fig.6

Available types for black and white television

Material: ferroxcube grade 3C6

B_1 (mm)	B_2 (mm)	H (mm)	K (mm)	D (mm)	Fig.	catalog number
40.7 ± 1.3	24.4 + 1.2	33 ± 0.2	23.1 + 0.9	11.4 - 0.5	3	3122 104 90481
39.6 ± 0.4		9.5 ± 0.2		11.4 - 0.5	4	3122 104 90471
49.6 ± 0.8	27 ± 1	44.2 ± 0.2	> 31	15.6 ± 0.4	3	4312 020 33381
50 ± 0.8		12.6 ± 0.2		15.6 ± 0.4	4	4312 020 33391
58 + 1.3	28 ± 1	44.6 ± 0.5	31.5 ± 0.5	15 ± 0.4	5	4312 020 33341
58 + 1.3	28 ± 1	34.6 ± 0.5	21.5 ± 0.5	15 ± 0.4	5	4312 020 33351
59.4 ± 0.8		13.5 ± 0.2		15 ± 0.4	6	4312 020 33361
72 ± 1	44 ± 1.4	33.1 ± 0.15	19 ± 0.4	14.1 ± 0.3	1[1])	4312 020 33001
93 ± 1.8	36.2 + 1.6	52 ± 0.5	24 ± 0.45	30 ± 0.6	1	4312 020 33102
93 ± 1.8		27.5 ± 0.5		30 ± 0.6	2	4312 020 33112
93 ± 1.8	36.2 + 1.6	76 ± 0.5	48 ± 0.9	30 ± 0.6	1	4312 020 33092
93 ± 1.8	36.2 + 1.6	76 ± 0.5	48 ± 0.9	16 ± 0.5	1	4312 020 33072
93 ± 1.8		27.5 ± 0.5		16 ± 0.5	2	4312 020 33082
101.6 ± 2	> 47	57.1 ± 0.4	31.7 ± 0.75	25.4 ± 0.8	1	4312 020 33122

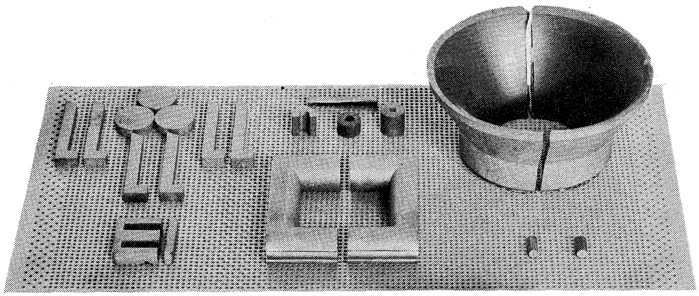
[1]) Notches in back.

Available types for colour television

Material: ferroxcube grade 3C6

B_1 (mm)	B_2 (mm)	H (mm)	K (mm)	D (mm)	Fig.	catalog number
60.35 ± 0.9	35.4 ± 1.2	33.35 ± 0.2	19.05 ± 0.5	17.25 ± 0.4	3	4312 020 33041
73 - 1.8	45.3 ± 1.2	65 - 1.5	49.9 ± 0.8	18.2 ± 0.4	3	3122 104 93121
73 - 1.8		14.8 ± 0.2		18.2 ± 0.4	4	3122 104 93131

FERRITES FOR COLOUR TV COMPONENTS

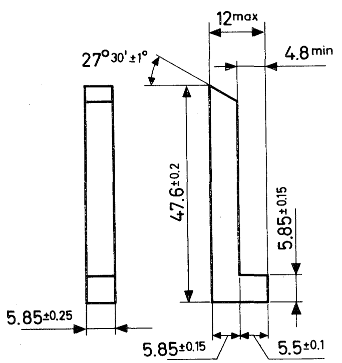


RZ 22938-3A

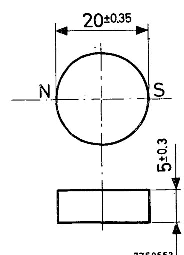
1. Yoke ring See page B21
2. U-cores See page B24

Special ferrite parts are:

3. Ferroxcube L-core and ferroxdure magnet for convergence units

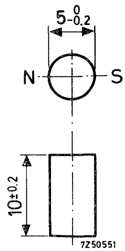


L-core
Ferroxcube 3C6
Catalog number: 3122 104 90682



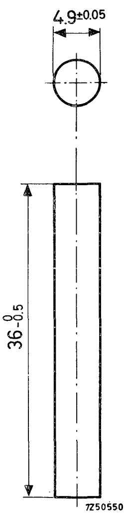
Disc magnet, diametrically magnetized
Ferroxdure 100
Catalog number: 3122 104 90622

4. Ferroxdure magnet for lateral convergency

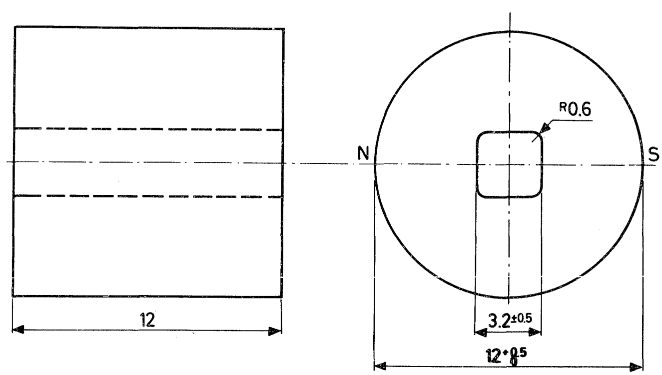


Rod magnet, diametrically magnetized
Ferroxdure 100
Catalog number: 3122 108 92851

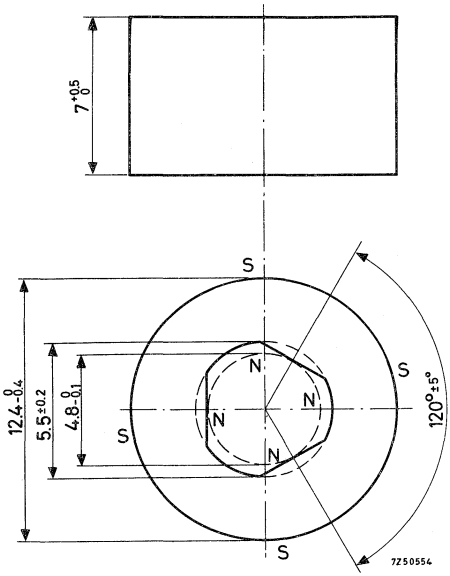
5. Ferroxcube rod and ferrite magnets for linearity-control units



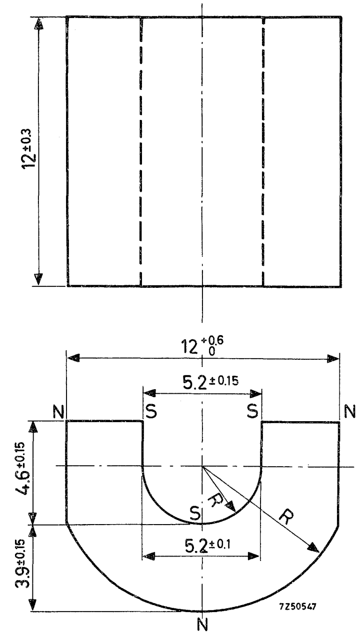
Rod core
Ferroxcube 3C6
Catalog number: 3122 104 90492



Ring magnet, diametrically magnetized
Ferroxdure 100. Catalog number 3122 104 92691

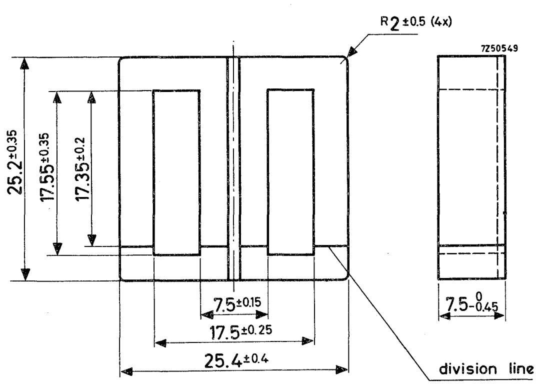


Ring magnet, radially magnetized
Plastic bonded ferroxdure P40
Catalog number: 3122 104 93532



Magnet segment, radially magnetized
Ferroxdure 100
Catalog number: 3122 104 90443

6. Ferroxcube E + I core for a raster correction transductor



E + I core
Ferroxcube 3C6
l_e = 5.75 cm
A_e = 0.55 cm^2
Catalog number:
3122 104 93213

FERROXPLANA, FOR V.H.F. AND U.H.F.

MATERIAL PROPERTIES

Ferroxplana is a hexagonal ferrite suitable for very high and ultra high frequencies. The main properties are:

	grade 1Z2	grade 1Z3
Initial permeability μ_i	15	10
$\frac{\tan\delta}{\mu_i}$ at 50 MHz	1.0×10^{-3}	-
100 MHz	2×10^{-3}	1.8×10^{-3}
200 MHz	6×10^{-3}	-
300 MHz	-	4×10^{-3}
500 MHz	-	10×10^{-3}
Temp. factor $\frac{\Delta\mu}{\mu^2 \Delta T}$	80×10^{-6}	250×10^{-6}
Spec. resistance (Ωcm)	10^6	10^6
Frequency range (MHz)	50 - 200	200 - 500

FERROXPLANA BEADS

Preferred types in 1Z2

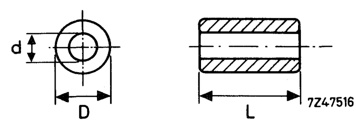


Fig.1. Tube

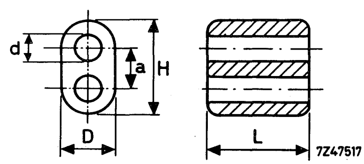


Fig.2. Twin-bead for balun transformers

Fig.	L (mm)	D (mm)	d (mm)	H (mm)	a (mm)	catalog number
1	15 ± 0.4	8.5 ± 0.3	3.9 ± 0.2	-	-	3122 104 91711
1	10 ± 0.6	4 + 0.6	2 + 0.4	-	-	91761
1	5 ± 0.3	4.6 - 0.6	2 + 0.4	-	-	91781
1	3.5 - 0.5	3.7 - 0.4	1.5 + 0.2	-	-	3122 104 90231
2.	14 ± 0.5	8.25 ± 0.25	3.4 + 0.6	14 ± 0.5	5.85 ± 0.25	4322 020 69751

Other shapes: on request

POWDER IRON CORES

MATERIAL PROPERTIES

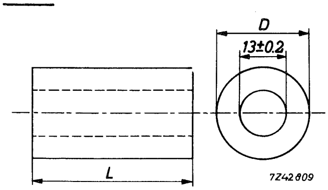
Main properties of the various grades of powder iron: 1P1, 1P2, 1P3, 2P1.

freq. range	grade	Q-factor measured on a small ring	μ_i	particle size
up to 10 MHz	1P1	300 at 10 MHz	10 appr.	6 - 8 μm
up to 40 - 80 MHz	1P2	350 at 30 MHz	8.5 appr.	4 - 6 μm
up to 40 - 80 MHz	1P3 [1]	350 at 30 MHz	8.5 appr.	4 - 6 μm
up to 100 MHz	2P1		2.5 appr.	

[1]) Only for cast parts

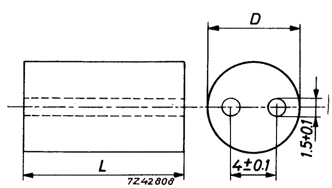
CORES FOR SMALL I.F. COILS

Tube



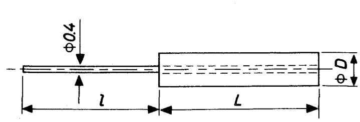
Grade 1P1
L = 31.7 ±0.2 mm
D = 18 ±0.2 mm
Catalog number:
4322 020 69521

Twin bead



Grade 2P1
L = 8 +0.2 mm
D = 8 -0.1 mm
Catalog number:
4322 020 69511

Cores with a tinned copper wire



Grade 1P3

l (mm)	L (mm)	D (mm)	catalog number
30 +4	30±0.5	4.00 - 0.15	3122 997 70401
33 +4	28±0.5	4.95 - 0.1	3122 108 70061
40 +4	22±0.5	4.95 - 0.1	3122 108 70051

Screw cores

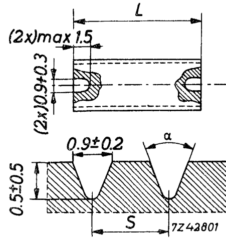


Fig.1

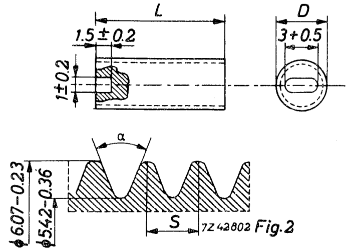


Fig.2

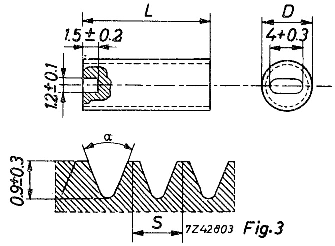


Fig.3

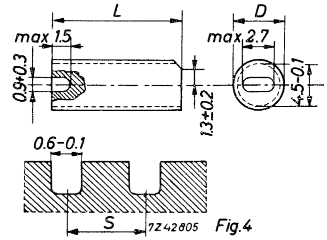


Fig.4

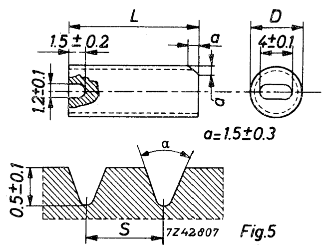


Fig.5

L (mm)	D (mm)	α	S (mm)	tol.[1] (mm)	n	grade	Fig.	catalog number
5±0.3	4.95 - 0.1	≤ 85°	1.5	0.1	1	1P1	1	3122 104 91581
6±0.5	6.07 - 0.23	60°	0.5			1P1	2	4322 020 69501
8±0.3	4.95 - 0.1	≤ 85°	1.5	0.2	4	1P2	1	3122 104 91611
10±0.3	7 - 0.1	60° ± 10°	1	0.1	1	1P2	3	3122 104 91591
12.25±0.3	4.95 - 0.1	≤ 85°	1.5	0.2	5	1P2	1	3122 104 91601
12.25±0.3	4.95 - 0.1	-	1.5	0.05	1	1P1	4	3122 104 93141
12.25±0.3	4.95 - 0.1	≤ 85°	1.5	0.2	5	1P1	1	3122 104 90971
13 - 1.5	6.07 - 0.23	60°	0.5	-	-	1P1	2	3122 104 90991
15±0.3	4.95 - 0.1	70° + 15°	1.5	-	-	1P1	1	3122 104 92971
16.5±0.3	7 - 0.1	60°	1.5	0.05	1	1P2	5	3122 104 91001
16.5±0.3	7 - 0.1	60° + 10°	1	0.1	1	1P2	3	3122 104 91661
20.25±0.4	4.95 - 0.1	≤ 85°	1.5	0.2	5	1P1	1	3122 104 90981

[1]) Tolerance on S in mm over n grooves

CORES FOR ERASING HEADS

10207

For good erasing of magnetic tape at a low noise level, a frequency is required that is several times higher than the maximum frequency to be recorded. That is why, for use in erasing heads a core material with low eddy current losses is recommended. Low eddy current losses imply low heat dissipation, and consequently less power for the erasing procedure.
Ferroxcube cores possess this property in a much higher degree than laminated metal cores, so that they are plainly indicated for this application.
The tables below contain data of ferroxcube cores in the material grades 3C1 and 3C2.

Material properties

low eddy current losses at frequencies up to 500 kHz

the initial permeability is approximately 900

the saturation flux at 23 °C is
of ferroxcube 3C1 approximately 3300 gauss
of ferroxcube 3C2 approximately 3800 gauss

two shapes are available: in ferroxcube 3C1 according to Fig. 1, in ferroxcube 3C2 according to Fig. 2.

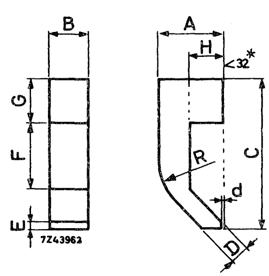


Fig. 1

* for 4322 020 30570 only

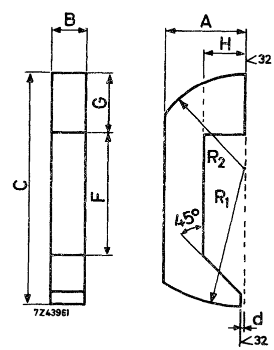


Fig. 2

Table 1, survey of cores in ferroxcube grade 3C1 and in shape according to Fig. 1.

catalog number	dimensions in mm										weight in grams
	A	B	C	D	d	E	F	G	H	R	
4322 020 30550	4.7-0.4	1.7-0.4	11±0.2	1.4±0.2	0	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.23
3104 101 80230	4.7-0.4	3.6-0.2	11±0.2	1.4±0.2	0	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.54
3922 860 20550	4.7-0.4	7.1-0.2	11±0.2	1.4±0.2	0	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	1.02
4322 020 30560	4.7-0.4	1.2-0.4	11±0.2	1.4±0.2	0	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.15
4322 020 30570	4.7-0.4	3.5-0.3	11±0.2	1.4±0.2	0	0.55±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.54
4322 020 30630	4.7-0.4	2.8-0.2	11±0.2	1.4±0.2	0+0.2	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.44
3122 104 92540	4.7-0.3	1.4-0.2	11±0.2	1.4±0.2	0+0.2	0.5 ±0.1	4.8+0.4	3.2-0.4	2.4+0.2	5±0.2	0.22
4322 020 30600	3.1-0.3	1.6-0.2	9.2±0.2	1.4±0.1	0+0.1	0.5 ±0.1	3.8+0.4	3.2-0.4	1.4+0.2	2±0.2	0.12

Table 2, survey of cores in ferroxcube grade 3C2 and in shape according to Fig. 2.

catalog number	dimensions in mm									weight in grams
	A	B	C	d	F	G	H	R_1	R_2	
4322 020 30580	5.8-0.4	3.6-0.2	18±0.4	0.1±0.05	9.4+0.4	4.5-0.4	3+0.2	11±0.2	7±0.2	1.22
4322 020 30590	5.8-0.4	1.6-0.2	18±0.4	0.1±0.05	9.4+0.4	4.5-0.4	3+0.2	11±0.2	7±0.2	0.52
4322 020 30610	5.8-0.4	2.6-0.2	18±0.4	0.1±0.05	9.4+0.4	4.5-0.4	3+0.2	11±0.2	7±0.2	0.87

Ferroxcube potcores

GENERAL

INTRODUCTION

Ferroxcube potcores have been developed for constant low loss filters, coils and transformers. Due to their closed shape they combine a low weight with a small volume.

The principal properties of a potcore with a given inductance value are the quality factor Q, the temperature coefficient T.F., the disaccommodation factor D.F. and, if the potcore is used on higher induction values, the non-linearity.

Our Ferroxcube potcore programme comprises three ranges of potcores:

- The preferred P-potcores, which are standardised in accordance with the international I.E.C., the German D.I.N. and the French C.C.T.U. specifications;
- The non-preferred S-potcores;
- The non-preferred D-potcores.

SURVEY OF SYMBOLS

l_e — effective length of the magnetic path in cm

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

μ_i — relative initial permeability, defined by:

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

μ_e — relative effective permeability, defined by

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

μ_{diff} — relative differential permeability, defined by

$$\mu_{diff} = \frac{dB}{dH}$$

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

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

Δ — length of the air gap in mm

α — turns factor = number of turns for 1 mH

A_L — inductance factor = inductance per turn in nanohenry (10^{-9} H)

$\hat{H}$ — peak field strength in oerstedt

$\hat{B}$ — peak induction in gauss

AT — amperes x turns

N — number of turns

$T.F. = \frac{1}{\mu^2} \cdot \frac{d\mu}{dT}$

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 and a constant has to be added for the wound bobbin.

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

The constant C lies between $+20 \times 10^{-6}$ and 40×10^{-6}.

$D.F. = \frac{\mu_1 - \mu_2}{\mu_1{}^2 \log \frac{t_2}{t_1}}$

disaccommodation factor, which gives the permeability variation of the core, measured between 10 and 100 minutes after demagnetisation.

So $D = D.F. \times \mu_e \log \frac{t_2}{t_1}$

Curie point

critical temperature in $^{\circ}C$ above which the ferromagnetic body is paramagnetic.

$\frac{\tan \delta}{\mu_i}$

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:

$$\frac{R}{L} = \frac{\tan \delta}{\mu_i} \times \mu_e \times 2\pi f \;\; \Omega/H \qquad \text{(f in Hz)}$$

$q_2 - 24 - 100$

constant for hysteresis losses standardized for an effective volume of $24\ cm^3$, $\mu_e = 100$ and measured between two currents, corresponding with two specified B_{max} values.

At 800 Hz for a given volume V_e and for an equivalent 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)

specific resistance in Ω.cm measured with d.c. current.

PRE-ADJUSTED POTCORES

In principle potcores with any μ_e value and A_L-factor can be manufactured. However, in practice the ranges are limited to the μ_e-values and A_L-factors required for the most important fields of application.

Recommended are the pre-adjusted potcores which are provided with a nut for an adjustor. However, for those users who prefer to insert the nut themselves, some information is given under Mounting Data in this general part and under Mounting Parts in the data sheets.

For each μ_e-value and A_L-factor of the pre-adjusted potcores a continuously variable adjustor mechanism can be delivered. These continuously variable adjustors are specially recommended if the coils are employed as filter coils. The maximum adjustment varies from 8 - 14 %, depending on the type.
For the potcores P26/16 and larger a step-by-step adjustment can be delivered, specially recommended if the coils are employed as loading coils. For detailed data see the relevant sections Inductance Adjustment in the data sheets.

When the aforementioned adjustors are used, coils with a higher μ_e value can be designed in order to obtain a maximum quality factor with a minimum volume, maintaining a small inductance tolerance field.

α AND A_L FACTORS

α is the number of turns for an inductance of 1 mH for a given core shape. For other inductance values the number of turns is $N = \alpha \sqrt{L}$ (L in millihenrys).

A_L is the inductance per turn in nanohenrys (10^{-9} H) for a given core shape. For a given number of turns the total inductance is $L = N^2 A_L$ (L in nanohenrys).

The α and A_L values mentioned under "Pre-adjusted potcores" in the data sheets are valid for potcores without inductance adjustor. The adjustors give an increase in inductance of the potcores as given under "Inductance adjustment".

Measurement

The α and A_L factors given in the data sheets are guaranteed by means of a tolerance on the inductance, which is valid when the ten following measuring conditions are met:

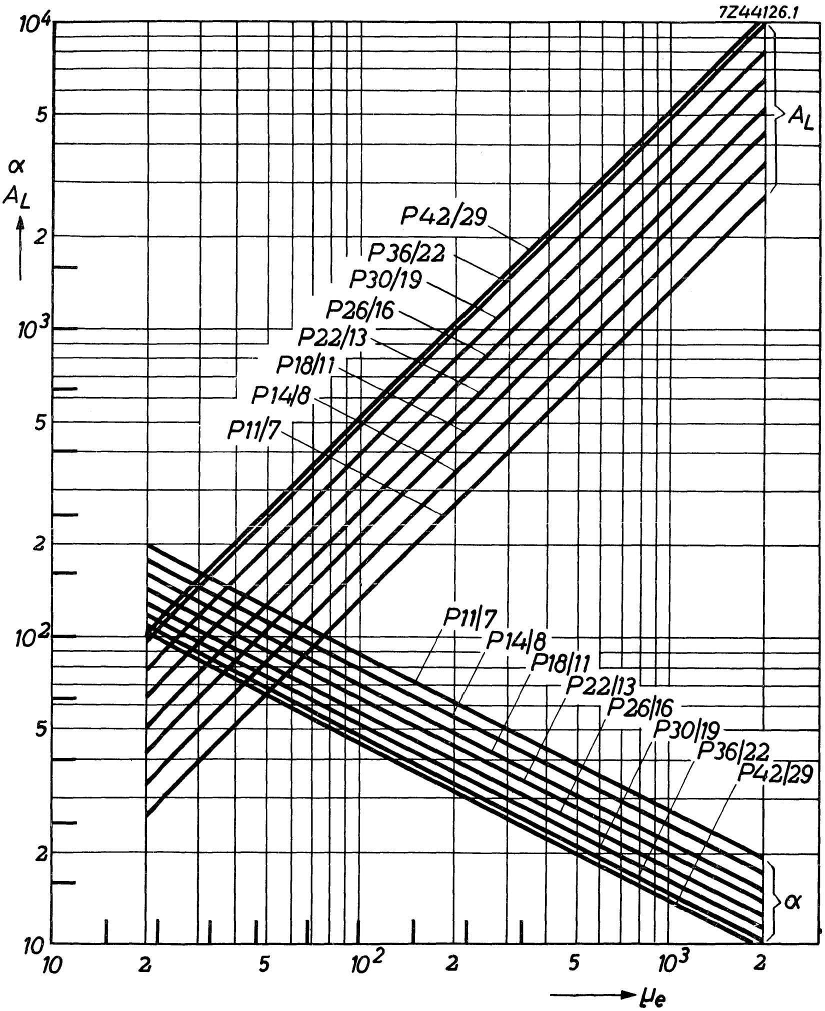
1. The core should be magnetically conditioned (demagnetised). The α or A_L value should not be measured less than 24 hours after the conditioning (demagnetisation).

2. The mating surfaces should be carefully cleaned.
3. A standard coil as indicated in the following table should be used.

for series	catalog number of standard coil	number of turns			number of layers	diam. of copper (mm)	catalog number of coil former
		total	per layer	upper layer			
P 11/7	7622 301 00301	71	12	11	6	0.25	4322 021 30240
P 14/8	7622 301 00501	90	13	12	7	0.30	4322 021 30250
P 18/11	7622 301 00701	83	12	11	7	0.45	4322 021 30270
P 22/13	7622 301 00901	71	12	11	6	0.60	4322 021 30300
P 26/16	7622 301 01101	71	12	11	6	0.70	4322 021 30330
P 30/19	7622 301 01301	104	15	14	7	0.70	4322 021 30360
P 36/22	7622 301 01501	135	17	16	8	0.70	4322 021 30390
P 42/29	7622 301 01701	199	20	19	10	0.80	4322 021 30420
P 66/56	7622 301 01901						
S 14/8	7622 301 02601	80	9	8	9	0.25	4312 021 28170
S 18/12	7622 301 02701	219	20	19	11	0.30	4312 021 28150
S 25/16	7622 301 02901	208	19	18	11	0.40	4312 021 28130
S 35/23	7622 301 03001	143	16	15	9	0.70	3522 200 00910
S 45/25	7622 301 03101	215	18	17	12	0.70	4322 021 31530
D 25/12	7622 301 03301	79	8	7	10	0.45	3522 200 13190
D 25/16	7622 301 03401	159	16	15	10	0.45	3522 200 13180
D 36/22	7622 301 03501	215	18	17	12	0.55	3522 200 03200
D 36/22N	7622 301 03601	143	12	11	12	0.55	3122 794 35270

4. The axial lines of the potcore halves have to coincide.
5. The silver reference lines (if any) on the circumference of the potcore halves should coincide.
6. A force is applied to the flat sides of the potcore by means of rings. The inner diameter of these rings should be equal to the average value of the inner diameter of the potcore.
7. The force mentioned above should be as given in the relevant data sheets.
8. The temperature should be $23 \pm 2\ ^{o}C$.
9. The frequency should be 4 kHz.
10. The current through or the voltage over the coil should correspond to a peak flux density ($\hat{B}$) in the core of ≤ 1 Gs.

Conversion of μ_e-values into α and A_L values



MEASUREMENT OF HYSTERESIS, EDDY CURRENT AND RESIDUAL LOSSES

The hysteresis losses are expressed in the factor $q_{2-24-100}$, see Survey of Symbols. For guaranteed values, measuring frequencies and induction values see the relevant data sheets.

The eddy current and the residual losses are measured at an induction $\hat{B} \leq 1$ Gs and are expressed in a $\frac{\tan \delta}{\mu_i}$ value. For guaranteed values and measuring frequencies see the relevant data sheets.

The windings used for the measurement of the above mentioned quantities are indicated in the following table. The winding data refer to a single-section bobbin.

potcore	FXC grade	4 kHz	100 kHz	0.5 - 1 MHz	2 MHz	5 MHz	10 MHz
P 9/5	3B5	-	35 turns 0.20 E	-	-	-	-
P 11/7	3B7/3H1	-	42 turns 0.18 E	-	-	-	-
	3D3	-	42 turns 0.18 E	22 turns 0.10 E	-	-	-
	4C4	-	-	-	16 turns 45 x 0.04 E	6 turns 40 x 0.04 E.S.	3 turns 1 x 1.55 Cu
P 14/8	3B7/3H1	53 turns 0.25 E	37 turns 0.10 E	-	-	-	-
	3D3	-	37 turns 0.10 E	19 turns 8 x 0.04 E.S.	-	-	-
	4C4	176 turns 0.14 E	-	-	14 turns 0.40 E	6 turns 0.5 x 1.9 Cu	3 turns 0.7 x 1.9 Cu
P 18/11	3B7/3H1	42 turns 0.50 E	35 turns 0.14 E	-	-	-	-
	3D3	-	35 turns 0.14 E	16 turns 12 x 0.04 E.S.	-	-	-
	4C4	150 turns 0.25 E	-	-	12 turns 0.60 E	5 turns 0.7 x 2.75 Cu	2 turns 2.2 x 2.75 Cu
P 22/13	3B7/3H1	37 turns 0.60 E	29 turns 0.20 E	-	-	-	-
	3D3	-	29 turns 0.20 E	16 turns 40 x 0.04 E.S.	-	-	-
	4C4	140 turns 0.25 E	-	-	11 turns 0.70 E	4 turns 1.2 x 3.5 Cu	2 turns 2.8 x 3.5 Cu
P 26/16	3B7/3H1	34 turns 0.70 E	28 turns 0.28 E	-	-	-	-
	3D3	-	28 turns 0.28 E	14 turns 40 x 0.04 E.S.	-	-	-
	4C4	125 turns 0.40 E	-	-	10 turns 0.90 E	4 turns 2.0 x 4.0 Cu	2 turns 3.5 x 4.0 Cu

potcore	FXC grade	4 kHz	100 kHz	0.5 - 1 MHz	2 MHz	5 MHz	10 MHz
P 30/19	3B7/3H1	30 turns 1.0 E	23 turns 0.40 E	–	–	–	–
	3D3	–	23 turns 0.40 E	8 turns 2 x (100 x 0.04)E.S.	–	–	–
P 36/22	3B7/3H1	27 turns 1.2 E	22 turns 0.50 E	–	–	–	–
	3D3	–	22 turns 0.50 E	7 turns 2 x (100 x 0.04)E.S.	–	–	–
P 42/29	3B7/3H1	26 turns 1.8 E	20 turns 0.45 E	–	–	–	–
	3B5	33 turns 1.4 E	32 turns 0.45 E	–	–	–	–
P 66/56	3H1/3B5	21 turns 1.5 E	18 turns 1.5 E	–	–	–	–
S 14/8	3B3	–	40 turns 0.16 E	12 turns 45 x 0.04 E.S.	–	–	–
	4B1	–	–	12 turns 45 x 0.04 E.S.	–	–	–
	4C1	–	–	–	11 turns 0.50 E	5 turns 100 x 0.04 E.S.	–
S 18/12	3B3	–	39 turns 0.14 E	12 turns 45 x 0.04 E.S.	–	–	–
	4B1	–	–	15 turns 45 x 0.04 E.S.	–	–	–
S 25/16	3B3	–	45 turns 0.16 E	10 turns 2 x (100 x 0.04)E.S.	–	–	–
S 35/23	3B5	–	26 turns 0.40 E	–	–	–	–
S 45/25	3B5	50 turns 0.45 E	24 turns 0.45 E	–	–	–	–

CALCULATIONS

LOSSES IN A COIL

The losses can be divided into two groups:

Losses in the winding	Losses in the core
- d.c. copper losses	- hysteresis losses
- eddy current losses	- eddy current losses
- dielectric losses	- residual losses

The screening losses may be neglected when using ferroxcube potcores. So we can say:

$$\frac{R_t}{L} = \frac{R_o}{L} + \frac{R_{ec}}{L} + \frac{R_d}{L} + \frac{R_h}{L} + \frac{R_r}{L} + \frac{R_e}{L} \qquad \Omega/H \qquad \text{Eq. (1)}$$

For filter coils as a rule the maximum Q can be obtained if the sum of the copper losses is made equal to the sum of the core losses.

D.C. copper losses

D.C. losses are given with the formula:

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times \text{constant} \qquad \Omega/H \qquad (2)$$

In this formula μ_e is the effective permeability of the magnetic circuit. f_{cu} is the space factor, which depends on the diameter and insulation of the wire in question, and the method of winding. Values from 0.6 to 0.1 can be obtained.

Eddy current losses in the winding

$$\frac{R_{ec}}{L} = \frac{C_{wcu}}{\mu_e} \times V_{cu} \times f^2 \times d^2 \qquad \Omega/H \qquad (3)$$

C_{wcu} is the eddy current copper factor, depending on the dimensions of the coil former and the core.

V_{cu} is the copper volume in cm^3
f is the frequency in Hz
d is the diameter of a single wire in cm

Dielectric losses

The distributed capacitance of the coil is not loss-free. This capacitance has a loss angle tan δ_c which increases the a.c. resistance of a coil.

$$\frac{R_d}{L} = \left(\frac{2}{Q} + \tan\delta_c\right) \times \omega^3 \times L \times C_o \qquad \Omega/H \qquad (4)$$

in which Q is the quality factor of the coil.

ω = 2 x π x f
f in Hz
L in henry
C_o in farad

Hysteresis losses

These losses depend on the $q_{2\text{-}24\text{-}100}$ value of the ferroxcube grade concerned, the μ_e value, effective volume of the potcore, inductance and current.

$$\frac{R_h}{L} = q_{2\text{-}V\text{-}\mu} \times \sqrt{L} \times i \times \frac{f}{800} \qquad \Omega/H \qquad (5)$$

For $q_{2\text{-}V\text{-}\mu}$ see Survey of symbols.

Eddy current and residual losses

In the survey of ferroxcube 3 and 4 core material properties, $\frac{\tan\delta}{\mu_i}$ is given as the sum of eddy current and residual losses. These losses are measured on a toroid of approximately 35 mm outer diameter. For these toroids we obtain:

$$\frac{\tan\delta_{e+r}}{\mu_i} = \frac{\tan\delta_e}{\mu_i} + \frac{\tan\delta_r}{\mu_i} = \frac{\tan\delta_r}{\mu_i} + K_1 f \qquad (6)$$

In eq.(6) K_1 is a constant. $K_1 f$ is small with regard to $\frac{\tan\delta_r}{\mu_i}$, but cannot fully be neglected.

Depending on the dimensions, the potcore may have a better or worse configuration than the toroid for eddy current losses.

For a potcore we obtain:

$$\frac{R_r}{L} = \left(\frac{\tan\delta_{e+r}}{\mu_i} - K_1 f\right) \times \mu_e \times 2\pi f \qquad \Omega/H \qquad (7)$$

and

$$\frac{R_e}{L} = K_2 \times f \times \mu_e \times 2\pi f \qquad \Omega/H \qquad (8)$$

In the latter equation K_2 is a constant depending on the potcore size and the resistivity of the material.

EXAMPLES OF CALCULATION

Example 1:

A filter coil has to be calculated for 2.99 mH with a maximum permissible temperature coefficient of $+5 \times 10^{-3}$ between +20 and +50 °C. The Q factor has to be at least 300 at 120 kHz, the alternating current through the coil is 1 mA.

First the maximum μ_e value is calculated from the maximum temperature coefficient.

$$\text{t.c.} = \left(\frac{\Delta\mu}{\mu_i^2} \times \mu_e + C \right) \times \Delta T \quad \text{(See T.F. in Survey of symbols)}$$

Assume $C = +30 \times 10^{-6}$, then:

$$\mu_e = \frac{\text{t.c.} - C \times \Delta T}{\frac{\Delta\mu}{\mu_i^2} \times \Delta T} = \frac{5 \times 10^{-3} - 900 \times 10^{-6}}{+2 \times 10^{-6} \times 30} = 68.3 \text{ maximum.}$$

At 120 kHz ferroxcube grade 3B2 is a good material, and the adjusted potcore S 18/12, with $\mu_e = 65$, number 4322 022 99540 could be used.

$$N = \alpha \sqrt{L} = 96 \sqrt{2.99} = 166 \text{ turns.}$$

For 120 kHz stranded wire 12 x 0.07 E.S.S. is used. The coil former 4312 021 28150 then should be wound fully.

Eq.(2): $$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 15.22 \times 10^3 \quad \Omega/\text{H (see data S 18/12)}$$

Say $f_{cu} = 0.29$ for this type of wire

$$\frac{R_o}{L} = \frac{1}{65} \times \frac{1}{0.29} \times 15.22 \times 10^3 = 808 \quad \Omega/\text{H}$$

Eq.(3): $$\frac{R_{ec}}{L} = \frac{C_{wcu}}{\mu_e} \times V_{cu} \times f^2 \times d^2 \quad \Omega/\text{H}$$

Assume that $C_{wcu} = 100 \times 10^{-6}$

$$\frac{R_{ec}}{L} = \frac{100 \times 10^{-6}}{65} \times 0.2\,(120 \times 10^3)^2 \times (0.07)^2 = 21.8 \quad \Omega/\text{H}$$

Eq.(4): $$\frac{R_d}{L} = \left(\frac{2}{Q} + \tan\delta_c \right) \omega^3 \times L \times C_o \quad \Omega/\text{H}$$

Assume that $\tan\delta_c = 0.01$ and $C_o = 25$ pF

$$\frac{R_d}{L} = \left(\frac{2}{300} + 0.01 \right) \times (2 \times \pi \times 120 \times 10^3)^3 \times 2.99 \times 10^{-3} \times 25 \times 10^{-12} = 530 \quad \Omega/\text{H}$$

Eq.(5): $\frac{R_h}{L} = q_{2\text{-}V\text{-}\mu} \times \sqrt{L} \times i \times f_{800}$ Ω/H

$$q_{2\text{-}V\text{-}\mu} = q_{2\text{-}24\text{-}100} \times \left\{\frac{\mu_e}{100}\right\}^{3/2} \times \sqrt{\frac{24}{V_e}} \qquad \Omega/H^{3/2}\ mA$$

Take $q_{2\text{-}24\text{-}100} = 8\ \Omega/H^{3/2}$ mA for grade 3B2 as an average value.

So $q_{2\text{-}V\text{-}\mu} = 8 \times \frac{65\sqrt{65}}{1000} \times \sqrt{\frac{24}{0.743}} = 23.9 \qquad \Omega/H^{3/2}\ mA$

Then $\frac{R_h}{L} = 23.9 \sqrt{2.99 \times 10^{-3}} \times 1 \times \frac{120 \times 10^3}{800} = 196 \qquad \Omega/H$

Eq.(7): $\frac{R_r}{L} = \left\{\frac{\tan \delta_{e+r}}{\mu_i} - K_1 f\right\} \times \mu_e \times 2\pi f \qquad \Omega/H$

Take $\frac{\tan \delta_{e+r}}{\mu_i}$ at 120 kHz of grade 3B2 = 18×10^{-6} as an average value and

$$K_1 = 0.29 \times 10^{-11}$$

$$\frac{R_r}{L} = (18 \times 10^{-6} - 0.29 \times 10^{-11} \times 120 \times 10^3) \times 65 \times 6.28 \times 120 \times 10^3 = 865 \qquad \Omega/H$$

Eq.(8): $\frac{R_e}{L} = K_2 \times f \times \mu_e \times 2\pi f \qquad \Omega/H$

Assume $K_2 = 0.13 \times 10^{-10}$ for potcore S 18/12

$$R_e = 0.13 \times 10^{-10} \times 120 \times 10^3 \times 65 \times 6.28 \times 120 \times 10^3 = 76.5 \qquad \Omega/H$$

Eq.(1): $\frac{R_t}{L} = \frac{R_o}{L} + \frac{R_{ec}}{L} + \frac{R_d}{L} + \frac{R_h}{L} + \frac{R_r}{L} + \frac{R_e}{L} \qquad \Omega/H$

$$= 808 + 21.8 + 530 + 196 + 865 + 76.5 = 2497.3 \qquad \Omega/H$$

Quality factor $Q = \frac{2\pi f}{R_t/L} = \frac{6.28 \times 120 \times 10^3}{2497.3} = 302$

The measured value, see Q-curve for $\mu_e = 65$ of potcore S 18/12 is 295. This is well in accordance with the calculated value of 302. An accuracy within ±15% for coil calculations is generally regarded as very good, as a very great number of variables has to be taken into account.

Example 2:

A loading coil for side circuits of 44 mH has to be calculated with an inductance tolerance of ±2%.

The d.c. resistance must be < 2.40 Ω and the resistance at 1800 Hz and 1 mA < 3.90 Ω.

The maximum permitted $\frac{R_c}{L} = \frac{2.40}{44 \times 10^{-3}} = 54.5 \quad \Omega/H$

Try for instance potcore S 35/23, for which

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 3.8 \times 10^3 \quad \Omega/H$$

Assume $f_{cu} = 0.47$ for solid wire with polyvinylformal insulation

$$\mu_e \min = \frac{3.8 \times 10^3}{(R_o/L) f_{cu}} = \frac{3.8 \times 10^3}{54.5 \times 0.47} = 148$$

So take $\mu_e = 150$ as for the adjusted potcore 4322 022 99700 in 3B5 grade.

$$N = \alpha \sqrt{L} = 37 \sqrt{44} = 246 \text{ turns.}$$

Take 0.40 ⌀ mm solid wire with polyvinylformal insulation, then the coilformer is fully wound.

Eq.(2): $\frac{R_o}{L} = \frac{1}{150} \times \frac{1}{0.47} \times 3.8 \times 10^3 = 54 \quad \Omega/H$

Eq.(3): $\frac{R_{ec}}{L} = \frac{C_{wcu}}{\mu_e} \times V_{cu} \times f^2 \times d^2 \quad \Omega/H$

Assume $C_{wcu} = 110 \times 10^{-6}$

then $\frac{R_{ec}}{L} = \frac{110 \times 10^{-6}}{150} \times 2.25 \times 3.24 \times 10^6 \times 0.16 = 0.86 \quad \Omega/H$

Eq.(4): $\frac{R_d}{L} = (\frac{2}{Q} + \tan \delta_c)\, \omega^3 \times L \times C_o \quad \Omega/H$

Assume Q at 1800 Hz = 190 and C_o = 30 pF and $\tan \delta_c = 0.01$, then

$$\frac{R_d}{L} = (\frac{2}{190} + 0.01) \times (2 \times \pi \times 1800)^3 \times 44 \times 10^{-3} \times 30 \times 10^{-12} = \text{negligible.}$$

Eq.(5): $\frac{R_h}{L} = q_{2\text{-}V\text{-}\mu} \times \sqrt{L} \times i \times \frac{f}{800}$ Ω/H

$q_{2\text{-}V\text{-}\mu} = q_{2\text{-}24\text{-}100} \times \left\{\frac{\mu_e}{100}\right\}^{3/2} \times \sqrt{\frac{24}{V_e}}$ $\Omega/H^{3/2} \times$ mA

Assume:

$q_{2\text{-}24\text{-}100} = 1.5 \times \frac{150\sqrt{150}}{1000} \times \sqrt{\frac{24}{11.7}} = 3.94$ $\Omega/H^{3/2} \times$ mA

$\frac{R_h}{L} = 3.94 \times \sqrt{44} \times 10^{-3} \times 1 \times \frac{1800}{800} = 1.86$ Ω/H

Eq.(7): $\frac{R_r}{L} = \frac{\tan\delta}{\mu_i} \times \mu_e \times 2 \times \pi \times f$

Assume:

$\frac{\tan\delta}{\mu_i}$ of 3B5 grade at 1800 Hz = 1.5×10^{-6} as an average value.

$\frac{R_r}{L} = 1.5 \times 10^{-6} \times 150 \times 6.28 \times 1800 = 2.55$ Ω/H

Eq.(8): Eddy current core losses are negligible at the frequency concerned.

Eq.(1): $\frac{R_t}{L} = \frac{R_o}{L} + \frac{R_{ec}}{L} + \frac{R_d}{L} + \frac{R_h}{L} + \frac{R_r}{L} + \frac{R_e}{L}$ Ω/H

$= 54 + 0.86 + 0 + 1.86 + 2.25 + 0 = 59.27$ Ω/H

or R_t at 1800 Hz and 1 mA = 2.61 ohms

So we see that the requirement for R_t at 1800 Hz - 1 mA is amply fulfilled and we also notice that the increase of resistance due to the a.c. losses is very low for ferroxcube.

Q-CURVES

As so many assumptions have to be made in calculating potcores, an accuracy in Q-factor of better than ± 15 % is difficult to obtain. Because of this, the proper value of μ_e or A_L for a given potcore is best arrived at by comparing Q-curves for various values of μ_e.

Several curves are included for most potcores, and for those of the P-range a series of transparent sheets, with curves identical to those included here, are available. These are all of the same size and to the same scale, and those for a given potcore have been made using identical coil windings, so that registration is obtainable when two or more sheets are superimposed for comparison.

Consequently curves for different μ_e values and the same potcore size can be compared, as well as curves for the same μ_e value and different potcore sizes.

The Q-factors for inductances other than those given in the curves may be found by inter- or extrapolation, as necessary.

HYSTERESIS CONSTANTS

In literature the hysteresis losses are expressed in several ways; also different hysteresis constants are used. The hysteresis contribution to the core losses can be expressed in the factor:

$$\frac{R_h}{L} \text{ in } \frac{\text{Ohm}}{\text{Henry}}$$

In table I several hysteresis constants are given:

Table I	R	L	B	H	I	V	l_e	f
	units							
$\frac{R_h}{L} = q_{2\text{-}24\text{-}100} \sqrt{\frac{24}{V_e}} \sqrt{\left(\frac{\mu_e}{100}\right)^3} \sqrt{L} \cdot I_{rms} \cdot \frac{f}{800}$	Ω	H			mA	cm^3		Hz
$\frac{R_h}{L} = a . \mu . \hat{B} . f$	Ω	H	G					Hz
$\frac{R_h}{L} = \frac{16}{3} \cdot \frac{\nu}{\mu^3} \cdot \mu^2 \cdot \hat{H} . f$	Ω	H		Oe				Hz
$\frac{R_h}{L} = \frac{h}{\mu^2} \cdot \mu^2 \cdot \frac{N I_{eff}}{l_{eff}} \cdot \frac{f}{800}$	Ω	H			A		cm	Hz
$\frac{R_h}{L} = \frac{h'}{\mu^2} \cdot \mu^2 \cdot H_{eff} \cdot f$	Ω	H		$\frac{A}{cm}$				kHz
$\frac{R_h}{L} = \eta_B \cdot \mu \cdot \hat{B} \cdot \omega \; (\omega = 2 \pi f)$	Ω	H	T					Hz

If the quantities of table I are used, the mutual reduction factors of the different hysteresis constants are indicated in table II.

Table II	$q_{2-24-100}$ x	a x	$\frac{\nu}{\mu^3}$ x	$\frac{h}{\mu^2}$ x	$\frac{h'}{\mu^2}$ x	η_B x
$q_{2-24-100}$ =	1	2.59×10^6	13.8×10^6	1.82×10^3	1.46×10^3	1.63×10^3
a =	0.386×10^{-6}	1	5.33	0.703×10^{-3}	0.563×10^{-3}	0.628×10^{-3}
$\frac{\nu}{\mu^3}$ =	72.4×10^{-9}	0.188	1	0.132×10^{-3}	0.106×10^{-3}	0.118×10^{-3}
$\frac{h}{\mu^2}$ =	0.549×10^{-3}	1.42×10^3	7.58×10^3	1	0.8	0.893
$\frac{h'}{\mu^2}$ =	0.686×10^{-3}	1.78×10^3	9.48×10^3	1.25	1	1.12
η_B =	0.615×10^{-3}	1.59×10^3	8.49×10^3	1.12	0.896	1

Example: $q_{2-24-100} = 1.46 \times 10^3 \times \frac{h'}{\mu^2}$

MARKING

Type of piece part	Type description	Position of description	Example
Separate halves without air gap diam. > 15 mm	dimensions, material, date and manufacturer	on the base	18/11 3H1 B3A
diam. $\leq$ 15 mm	material	on the base	
	type, material, date and manufacturer	on the primary pack	P 14/8 3H1 - B3A
Separate halves with an air gap diam. > 15 mm	dimensions, material, date and manufacturer, air gap	on the base	25/16 3H1 B3A 0.5
diam. $\leq$ 15 mm	material, air gap	on the base	
	type, material, date and manufacturer, air gap	on the primary pack	S 14/8 - 3 B B3A - 0.3
Pre-adjusted potcores diam. > 15 mm	dimensions, material, date and manufacturer, μ_e or A_L	on the base	26/16 3B7 B3A μ33

Type of piece part	Type description	Position of description	Example
Pre-adjusted potcores (continued)	material μ_e or A_L	on the base	
diam. $\leq$ 15 mm with an air gap	type, material, date and manufacturer, μ_e or A_L	on the primary pack	P 14/8 - 3B7 B3A - μ33
diam. $\leq$ 15 mm without air gap	material, zero air gap	on the base	
	type, material, date and manufacturer, μ_e or A_L	on the primary pack	P 14/8 - 3B7 B3A - μ33
Discs for D-potcores	material, date and manufacturer	on the $\stackrel{80}{\surd}$ ground surface	3B3 B1A
	catalog No.	on the primary pack	3522 200 03550
Slugs for D-potcores	height material	on the circumference	11.5 - 3B3
	catalog No., date and manufacturer	on the primary pack	4322 020 25870 B1A
Rings for D-potcores	material, date and manufacturer	on the circumference	3B5 - B1A
height > 8 mm	catalog No.	on the primary pack	3522 200 04020
height $\leq$ 8 mm	material	on the circumference	3B3
	catalog No., date and manufacturer	on the primary pack	3522 200 03900 B1A

MOUNTING DATA

ASSEMBLING

To obtain a stable inductance it is advisable to glue the coil former to the inside of one potcore half.
The potcore assembled with the accessories, as stated in the relevant data sheets, fulfils the normal requirements of temperature stability and stability against shock and vibration. However, if the requirements are extremely severe it is advisable to glue also the potcore halves to each other. (The halves of potcore S 18/12 should always be cemented to each other.)
As the difference between the outer diameter of the adjustor of P-potcores and the diameter of the hole in the potcore is very small the potcore halves must be accurately centred. For small quantity production, assembly plugs are useful aids to this end. These assembly plugs are not supplied, however drawings of the plugs are supplied on request, see table below.

core type	drawing number of assembly plug
P 11/7	-
P 14/8	4E 621 50
P 18/11	4E 621 50
P 22/13	4E 621 51
P 26/16	4E 621 52
P 30/19	4E 621 52
P 36/22	4E 621 52
P 42/29	4E 621 52

The centring must be done before the lips of the containers are bent.

The assembly plugs mentioned above can also be used during the impregnation process with wax or other compounds.
After impregnation the plugs must be removed and the inductance adjustors must be inserted; see pages "Inductance adjustment" of the potcore concerned.

For large quantity production special tools have been designed, which first centre the potcore halves and afterwards bend the lips of the containers. These tools are not supplied, however drawings of the tools are sent on request, see table below.

core type	drawing number of tool
P 11/7	4322 058 00070
P 14/8	4322 058 00000
P 18/11	4322 058 00010
P 22/13	4322 058 00020
P 26/16	4322 058 00030
P 30/19	4322 058 00040
P 36/22	4322 058 00050
P 42/29	4322 058 00060

See also the remarks under Mounting Parts in the data sheets.

INSERTING THE NUT FOR THE ADJUSTOR (P-potcores)

The pre-adjusted potcores can be supplied with a nut for the inductance adjustor, pushed into the hole of one of the potcore halves.

For those manufacturers however, who prefer to insert the nut themselves, the following remarks are given.
Push the nut into the centre hole of one of the potcore halves from the flat side. The recommended distance between the nut and the mating surface of the potcore is given under "Inductance adjustment".

Glue the nut in the hole of the potcore half. A suitable adhesive is Araldite D with hardener Versamite 140. Mixing ratio is 70 : 30, curing time at least 24 hours at room temperature.

The tools recommended for insertion of the nut are not supplied, but drawings are sent on request.

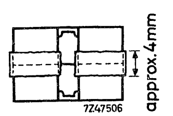
core type	drawing number of tool
P 14/8 and P 18/11	7V48160
P 22/13	7V48161
P 26/16 - P 42/29	7V48198

Also for the dosating devices, recommended for wetting the insides of the centre hole with Araldite, are drawings available:

core type	drawing number of tool
P 14/8 and P 18/11	7V12356
P 22/13	7V12353
P 26/16 - P 42/29	7V12341

GLUING FERROXCUBE POTCORES WITH ARALDITE 101

1. Carefully remove all dust of the in- and outside of the potcore with a dry brush, if possible with a rotating brushing machine.
2. Remove all grease by placing the potcore in a trichloro vapor bath during at least 10 seconds.
   After cleaning and degreasing the potcore must be carefully protected against dust and the joint surfaces may not be touched by hand anymore.
3. Mix the Araldite 101 with hardener number 951 in a ratio of 17 : 1 under an exhauster. After mixing, the mixture must be used as soon as possible; its potlife is only 20 till 30 minutes depending on the temperature.
4. Place the wound coil former in the potcore; if wanted, glue the coil former in one of the potcore halves.
5. Centre the potcore halves and place the potcore under pressure. The required force, depending on the type, is given below.
   P 11/7 : 35 Newton
   P 14/8 : 60 Newton
   P 18/11 : 100 Newton
   P 22/13 : 140 Newton
   P 26/16 : 200 Newton
   P 30/19 : 250 Newton
   P 36/22 : 350 Newton
   P 42/29 : 550 Newton
6. Heat the potcore to about 35 ^{o}C so that moisture, if any, disappears.
7. Apply the adhesive with a brush on the round surface of the potcore, approximately 2 mm on each side of the mating surface (see figure below).



8. In order to harden, place the potcore in a kiln, still under the pressure given in item 5. Curing temperature is 70 ^{o}C; curing time is 15 till 16 hours at least.

Attention: Before removing the pressure, the potcore must be cooled down till room temperature.

P-POTCORES

POTCORES

INTRODUCTION

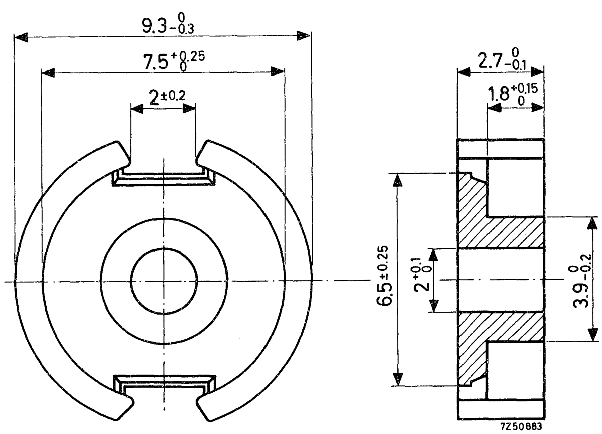
This type of potcore can only be delivered in halves without airgap.

The core halves are ordered by their type number; the type number of a separate core half of ferroxcube 3B5 is:

2P 655 42

Quantity: A primary pack contains 40 potcore halves, so please order a multiple of 40 pieces.

DIMENSIONS (in mm)



PROPERTIES

For toroidally wound core halves the values in Table I are guaranteed.

Table I	temperature (°C)	grade 3B5
T.F. x 10^6	+23 to +55	+0.5 to +2.3
D.F. x 10^6 (10 min - 100 min)	23 ± 1	≤ 10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 25 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	frequency (kHz)	grade 3B5
μ_e	≤ 1	4	$\geq$ 720
α	≤ 1	4	$\leq$ 37.0
$\frac{\tan \delta}{\mu_i} \times 10^{-6}$	≤ 1	100	$\leq$ 8
	≤ 1	200	$\leq$ 20
$q_{2-24-100}$	15-30	4	$\leq$ 3.0

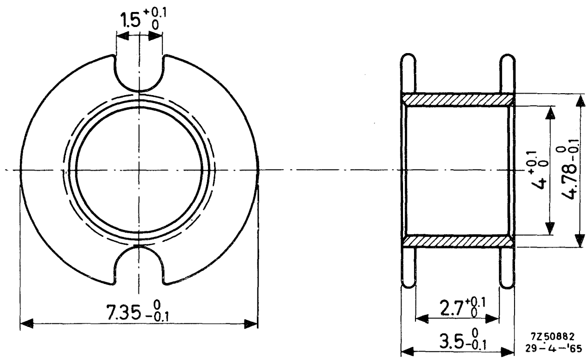
Core factor and effective dimensions:

Effective length l_e = 1.25 cm

$\Sigma \frac{l_e}{A_e}$ = 12.4 cm^{-1}

Effective volume V_e = 0.126 cm^3

COIL FORMERS



Dimensions in mm

Type number	4E 801 85
Material	polycarbonate K486
Window area	3.4 mm^2
Mean length of turn	1.9 cm
Maximum temperature	130 ^oC
D.C. losses	$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 69.5 \times 10^3\ \Omega/H$
Weight	0.07 g

POTCORES

INTRODUCTION

Three types of core can be supplied:

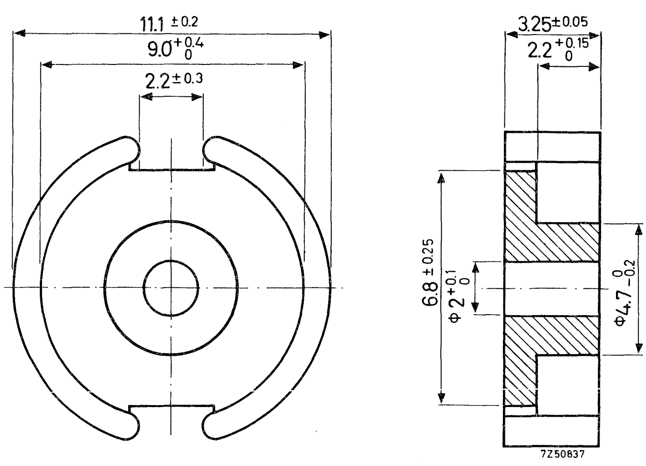
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specification : D.I.N.41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number. Quantity: a primary pack contains 40 potcore halves or 20 pieces of pre-adjusted potcore, so please order in multiples of these quantities.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 21000
3H1	4322 020 21010
3D3	4322 020 21020
4C4	4322 020 21030
4C6	

Properties

For toroidally wound core halves the values in Table I are guaranteed.

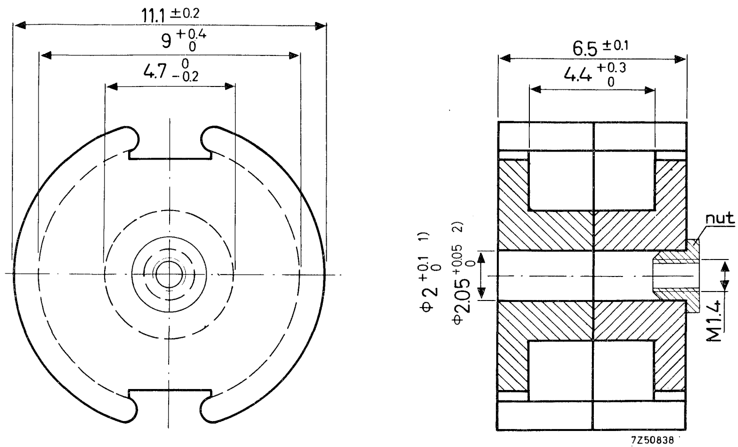
Table I	temp. (^oC)	grade				
		3B7	3H1	3D3	4C4	4C6
T.F. x 10^6	+5 to +23	–	–	–	–	−2 to +4
	+23 to +55	–	–	–	−10 to 0	0 to +6
	+23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to 2	–	–
D.F. x 10^6 (10-100 min)	23 ± 1	$\leq$4.3	$\leq$4.3	$\leq$15	$\leq$33	$\leq$10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 35 Newton, the values in Table II are guaranteed at 25 ± 10 ^oC.

Table II	$\hat{B}$ (Gs)	freq. (MHz)	grade				
			3B7	3H1	3D3	4C4	4C6
μ_e	$\leq$1	0.1	$\geq$975	$\geq$975	$\geq$495	$\geq$93	
α	$\leq$1	0.1	$\leq$27.9	$\leq$27.9	$\leq$39.2	$\leq$90.5	
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	$\leq$1	0.1	$\leq$5	$\leq$5	$\leq$8		
	$\leq$1	0.5			$\leq$14		
	$\leq$1	1			$\leq$30		
		2					
		5					
		10					
$q_{2-24-100}$	3-12	0.1			$\leq$3.6		
	15-30	0.004	$\leq$2.0	$\leq$2.0			

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 2....
Without nut, catalog number = 4322 022 0....

Weight			1.8	g
Mean length of lines of force	l_e	=	1.55	cm
	$\Sigma \frac{l_e}{A_e}$	=	9.56	cm^{-1}
Effective volume	V_e	=	0.251	cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 2 for potcores with nut, insert 0 for potcores without nut.
   Examples of catalog number:
   μ_e = 15, grade 4C4, potcore with nut, catalog number = 4322 022 20610
   A_L = 100, grade 3B7, potcore without nut, catalog number = 4322 022 01040
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

In the drawing: 1) = without nut
2) = with nut

Potcores with standard μ_e values [1]

μ_e	α	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
15	225	± 1	–	–	–	.0610
22	186	± 1	–	–	–	.0620
33	152	± 1	–	–	.0430	.0630
47	127	± 1	–	–	.0440	–
68	105.8	± 1	.0050	.0250	.0450	–
100	87.2	± 1.5	.0060	.0260	–	–
150	71.2	± 2	.0070	.0270	–	–
220	58.8	± 5	.0080	.0280	–	–
660	33.9	± 25	–	–	00310	–
1300	24.2	± 25	00290	00300	–	–

Number of turns $N = \alpha \sqrt{L}$ (L in 10^{-3} H)

Potcores with standard A_L factors [1]

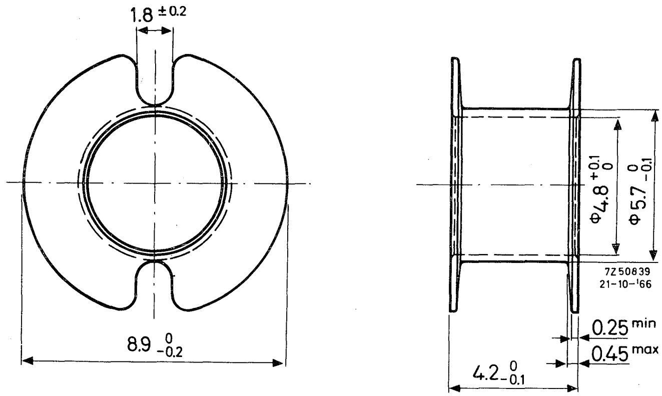
A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
25	19.0	± 1	–	–	–	.1610
40	30.5	± 1	–	–	.1420	.1620
63	48	± 1	–	–	.1430	–
100	76	± 1	.1040	.1240	.1440	–
160	122	± 1.5	.1050	.1250	–	–
250	190	± 3	.1060	.1260	–	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

COIL FORMER

Dimensions in mm



Catalog number	4322 021 30240
Material	polycarbonate K486
Window area	5.5 mm^2
Mean length of turn	2.3 cm
Max. temperature	130 °C
D.C. losses	$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 58.1 \times 10^3\ \Omega/H$
Weight	0.1 g

The dimensions conform with the following specifications: I.E.C.133 (international), and D.I.N.41 294 (Germany).

INDUCTANCE ADJUSTMENT

ADJUSTORS

The tolerances on inductance of the pre-adjusted potcores (without adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy $< 0.03\%$ by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.

The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.

The influence of the adjustors on the variability of the inductance is negligible.

The maximum permissible temperature is 110 °C.

Table II shows the type of adjustor recommended for different potcores.

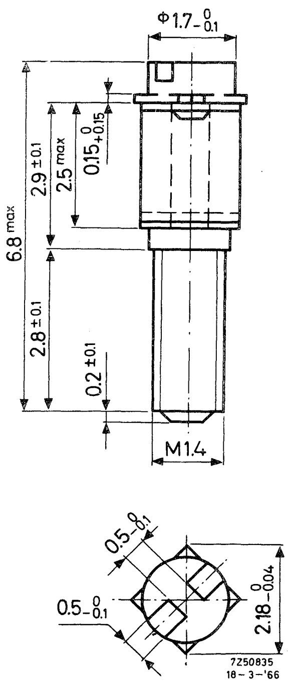


Table I, available types

colour	catalog number
green	4322 021 31250
red	4322 021 31260
yellow	4322 021 31270
grey	4322 021 31280
brown	4322 021 31540

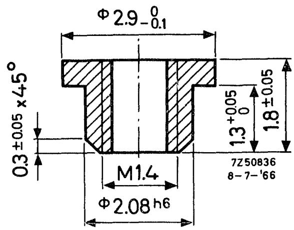
Table II, recommended application

μ_e	A_L	3B7/3H1/3D3
	40	4322 021 31250
33		4322 021 31250
	63	4322 021 31260
47		4322 021 31260
68		4322 021 31270
	100	4322 021 31270
100		4322 021 31540
150	160	4322 021 31540
	250	4322 021 31280
220		4322 021 31280

Dimensions in mm

NUT FOR ADJUSTOR

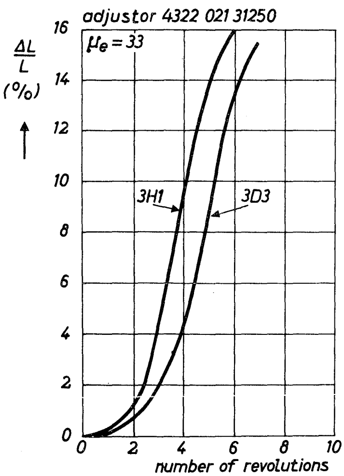
These data are given for those manufacturers who prefer to insert the nut themselves.



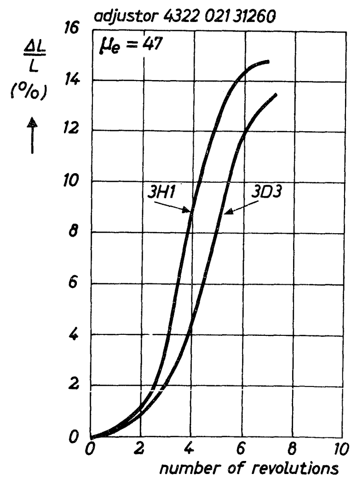
Catalog number	4322 021 31230
Material	brass, nickel plated

For more information see Potcores General, Mounting data.

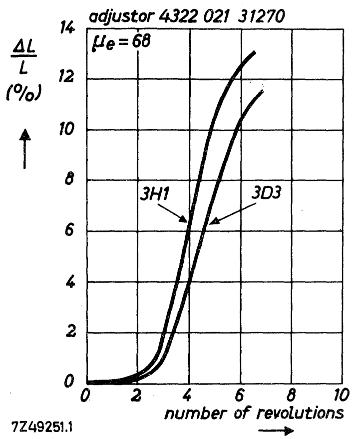
ADJUSTMENT CURVES

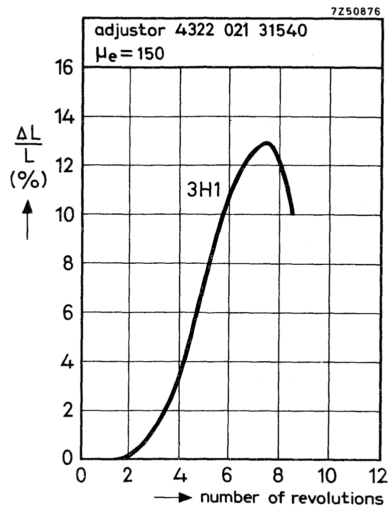


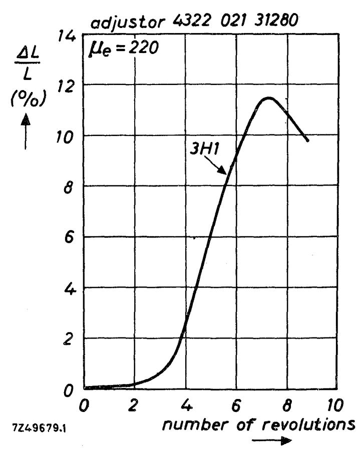
7Z49250.1



7Z49248.1

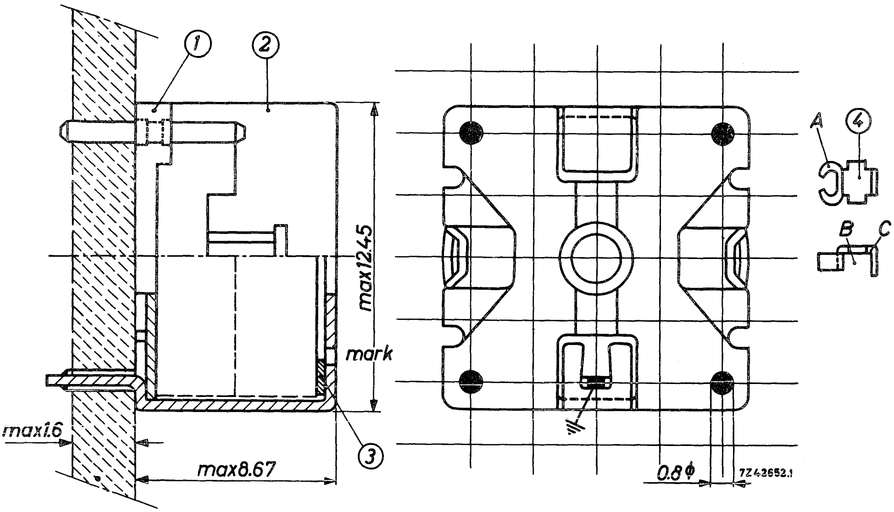

adjustor 4322 021 31270
μe = 68
ΔL/L (%)
3H1
3D3
number of revolutions
7Z49251.1


7Z50876
adjustor 4322 021 31540
μe = 150
ΔL/L (%)
3H1
number of revolutions


adjustor 4322 021 31280
μe = 220
ΔL/L (%)
3H1
number of revolutions
7Z49679.1

MOUNTING PARTS

MOUNTING



(1) tag plate 4322 021 30180
(2) brass container 4322 021 30510
(3) spring 4322 021 30620
(4) soldering spring 4322 021 30700 (4x)

The core is suitable for mounting on printed-wiring boards.

The four soldering pins and the earth tag are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 1.6 mm. The board should be provided with holes of 1.3 $\pm$ 0.1 mm diameter.

If stranded wire is applied the use of a soldering spring (4) is recommended. Part A of this spring is put over the pin, then the wire is put in B and lip C is bent over. For solid wire the soldering spring is not strictly necessary.

The container is provided with an earth tag.

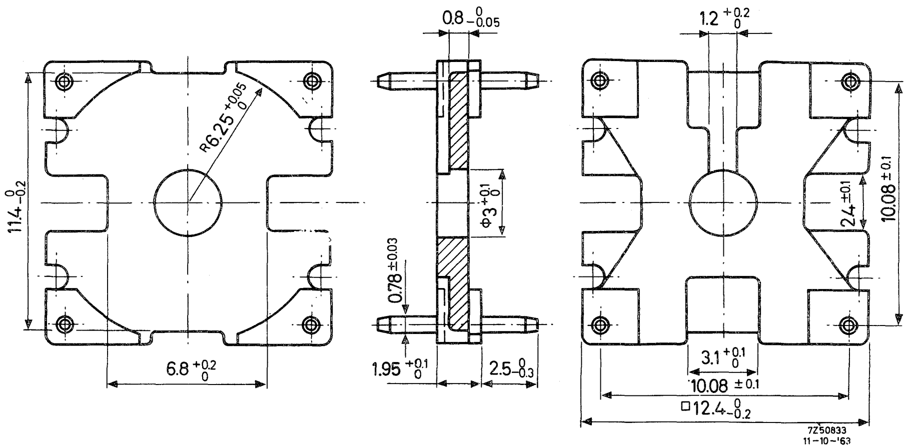
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 35 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

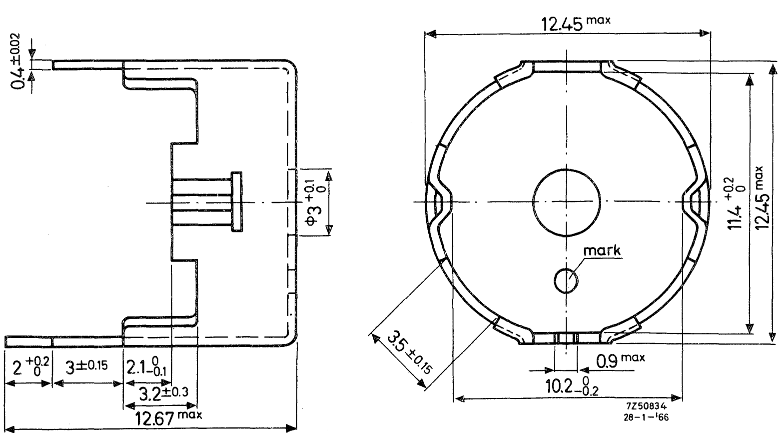
(1) Tag plate 4322 021 30180

Plate : reinforced polyester
Pins : phosphorbronze, dipsoldered



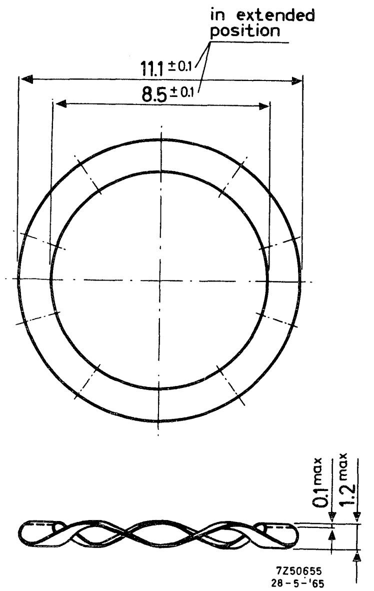
(2) Container 4322 021 30510

Material : brass, nickel plated



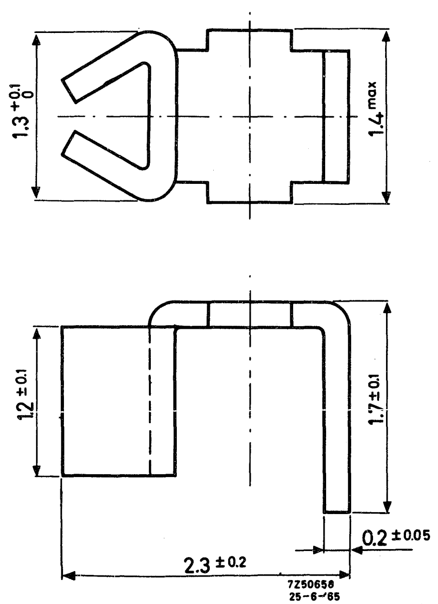
(3) Spring 4322 021 30620

Material : chrome-nickelsteel



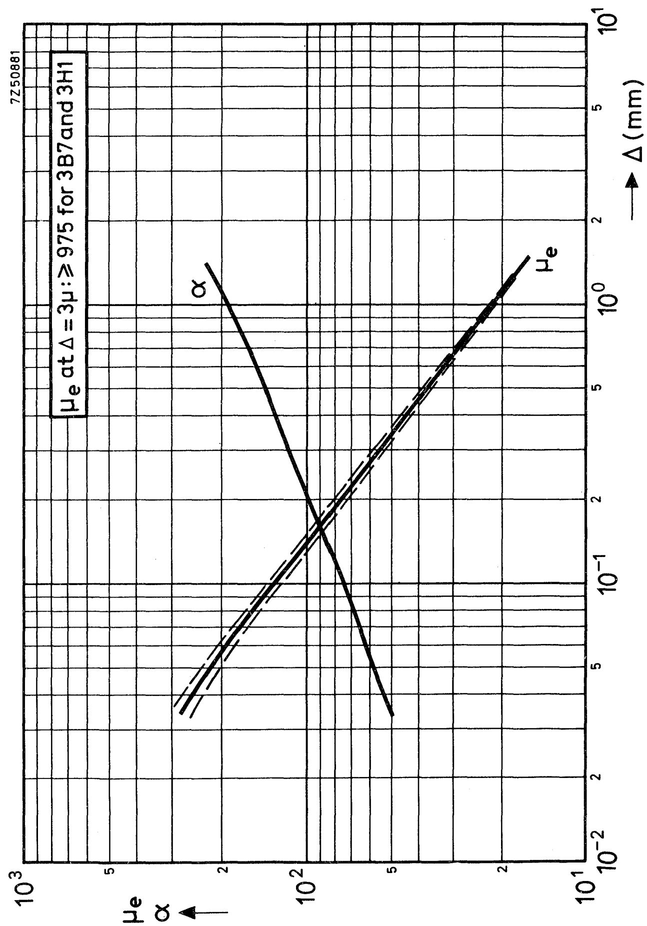
(4) Soldering spring 4322 021 30700

Material : brass, dipsoldered



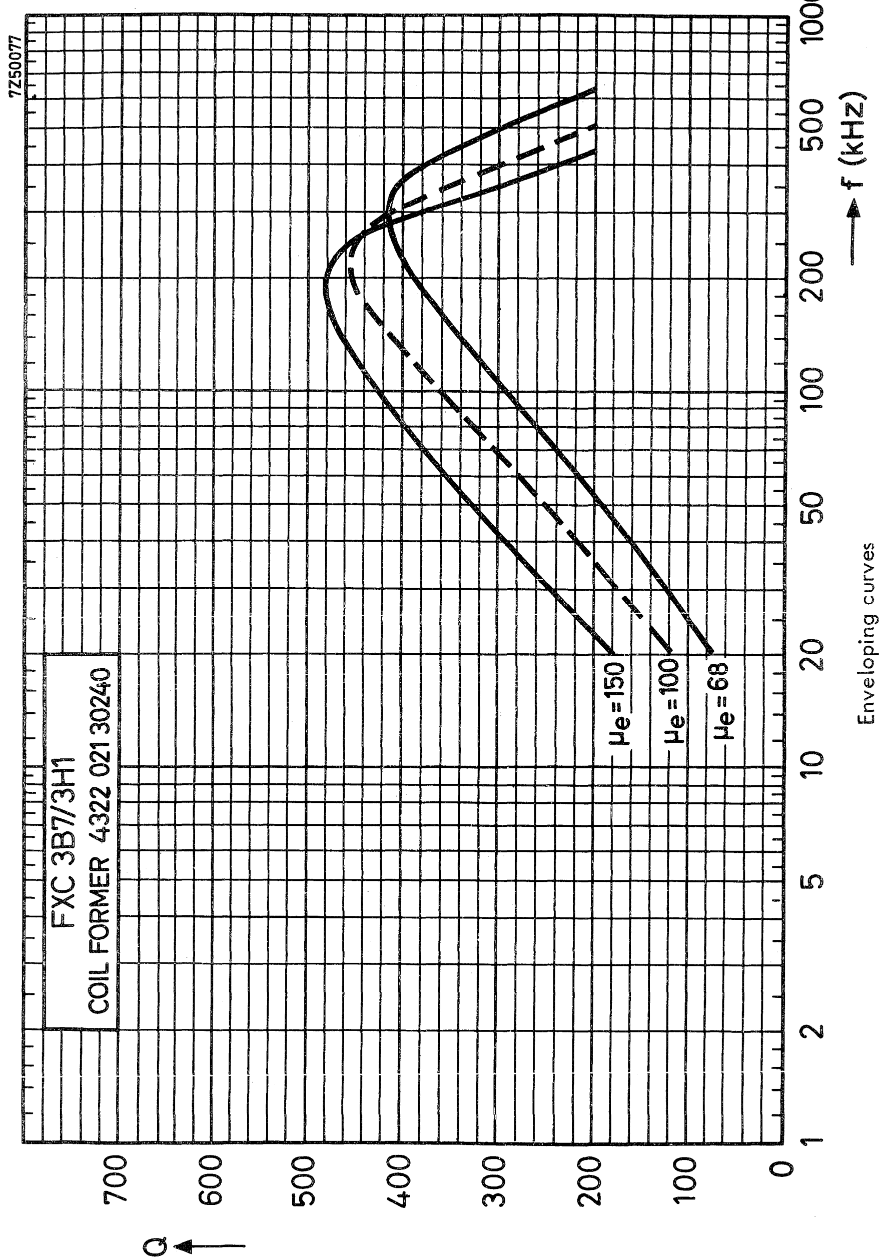
CHARACTERISTIC CURVES

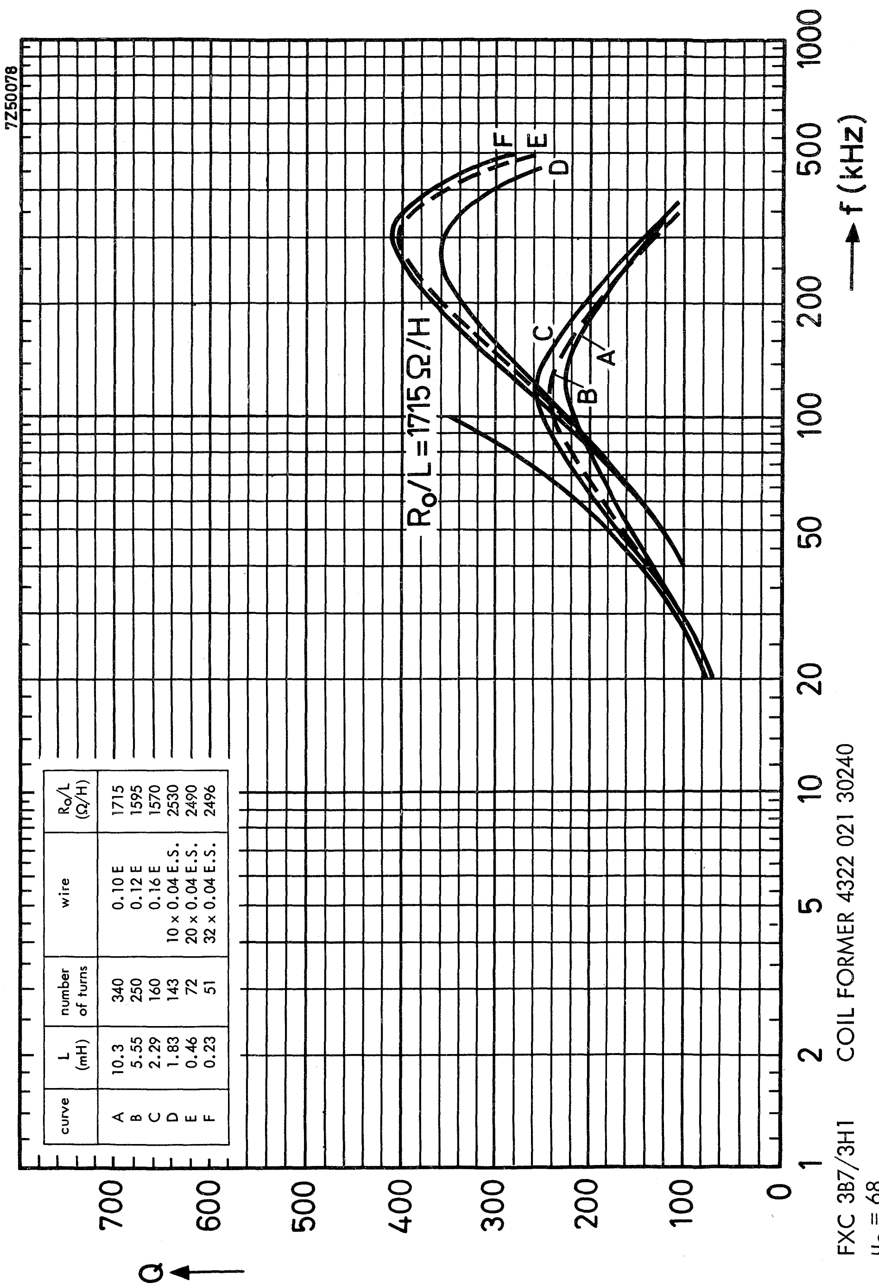
μ_e - α CURVE



Effective permeability and turn factor for 1 mH as a function of the air gap length

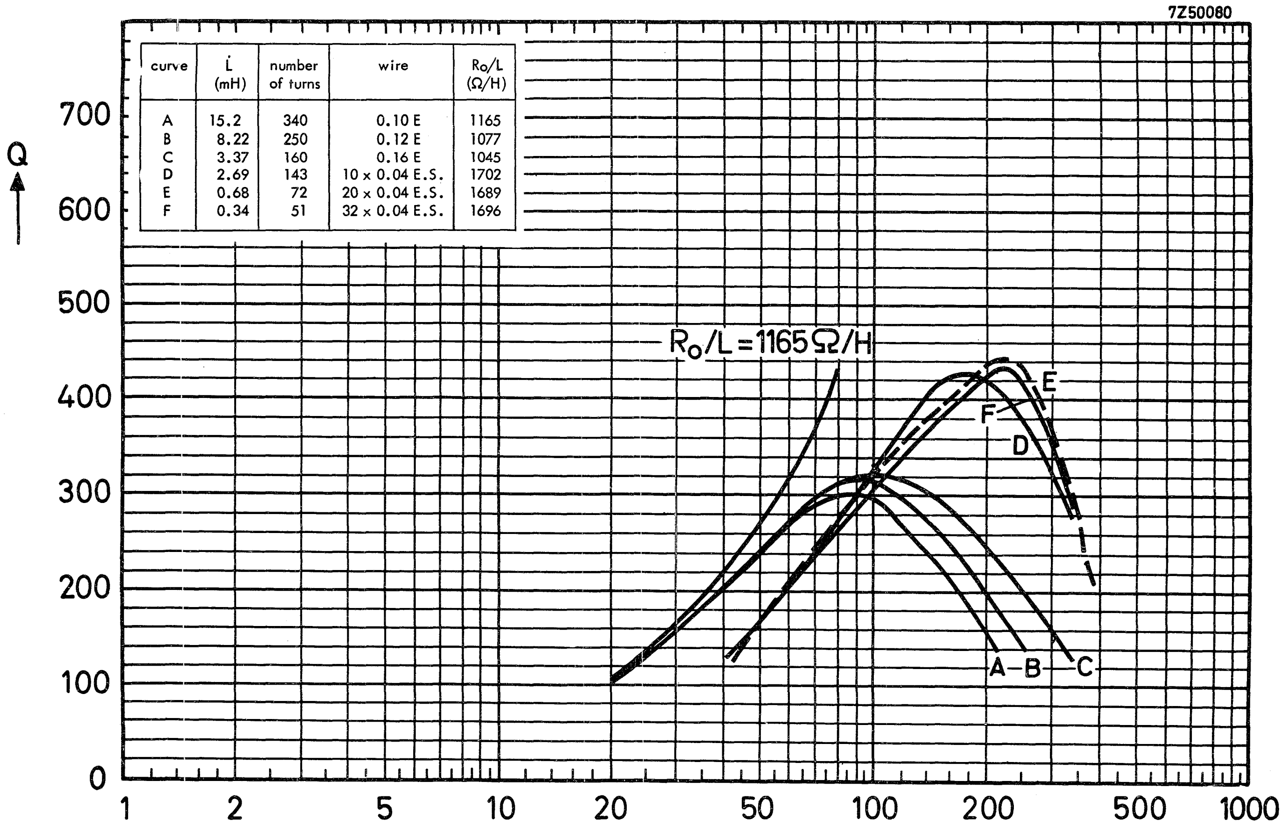
TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1





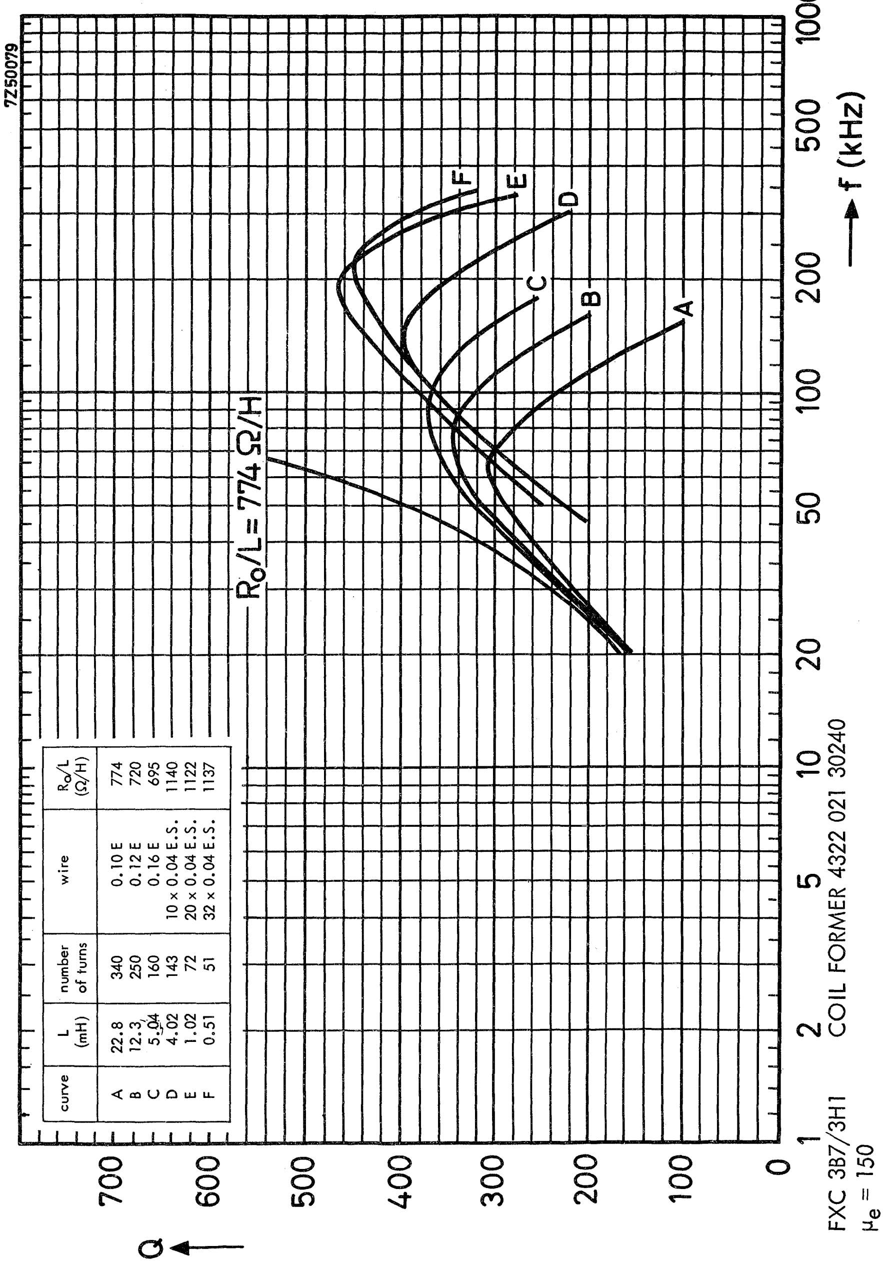
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	10.3	340	0.10 E	1715
B	5.55	250	0.12 E	1595
C	2.29	160	0.16 E	1570
D	1.83	143	10 × 0.04 E.S.	2530
E	0.46	72	20 × 0.04 E.S.	2490
F	0.23	51	32 × 0.04 E.S.	2496

FXC 3B7/3H1 COIL FORMER 4322 021 30240
$\mu_e = 68$



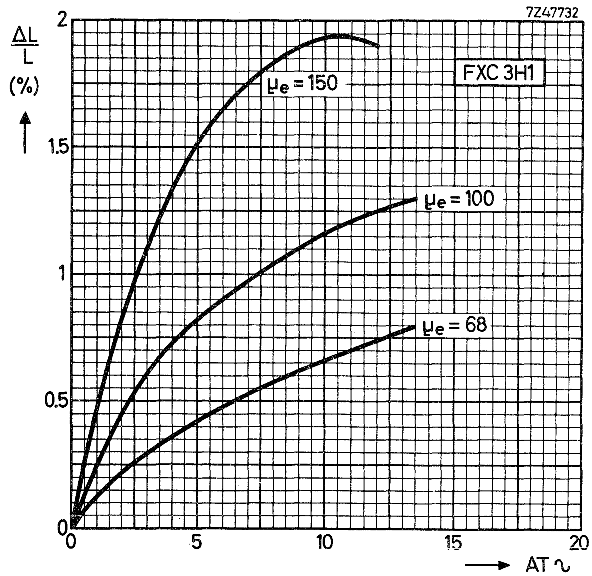
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	15.2	340	0.10 E	1165
B	8.22	250	0.12 E	1077
C	3.37	160	0.16 E	1045
D	2.69	143	10 × 0.04 E.S.	1702
E	0.68	72	20 × 0.04 E.S.	1689
F	0.34	51	32 × 0.04 E.S.	1696

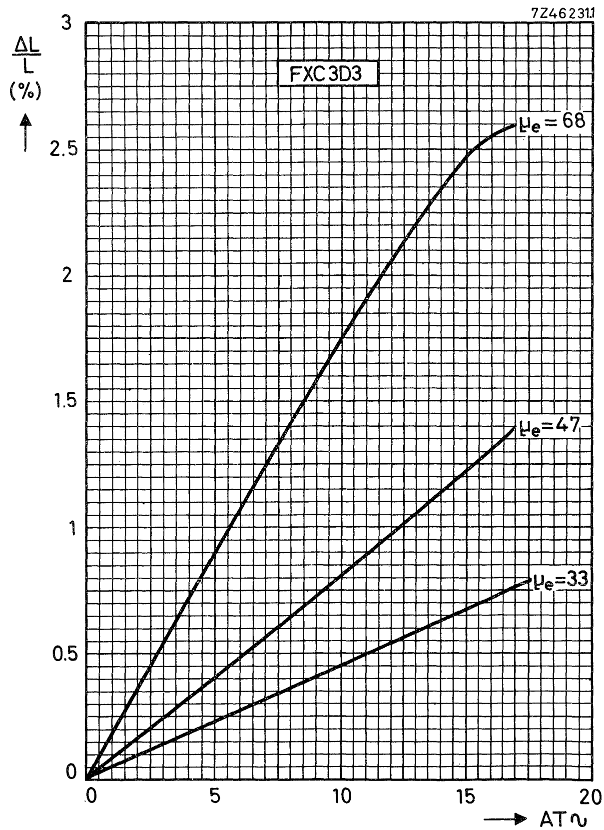
FXC 3B7/3H1 COIL FORMER 4322 021 30240
μ_e = 100



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	22.8	340	0.10 E	774
B	12.3	250	0.12 E	720
C	5.04	160	0.16 E	695
D	4.02	143	10 × 0.04 E.S.	1140
E	1.02	72	20 × 0.04 E.S.	1122
F	0.51	51	32 × 0.04 E.S.	1137

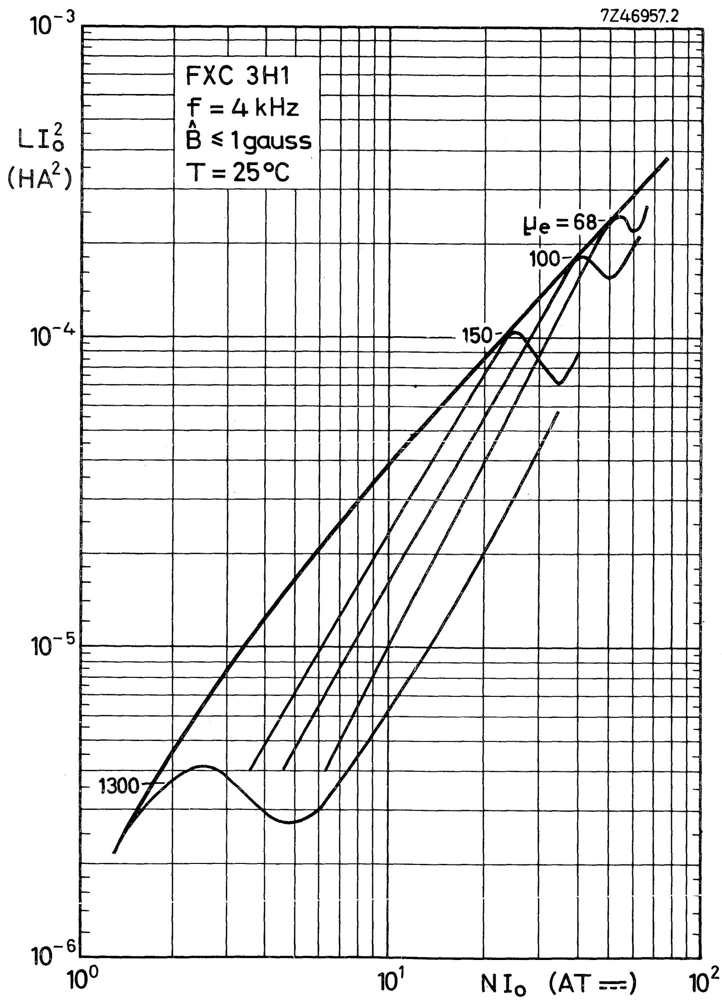
INDUCTANCE VARIATION AS A FUNCTION OF AT~



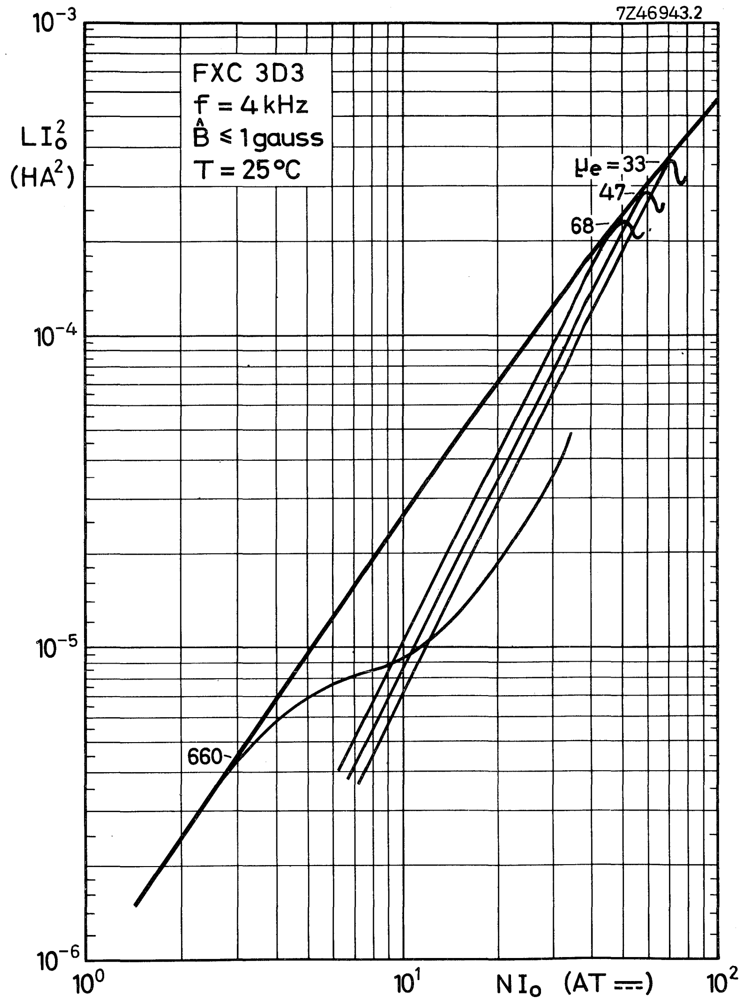

7Z46231.1
FXC 3D3
ΔL/L (%)
$\mu_e = 68$
$\mu_e = 47$
$\mu_e = 33$
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
AT∿

HANNA CURVES

Indicating the optimum inductance for a certain μ_e-value and direct current.
Typical values



Typical values



POTCORES

INTRODUCTION

Three types of core can be supplied:

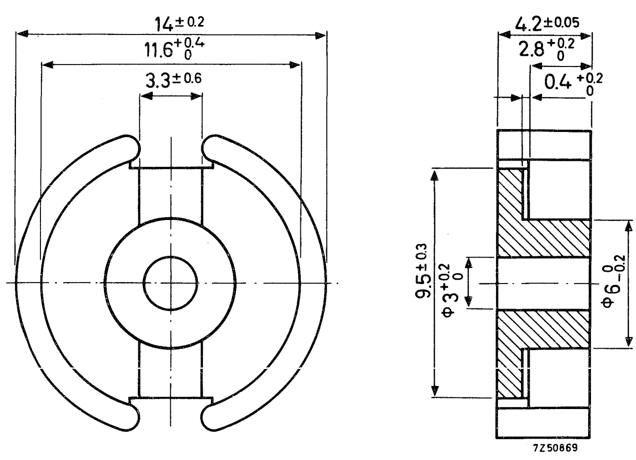
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number. Quantity: a primary pack contains 30 potcore halves or 15 pieces of pre-adjusted potcore, so please order in multiples of these quantities.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 21250
3H1	4322 020 21260
3D3	4322 020 21270
4C4	4322 020 21280
4C6	

Properties

For toroidally wound core halves the values in Table I are guaranteed.

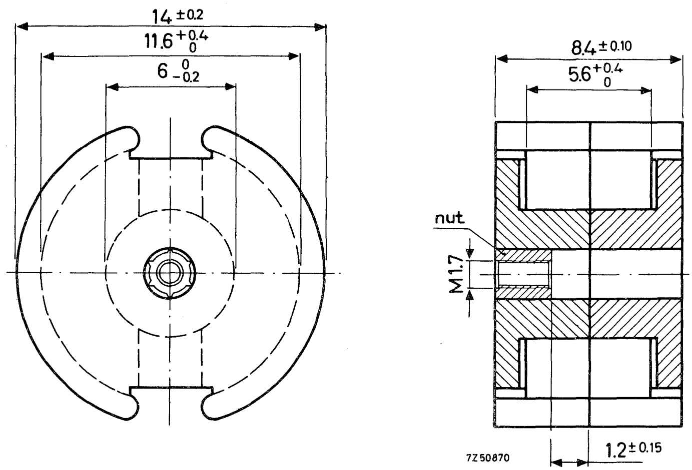
Table I	temp. (°C)	grade				
		3B7	3H1	3D3	4C4	4C6
T.F. x 10^6	+5 to +23		–	–	–	−2 to +4
	+23 to +55		–	–	−10 to 0	0 to +6
	+23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to 2	–	–
D.F. x 10^6 (10-100 min)	23 ± 1	$\leq$4.3	$\leq$4.3	$\leq$15	$\leq$33	$\leq$10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 60 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (MHz)	grade				
			3B7	3H1	3D3	4C4	4C6
μ_e	$\leq$ 1	0.1	$\geq$1050	$\geq$1050	$\geq$510	$\geq$93	$\geq$80
α	$\leq$ 1	0.1	$\leq$24.4	$\leq$24.4	$\leq$35.1	$\leq$81.8	
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	$\leq$ 1	0.1	$\leq$5	$\leq$5	$\leq$8		
	$\leq$ 1	0.5			$\leq$14		
	$\leq$ 1	1			$\leq$30		
		2					$\leq$45
		5					$\leq$60
		10					$\leq$100
$q_{2\text{-}24\text{-}100}$	3-12	0.1			$\leq$3.0		
	15-30	0.004	$\leq$1.8	$\leq$1.8			

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 2....
Without nut, catalog number = 4322 022 0....

Weight			3.2	g
Mean length of lines of force	l_e	=	1.98	cm
	$\Sigma \frac{l_e}{A_e}$	=	7.89	cm^{-1}
Effective volume	V_e	=	0.495	cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 2 for potcores with nut, insert 0 for potcores without nut.
   Examples of catalog number:
   μ_e = 15, grade 4C4, potcore with nut, catalog number = 4322 022 22610
   A_L = 100, grade 3B7, potcore without nut, catalog number = 4322 022 03040
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
15	205	± 1	–	–	–	.2610
22	169	± 1	–	–	–	.2620
33	137.9	± 1	.2030	.2230	.2430	.2630
47	115.5	± 1	.2040	.2240	.2440	–
68	96.1	± 1	.2050	.2250	.2450	–
100	79.2	± 1.5	.2060	.2260	–	–
150	64.6	± 2	.2070	.2270	–	–
220	53.3	± 3	.2080	.2280	–	–
680	30.3	± 25	–	–	02400	–
1400	21.2	± 25	02000	02200	–	–

Number of turns $N = \alpha\sqrt{L}$ (L in 10^{-3} H)

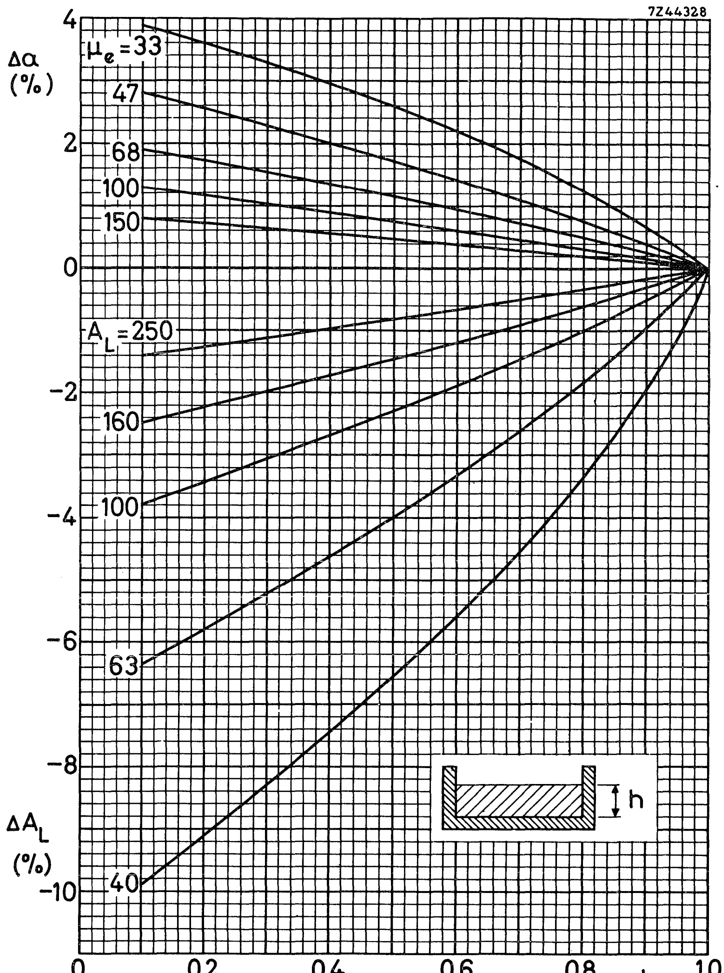
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
25	15.7	± 1	–	–	–	.3610
40	25	± 1	–	–	.3420	.3620
63	39.5	± 1	–	–	.3430	.3630
100	63	± 1	.3040	.3240	.3440	–
160	100.5	± 1.5	.3050	.3250	–	–
250	157	± 2	.3060	.3260	–	–
315	198	± 2	03070	.3270	–	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

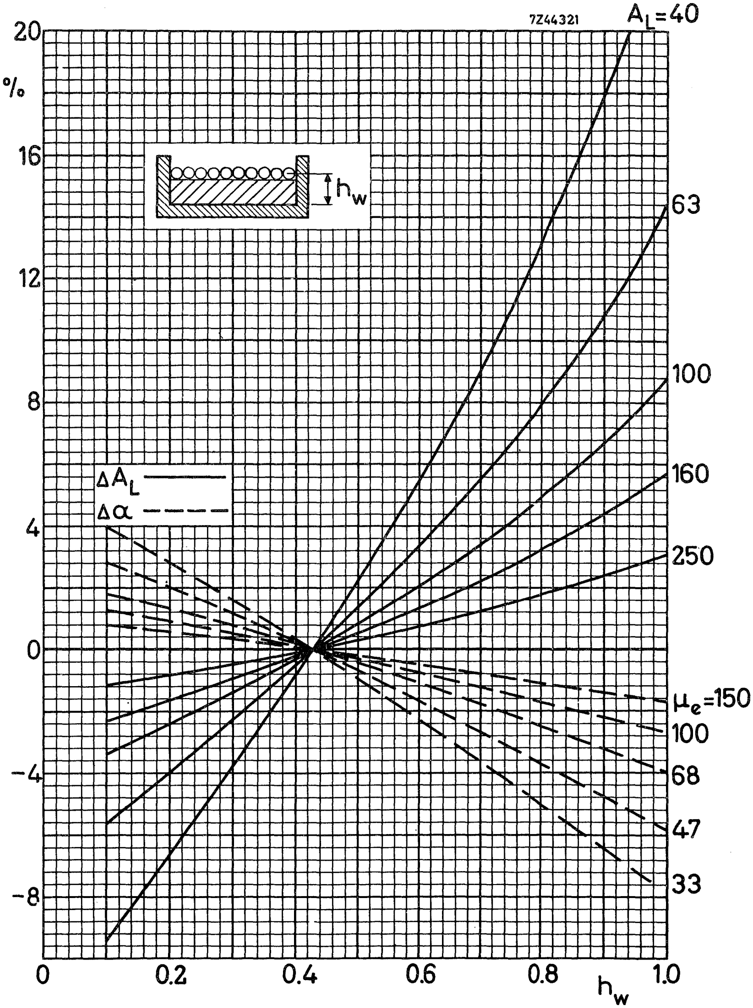
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 96.1 + 1.3 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_w on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 96.1 - 1.7 %.

COIL FORMERS

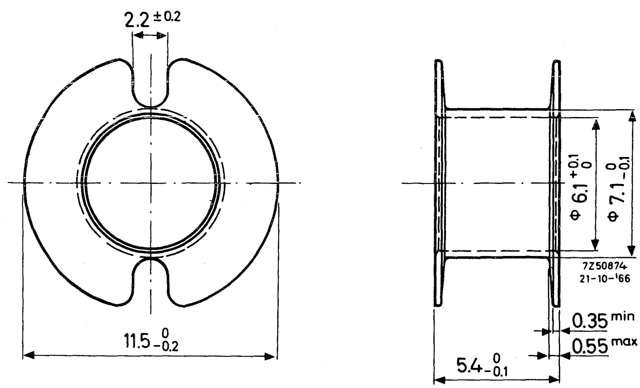
GENERAL

Three types of coil former can be supplied:

- with one section
- with two sections
- with one section and with soldering pins to fit 0.1" and 2.50 mm grid.

The dimensions conform with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



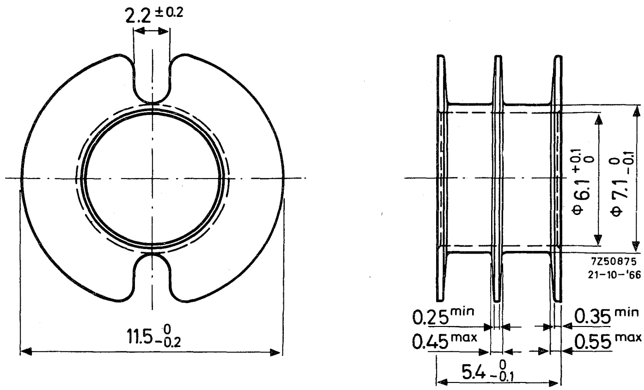
Catalog number	4322 021 30250
Material	polycarbonate K486
Window area	9.7 mm^2
Mean length of turn	2.9 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 32.3 \times 10^3 \ \Omega/H$$

Weight	0.15 g

TWO-SECTION COIL FORMER



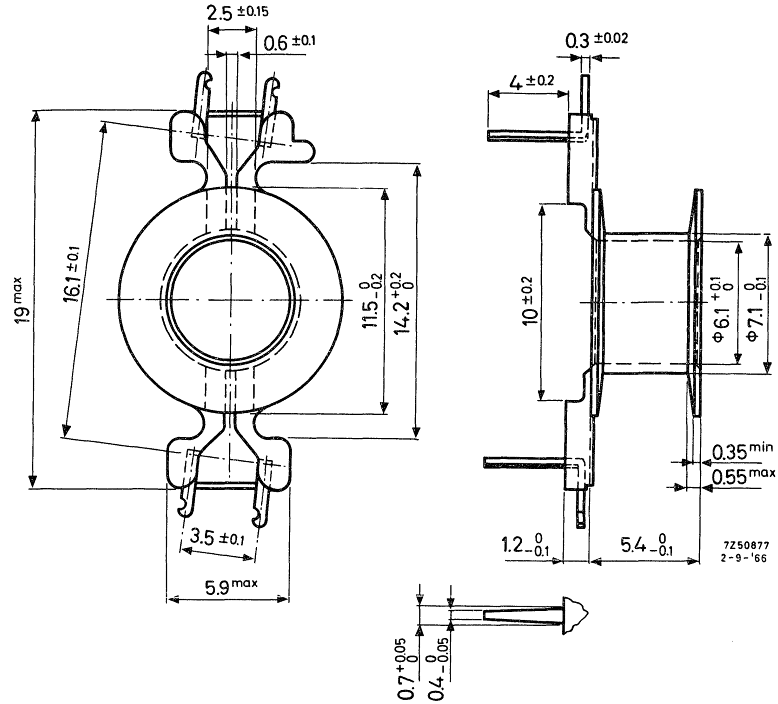
Catalog number	4322 021 30260
Material	polycarbonate K486
Window area	2 x 4.5 mm^2
Mean length of turn	2.9 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 35.1 \times 10^3 \ \Omega/H$$

Weight 0.2 g

SINGLE-SECTION COIL FORMER WITH SOLDERING PINS



Catalog number 4322 021 30070

Material: reinforced polyester with brass dipsoldered pins

Window area 9.7 mm²

Mean length of turn 2.9 cm

Max. temperature 130 °C

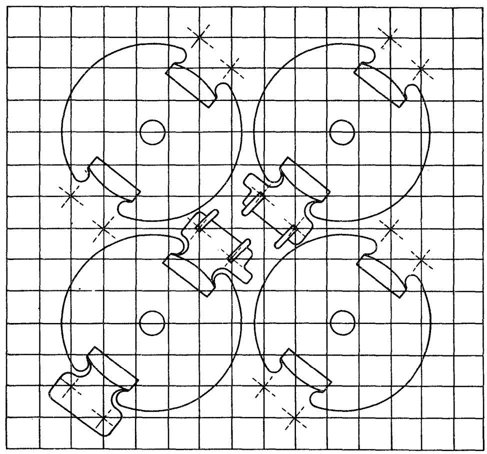
Max. dipsolder temperature for 5 - 6 s 280 °C

D.C. losses:

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 32.3 \times 10^3 \quad \Omega/H$$

Weight 0.25 g

The soldering pins are so arranged as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes 1.3 ± 0.1 mm diameter. For this coil former the potcore halves must be cemented together, and it is recommended to cement the coil former to the lower potcore half.



7Z44850

INDUCTANCE ADJUSTMENT

ADJUSTORS

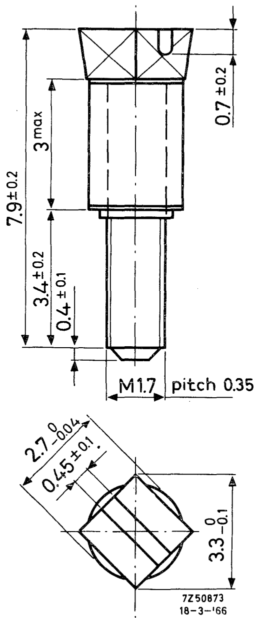


Fig.A

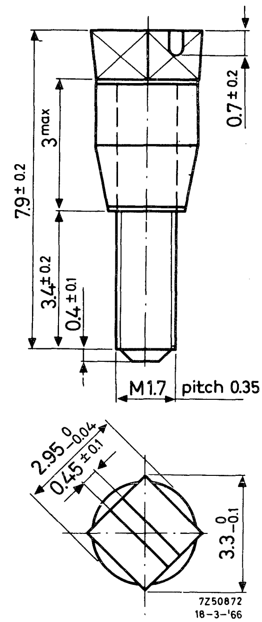


Fig.B

The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.3 ‰ by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.

The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.

The influence of the adjustors on the variability of the inductance is negligible.

The maximum permissible temperature is 110 °C.

Table II shows the type of adjustor recommended for different potcores.

Table I, available types

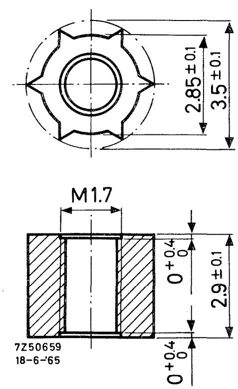
Fig.	colour	catalog number
A	red	4322 021 30740
A	green	4322 021 30750
B	yellow	4322 021 30940
B	white	4322 021 30950
A	brown	4322 021 31070
B	grey	4322 021 31130

Table II, recommended application

μ_e	A_L	3B7/3H1/3D3	4C4
		cat. number 4322 021	
15		–	30740
	25	–	30740
22		–	30740
	40	30750	30940
33		30750	30950
	63	30740	30940
47		30740	–
	100	30940	–
68		30940	–
100		30950	–
	160	30950	–
150		31070	–
	250	31070	–
220		31130	–

NUT FOR ADJUSTOR

These data are given for those manufacturers who prefer to insert the nut themselves.



Catalog number 4322 021 30140

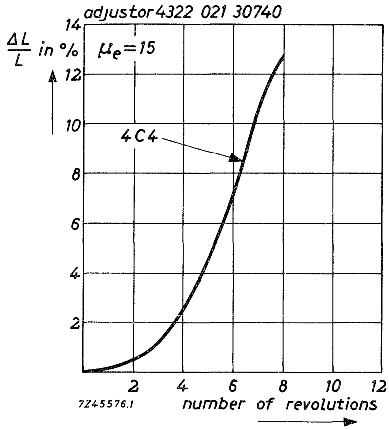
Material polycarbonate

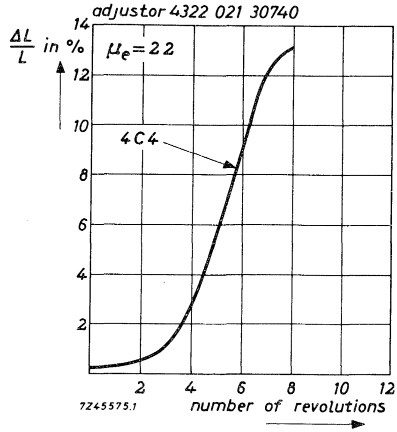
Max. impregnation temperature during 24 hours 120 °C

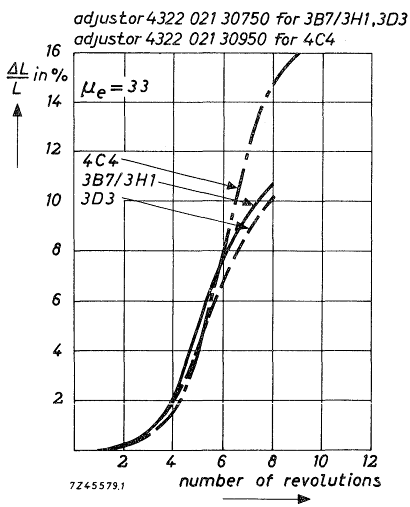
Recommended distance from mating surface to nut 1.2 ± 0.15 mm

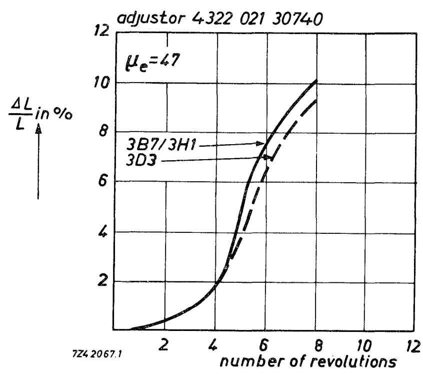
For more information see Potcores General, Mounting data.

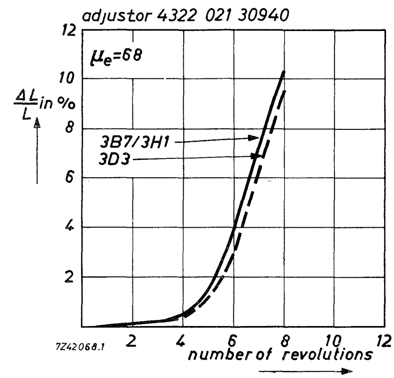
ADJUSTMENT CURVES

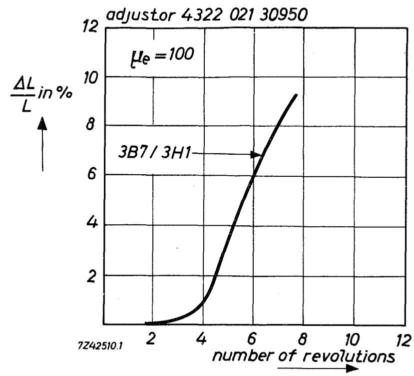


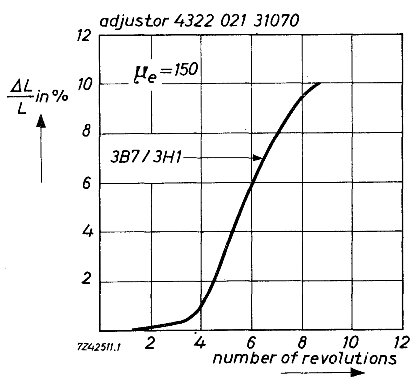


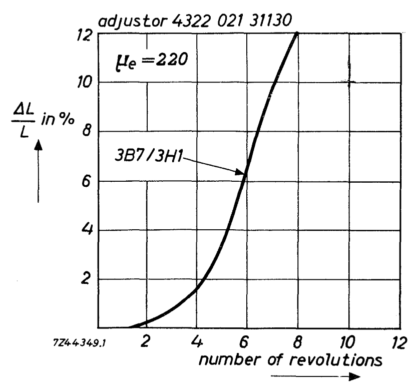





adjustor 4322 021 30940
μ_e=68
$\frac{\Delta L}{L}$ in %
3B7/3H1
3D3
number of revolutions
7Z42068.1

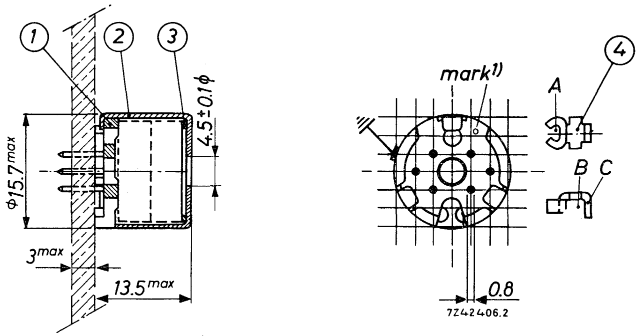

adjustor 4322 021 30950
μ_e =100
$\frac{\Delta L}{L}$ in %
3B7 / 3H1
number of revolutions
7Z42510.1


adjustor 4322 021 31070
μ_e =150
$\frac{\Delta L}{L}$ in %
3B7 / 3H1
number of revolutions
7Z42511.1


adjustor 4322 021 31130
μ_e =220
$\frac{\Delta L}{L}$ in %
3B7/3H1
number of revolutions
7Z44349.1

MOUNTING PARTS

MOUNTING ON PRINTED-WIRING BOARDS



(1) tag plate	4322 021 30440
(2) brass container	4322 021 30520
(3) spring	4322 021 30630
(4) soldering spring	4322 021 30700 (6x)

The container is suitable for mounting on printed-wiring boards only.

If stranded wire is applied the use of a soldering spring (4) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over. For solid wire the soldering spring is not strictly necessary.

The six soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1.3 ± 0.1 mm diameter.

The container is provided with an earth tag on its circumference. This tag also serves the purpose of mounting the coil assembly on the printed-wiring board.

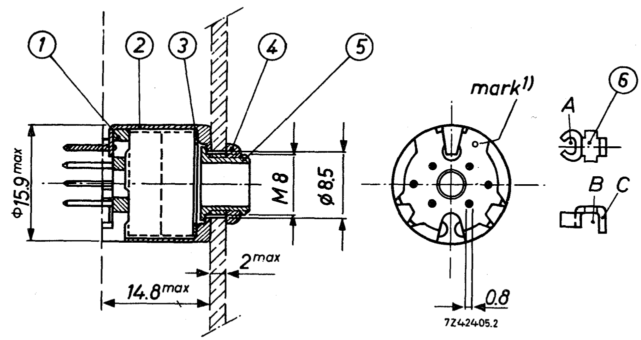
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 60 Newton. After bending the lips the spring will have the correct tension.

---

1) There is another mark hole in a similar position on the top of the container.

MOUNTING ON PANELS



(1) tag plate	4322 021 30440	(4) nut	4322 021 30710	
(2) aluminium container	4322 021 30600	(5) fixing bush	4322 021 30720	
(3) spring	4322 021 30630	(6) soldering spring	4322 021 30700	(6x)

The container is suitable for mounting on panels only.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The coil assembly may be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

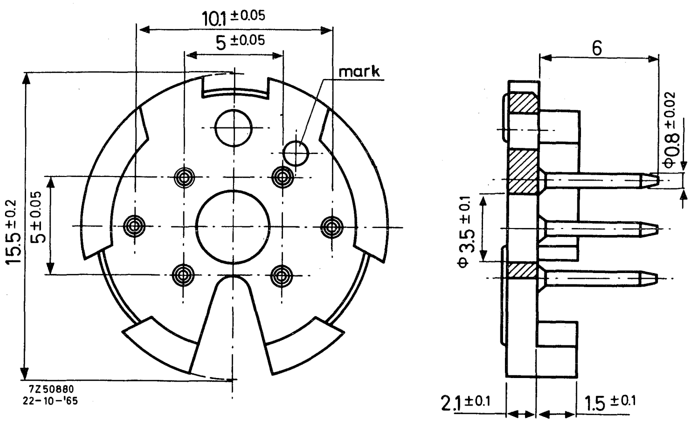
Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 60 Newton. After bending the lips the spring will have the correct tension.

1) There is another mark in a similar position on the top of the container.

PART DRAWINGS (dimensions in mm)

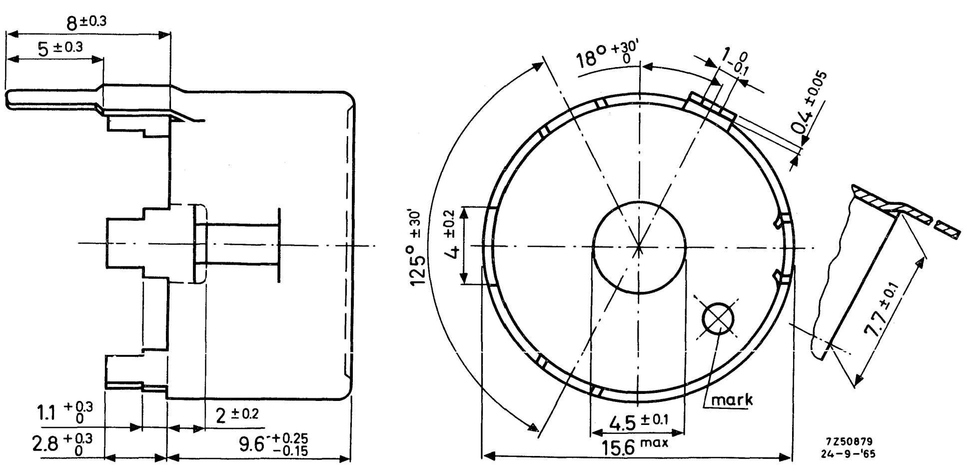
Tag plate 4322 021 30440

Plate : reinforced polyester
Pins : phosphorbronze, dipsoldered

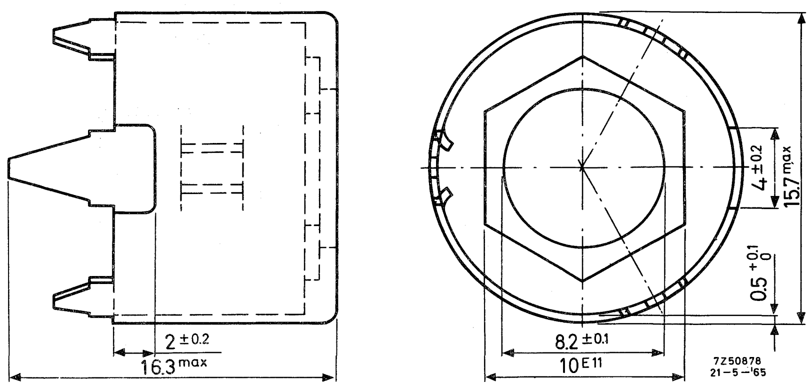


Container for mounting on printed-wiring boards 4322 021 30520

Material : brass, nickel plated

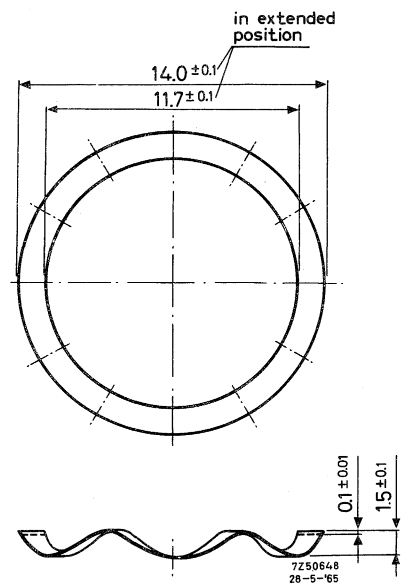


Container for mounting on panels 4322 021 30600 Material: aluminium



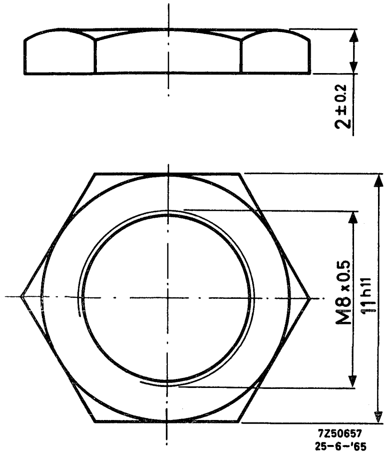
Spring 4322 021 30630

Material : chrome-nickelsteel



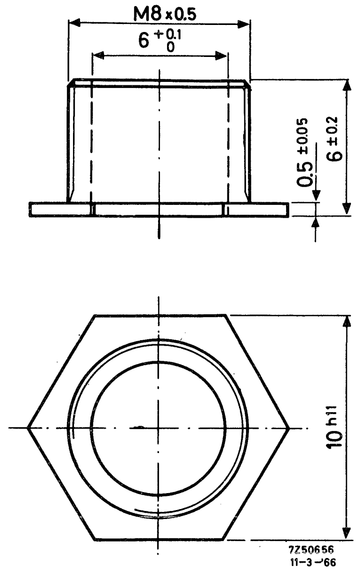
Nut 4322 021 30710

Material: brass, nickel plated



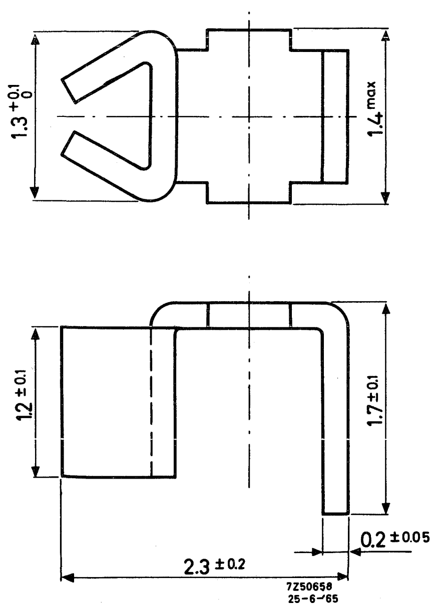
Fixing bush 4322 021 30720

Material: aluminium



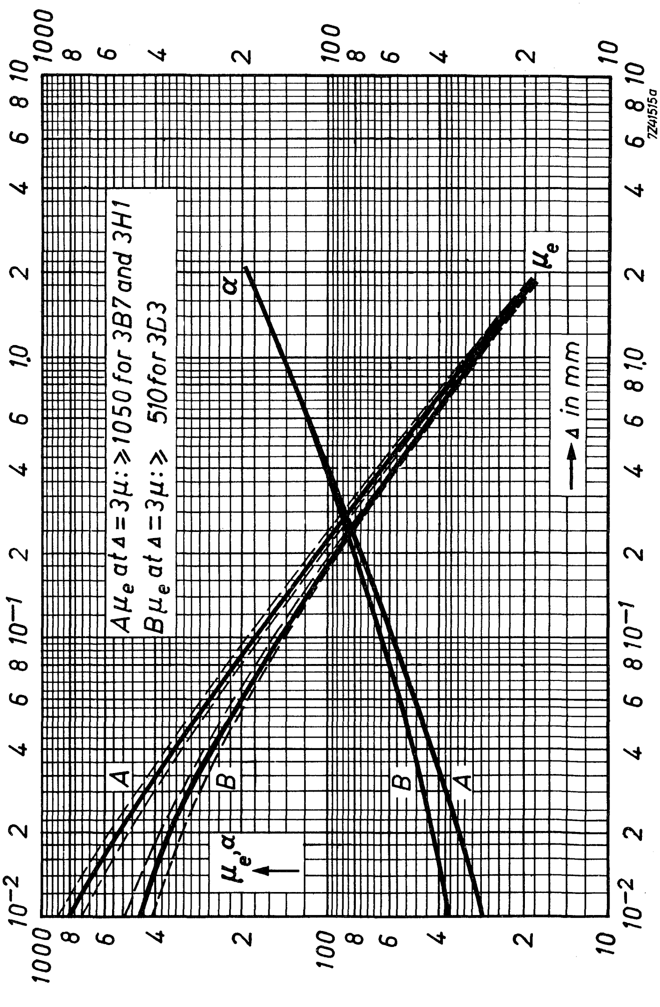
Soldering spring 4322 021 30700

Material: brass, dipsoldered



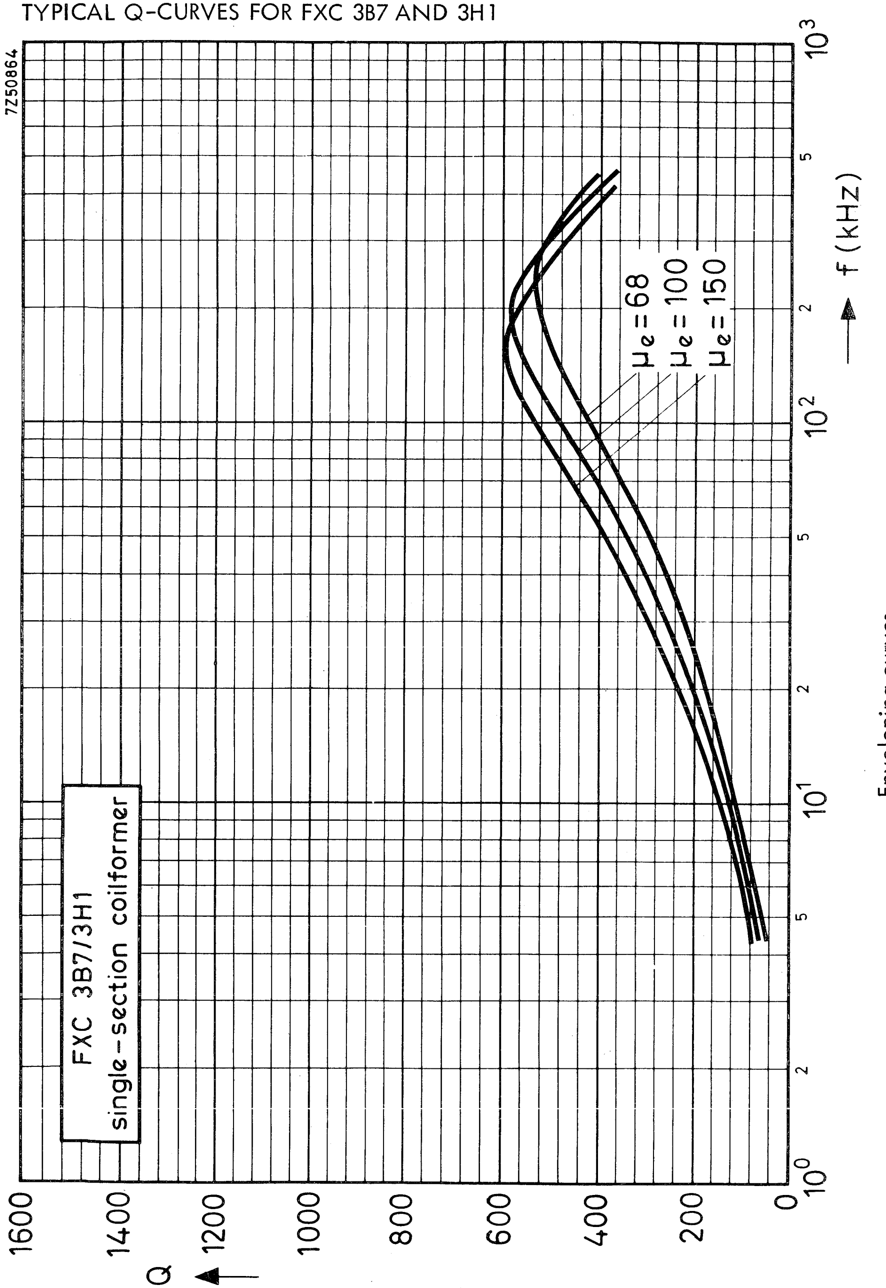
CHARACTERISTIC CURVES

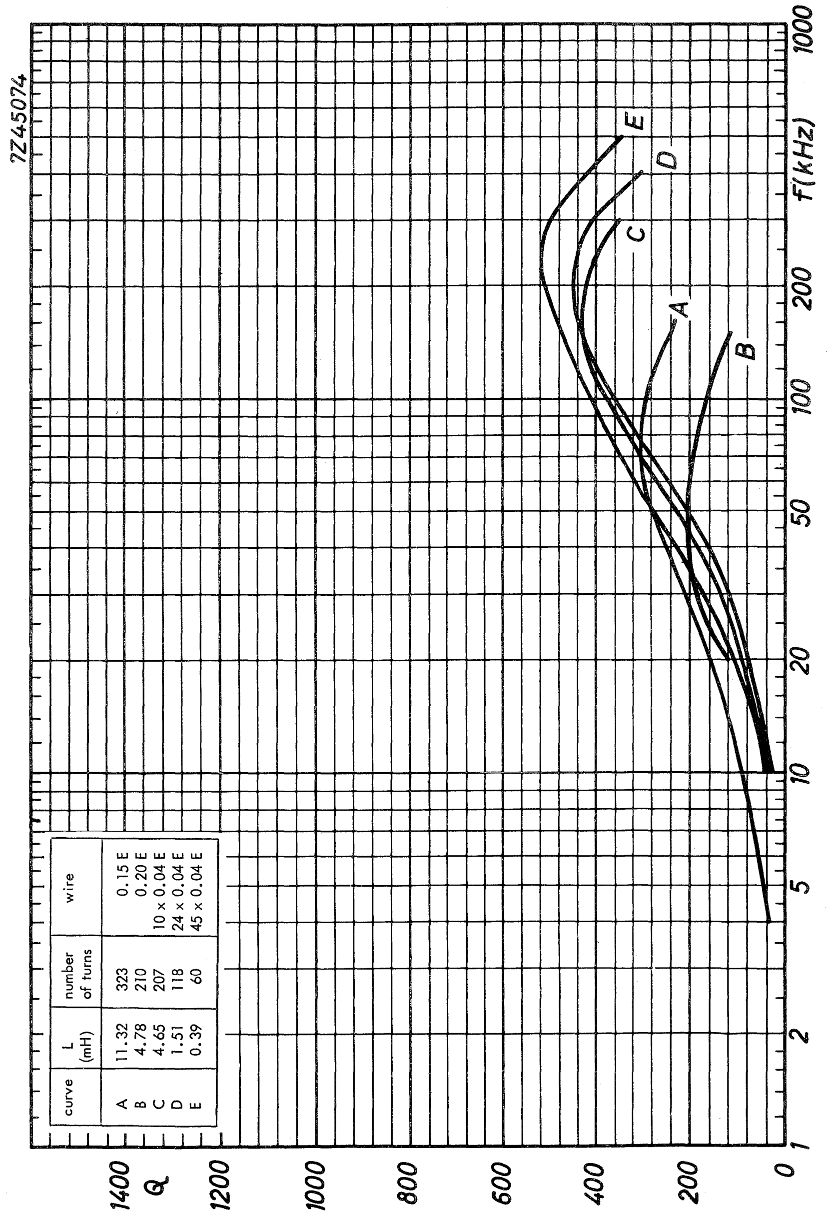
μ_e - α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length

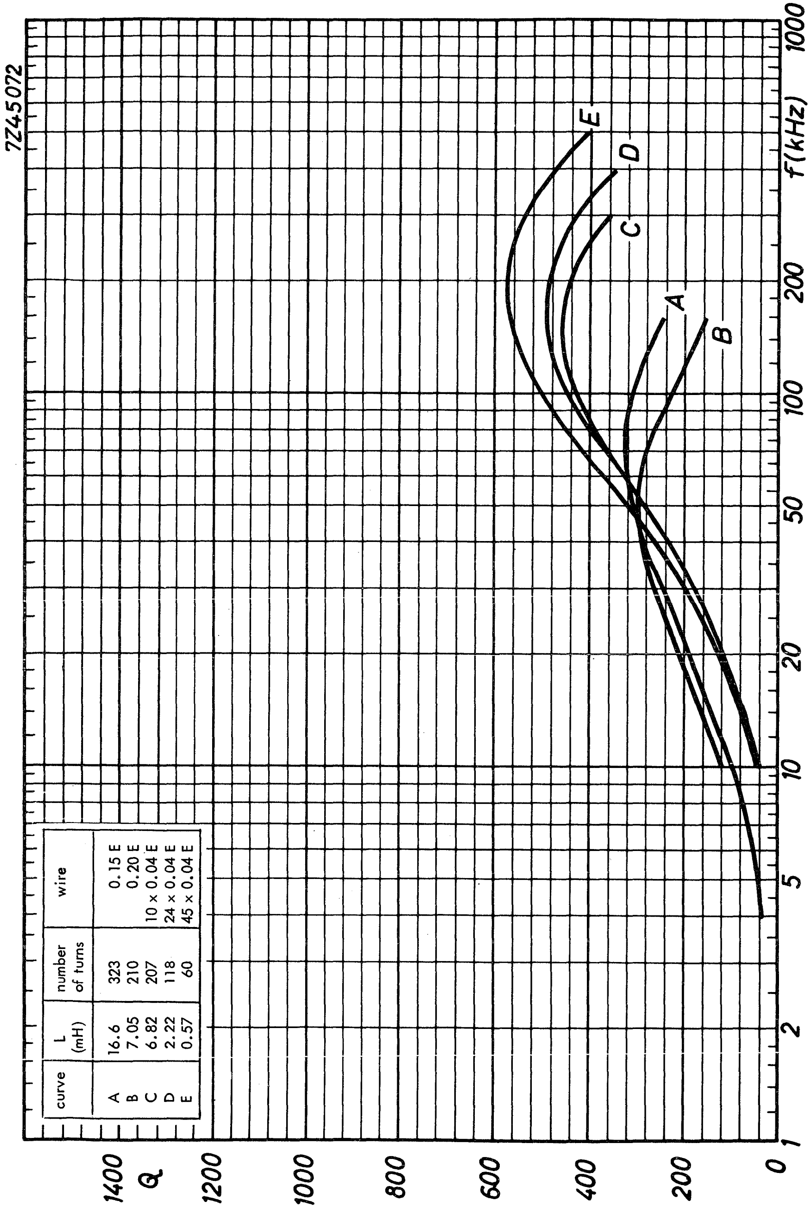
TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1





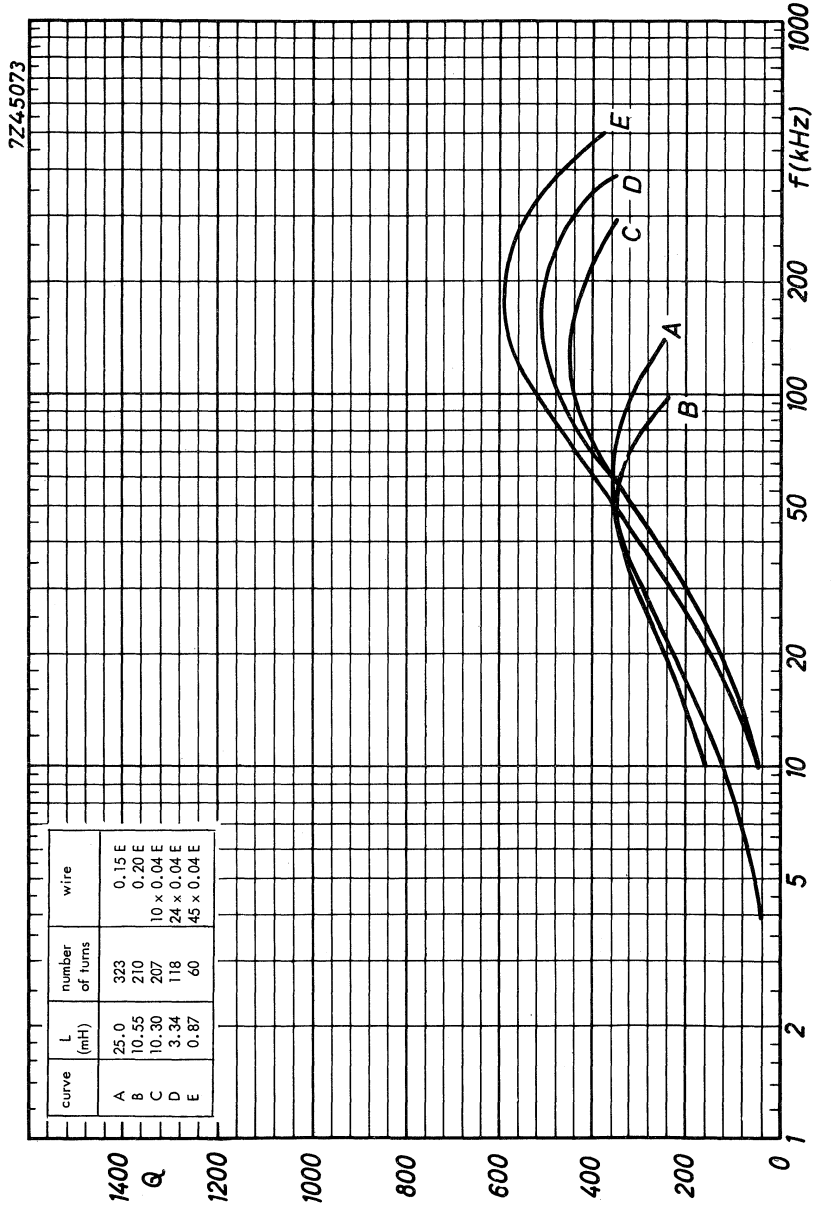
curve	L (mH)	number of turns	wire
A	11.32	323	0.15 E
B	4.78	210	0.20 E
C	4.65	207	10 × 0.04 E
D	1.51	118	24 × 0.04 E
E	0.39	60	45 × 0.04 E

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 68$



curve	L (mH)	number of turns	wire
A	16.6	323	0.15 E
B	7.05	210	0.20 E
C	6.82	207	10 × 0.04 E
D	2.22	118	24 × 0.04 E
E	0.57	60	45 × 0.04 E

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 100$

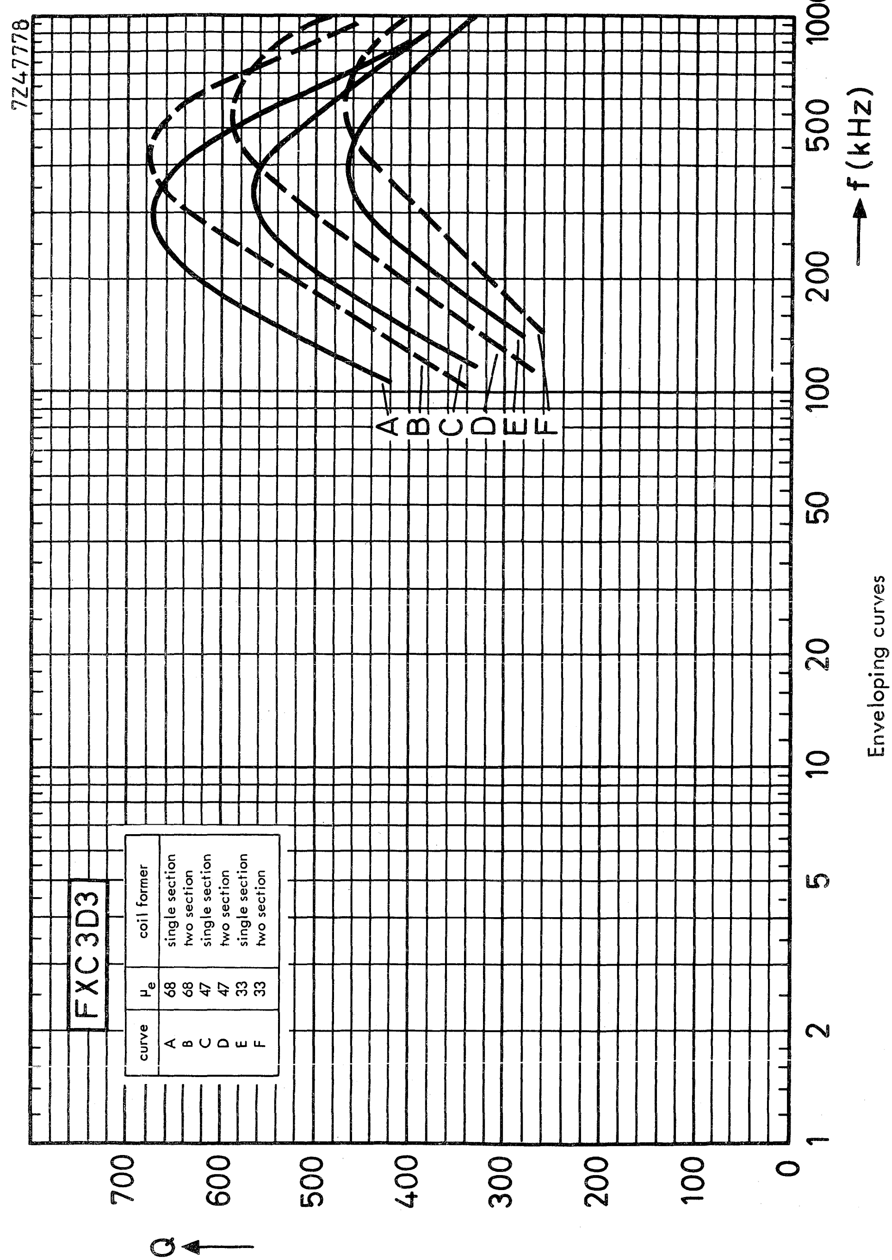


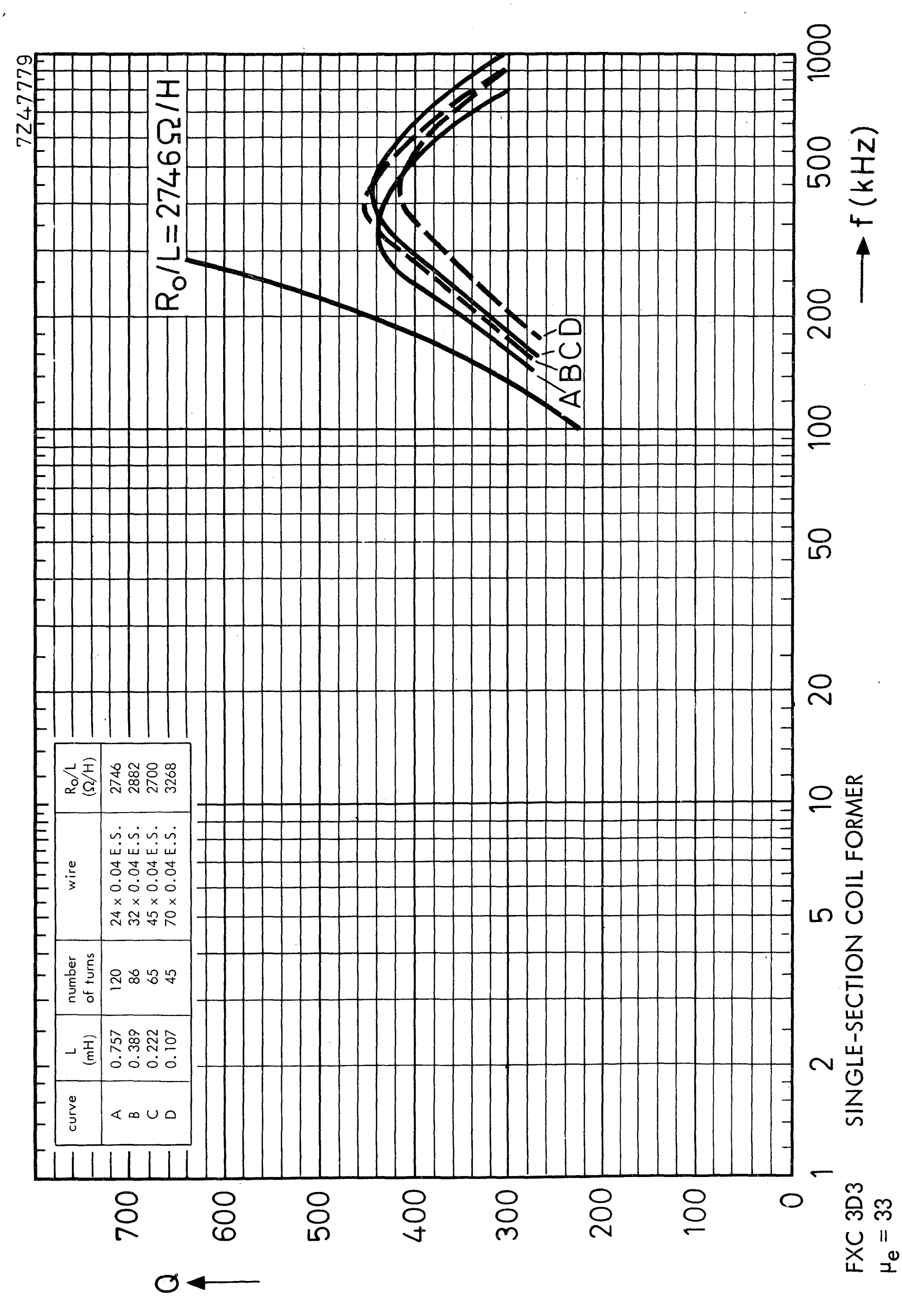
curve	L (mH)	number of turns	wire
A	25.0	323	0.15 E
B	10.55	210	0.20 E
C	10.30	207	10 × 0.04 E
D	3.34	118	24 × 0.04 E
E	0.87	60	45 × 0.04 E

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

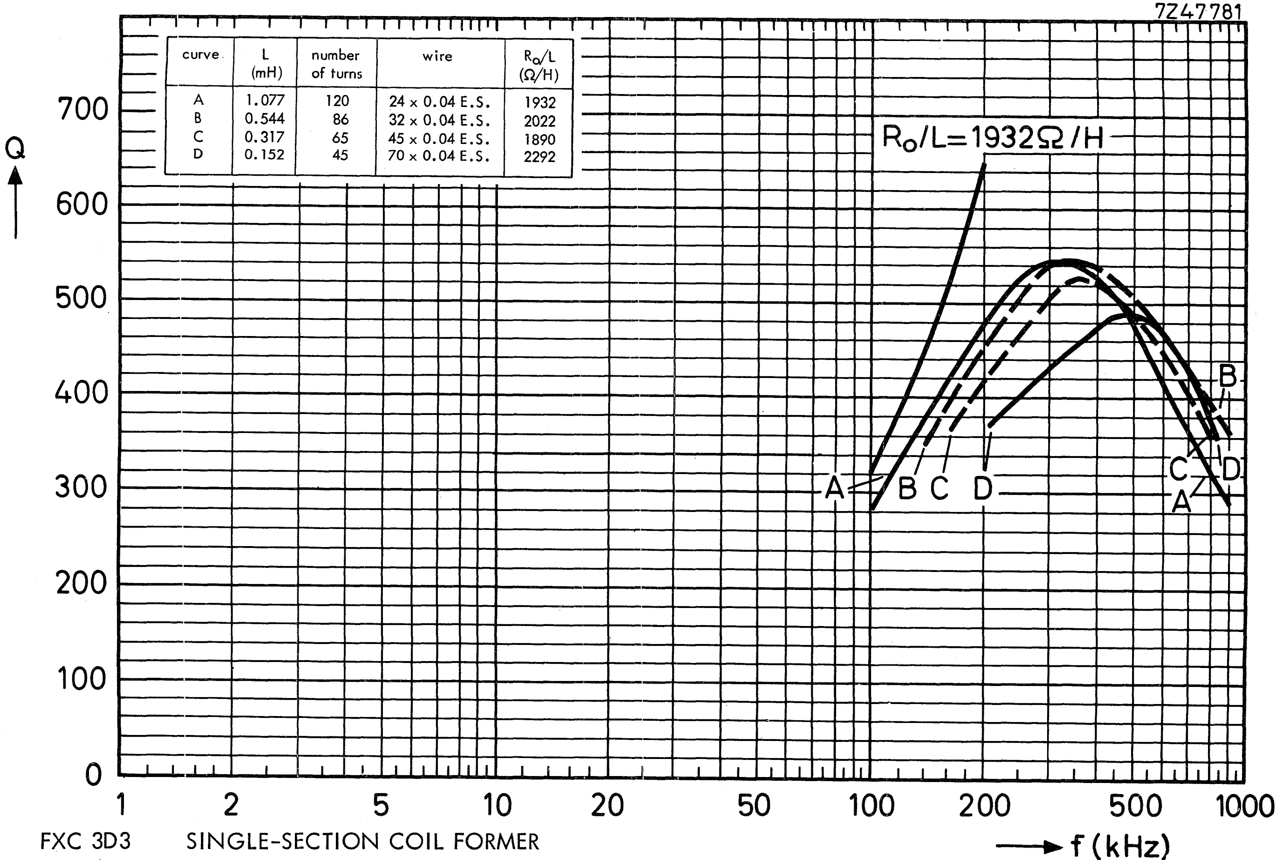
$\mu_e = 150$

TYPICAL Q-CURVES FOR FXC 3D3



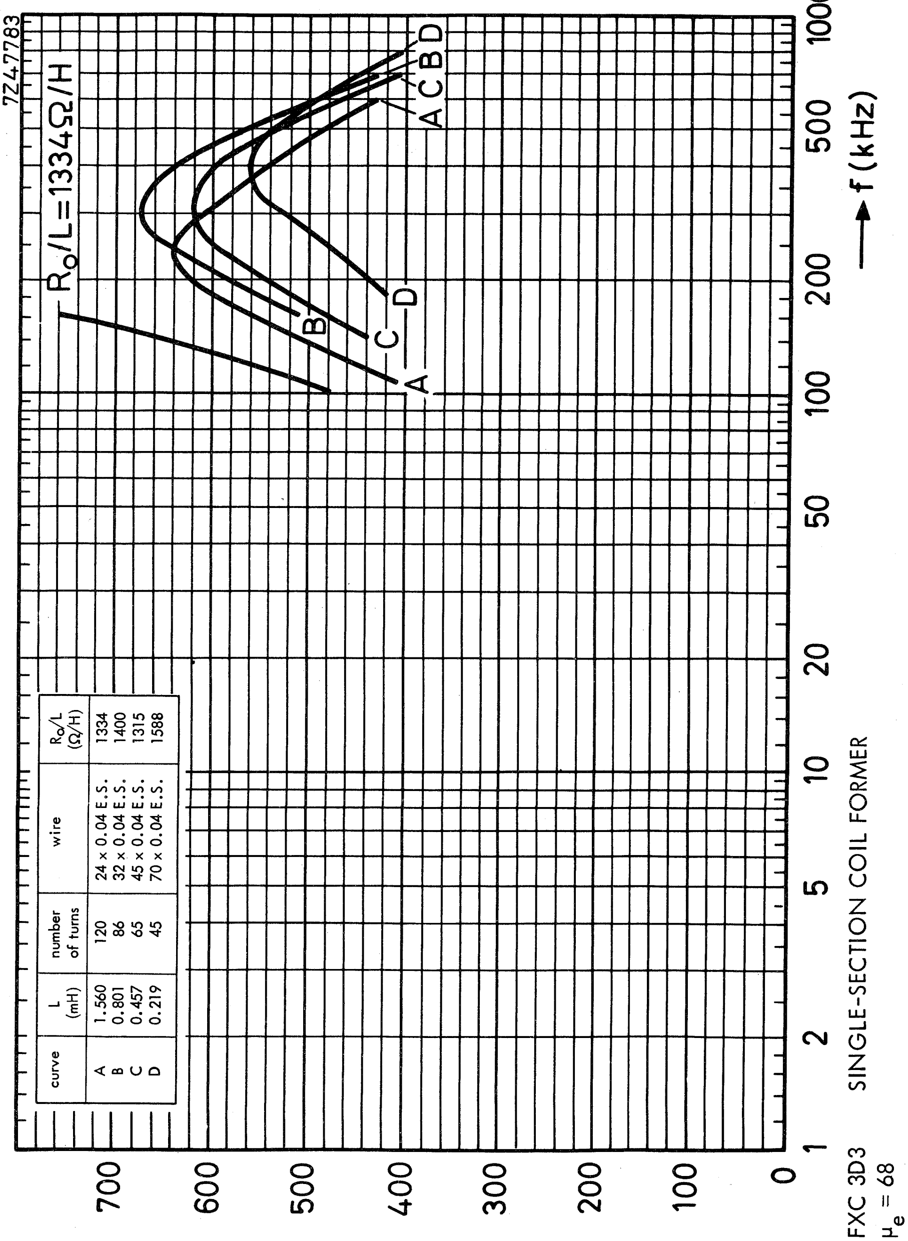


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	0.757	120	24 × 0.04 E.S.	2746
B	0.389	86	32 × 0.04 E.S.	2882
C	0.222	65	45 × 0.04 E.S.	2700
D	0.107	45	70 × 0.04 E.S.	3268



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	1.077	120	24 × 0.04 E.S.	1932
B	0.544	86	32 × 0.04 E.S.	2022
C	0.317	65	45 × 0.04 E.S.	1890
D	0.152	45	70 × 0.04 E.S.	2292

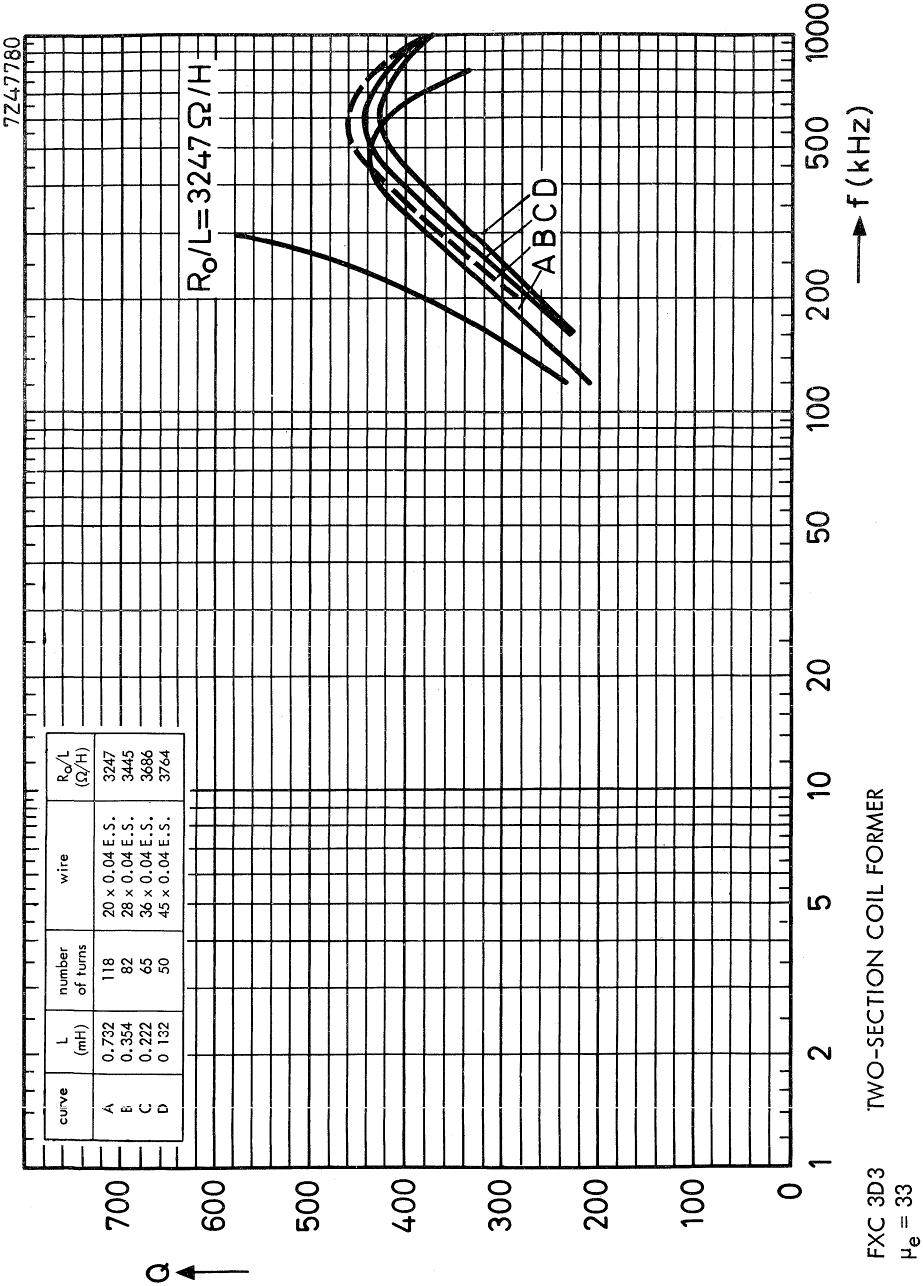
FXC 3D3 SINGLE-SECTION COIL FORMER
$\mu_e = 47$



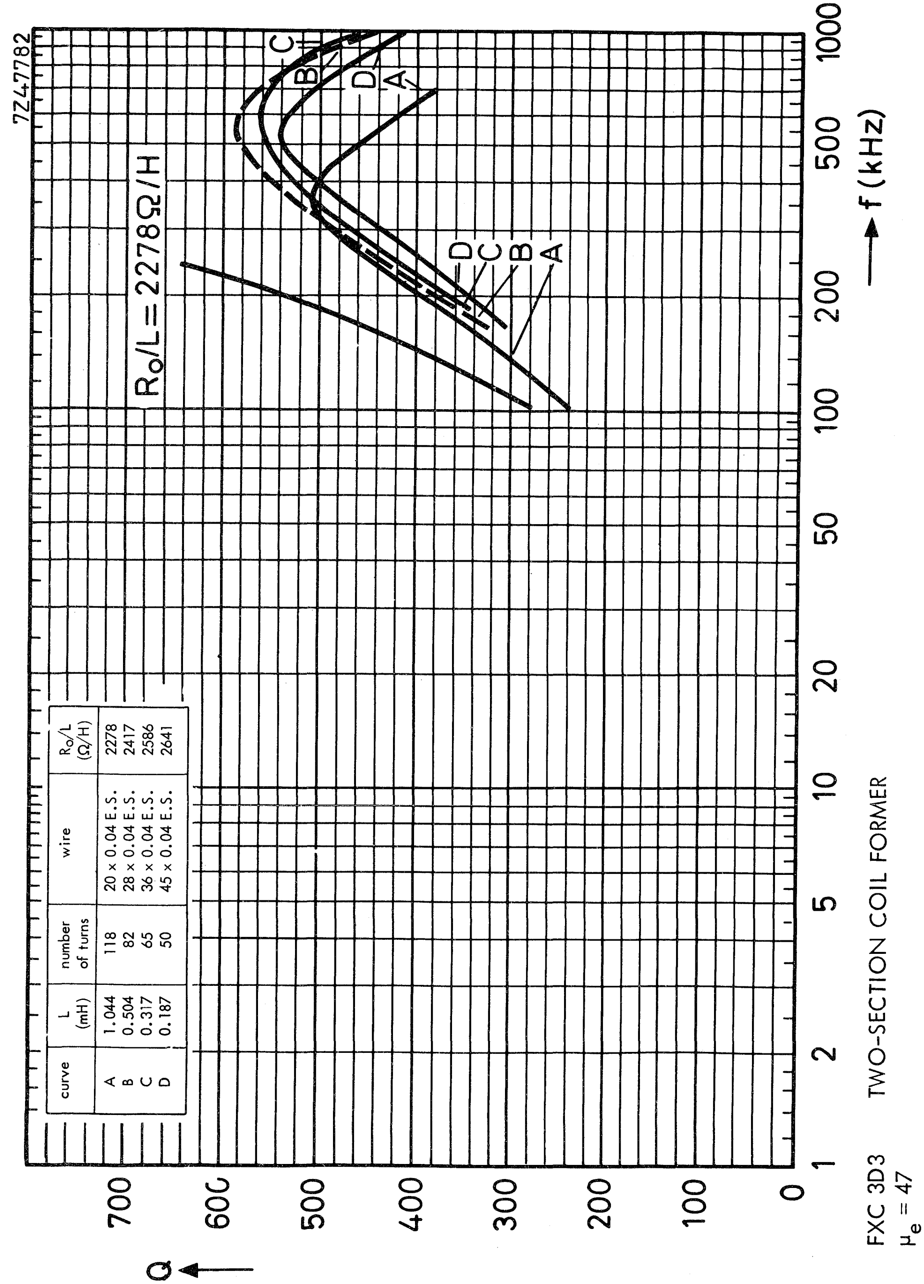
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	1.560	120	24 × 0.04 E.S.	1334
B	0.801	86	32 × 0.04 E.S.	1400
C	0.457	65	45 × 0.04 E.S.	1315
D	0.219	45	70 × 0.04 E.S.	1588

SINGLE-SECTION COIL FORMER

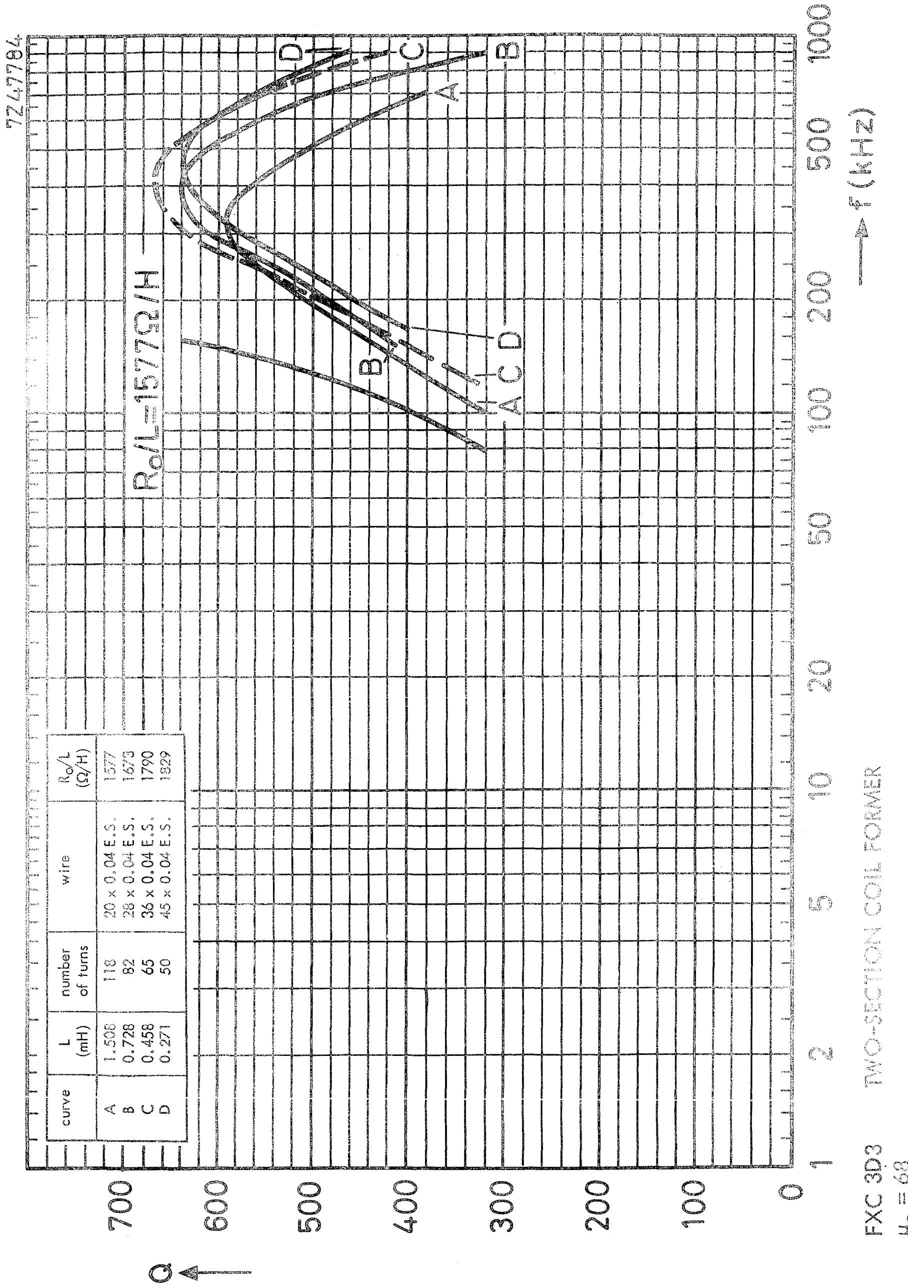
FXC 3D3
$\mu_e = 68$



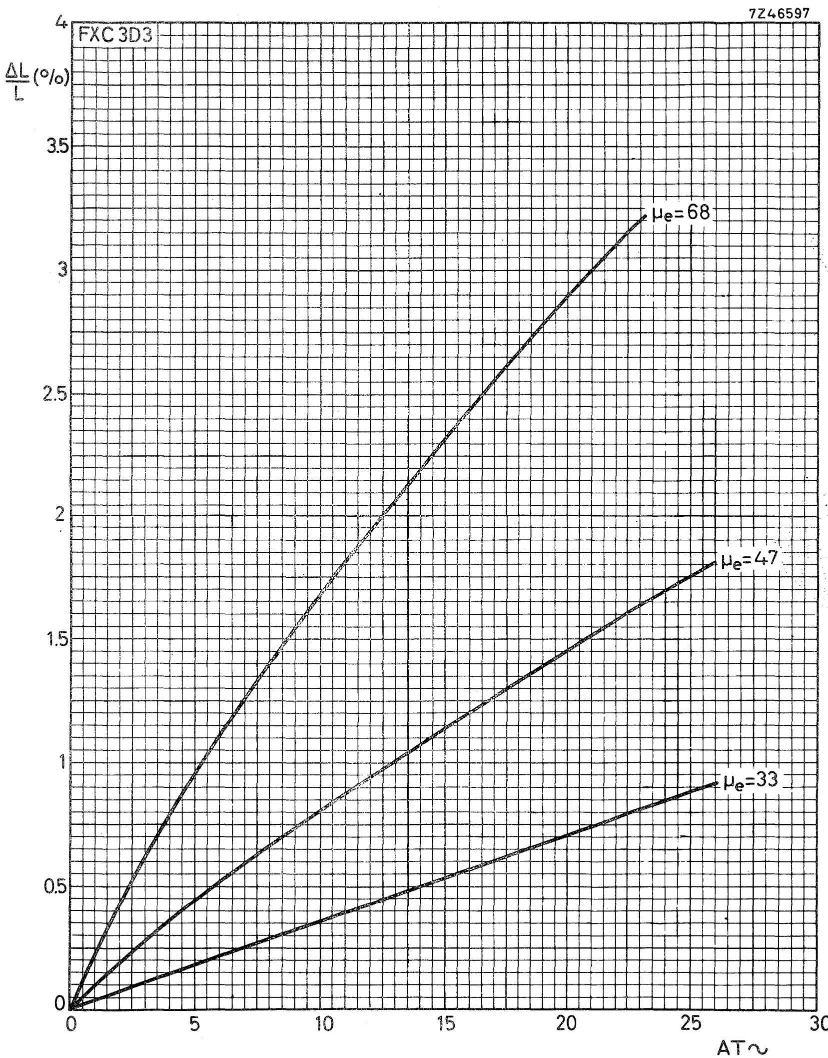
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	0.732	118	20 × 0.04 E.S.	3247
B	0.354	82	28 × 0.04 E.S.	3445
C	0.222	65	36 × 0.04 E.S.	3686
D	0 132	50	45 × 0.04 E.S.	3764

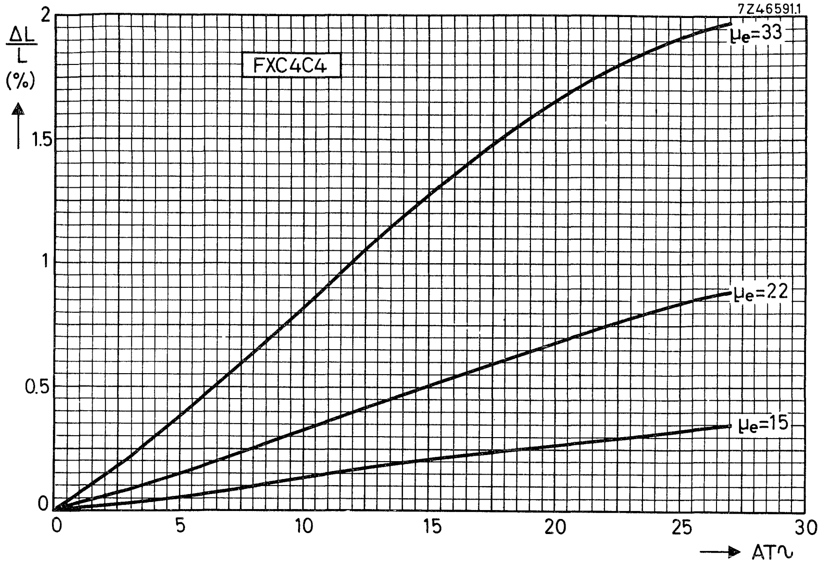


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	1.044	118	20 × 0.04 E.S.	2278
B	0.504	82	28 × 0.04 E.S.	2417
C	0.317	65	36 × 0.04 E.S.	2586
D	0.187	50	45 × 0.04 E.S.	2641

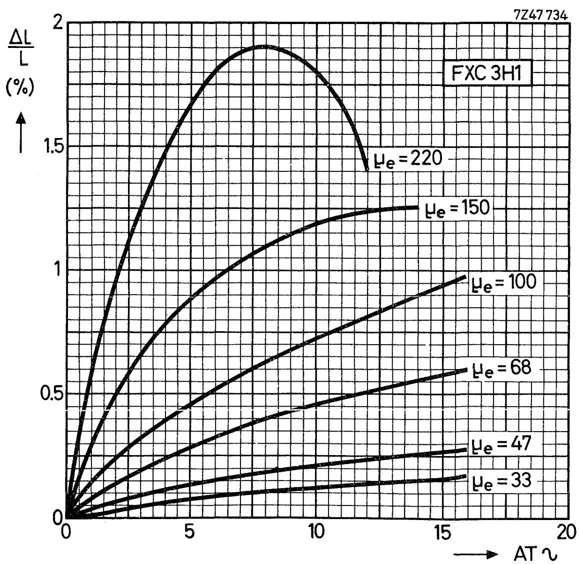

7247784
curve | L (mH) | number of turns | wire | R_o/L (Ω/H)
A | 1.508 | 118 | 20 x 0.04 E.S. | 1577
B | 0.728 | 82 | 28 x 0.04 E.S. | 1673
C | 0.458 | 65 | 36 x 0.04 E.S. | 1790
D | 0.271 | 50 | 45 x 0.04 E.S. | 1829
R_o/L=1577Ω/H
A
B
C
D
Q
700
600
500
400
300
200
100
0
1
2
5
10
20
50
100
200
500
1000
f (kHz)
FXC 3D3
TWO-SECTION COIL FORMER
μ_e = 68

INDUCTANCE VARIATION AS A FUNCTION OF AT~





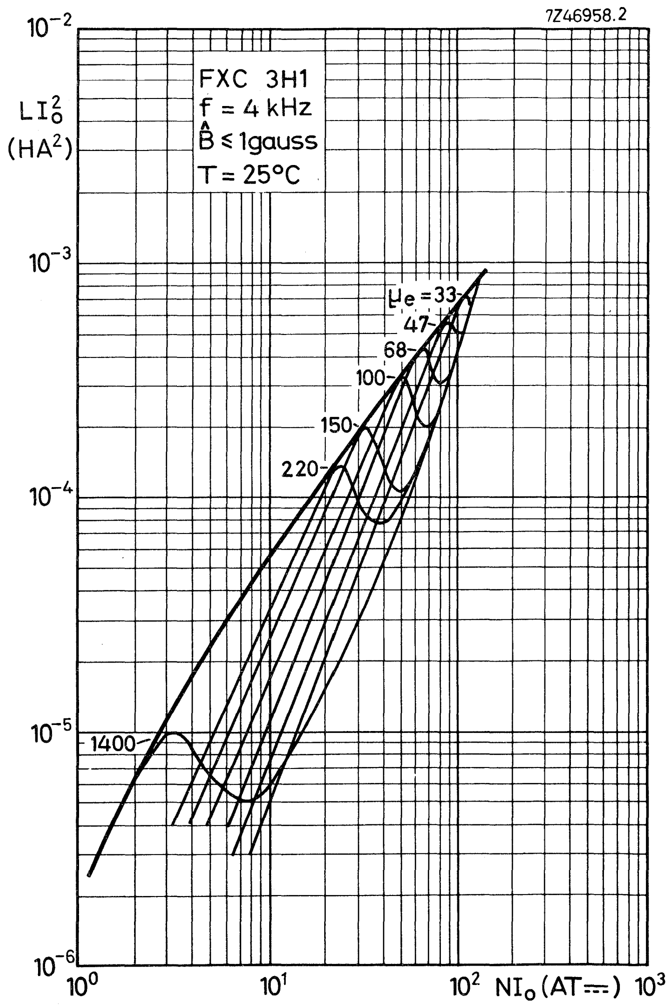
7Z46591.1
ΔL/L (%)
FXC4C4
μe=33
μe=22
μe=15
0
0.5
1
1.5
2
0
5
10
15
20
25
30
AT∿

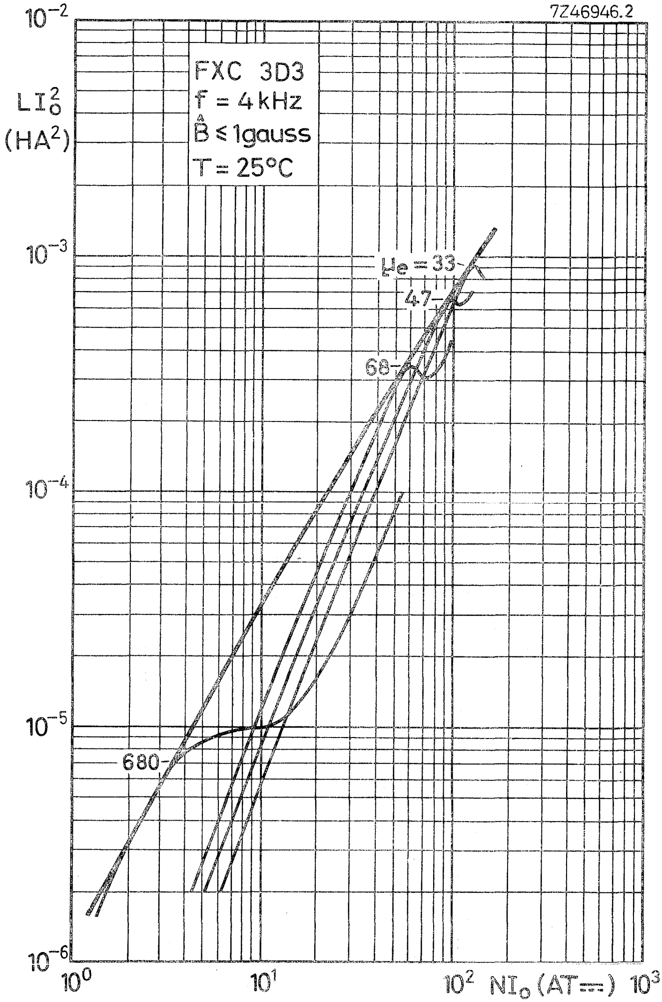


7Z47734
ΔL/L (%)
FXC 3H1
μe = 220
μe = 150
μe = 100
μe = 68
μe = 47
μe = 33
0
0.5
1
1.5
2
0
5
10
15
20
AT ∿

HANNA CURVES

Indicating the optimum inductance for a certain μ_e-value and direct current
Typical values




7Z46946.2
FXC 3D3
f = 4 kHz
B̂ ≤ 1gauss
T = 25°C
LI_o^2 (HA^2)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
μ_e = 33
47
68
680
10^0
10^1
10^2
NI_o (AT⎓)
10^3

POTCORES

INTRODUCTION

Three types of core can be supplied:

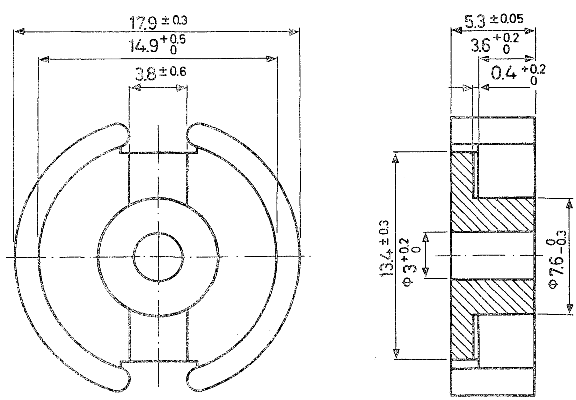
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C.133 (international), C.C.T.U.06-02 (France) and D.I.N.41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number.
Quantity: a primary pack contains 20 potcore halves or 10 pieces of pre-adjusted potcore, so please order in multiples of these quantities.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 21500
3H1	4322 020 21510
3D3	4322 020 21520
4C4	4322 020 21530
4C6	

Properties

For toroidally wound core halves the values in Table I are guaranteed.

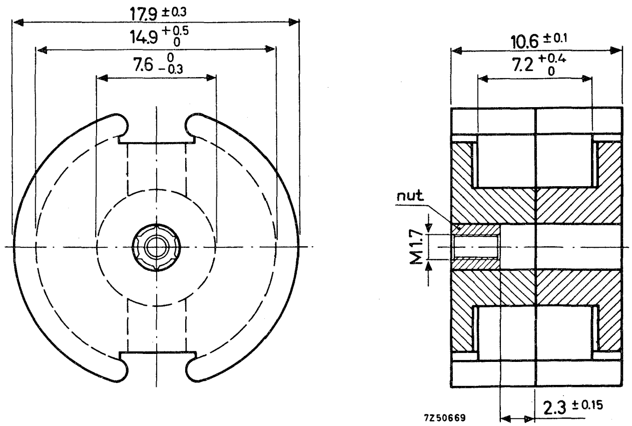
Table I	temp. (°C)	grade				
		3B7	3H1	3D3	4C4	4C6
T.F. x 10^6	+5 to +23	–	–	–	–	−2 to +4
	+23 to +55	–	–	–	−10 to 0	0 to +6
	+23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to 2	–	
D.F. x 10^6 (10-100 min)	23 ± 1	≤ 4.3	≤ 4.3	≤ 12	≤ 33	≤ 10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 100 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (MHz)	grade				
			3D3	3H1	3B7	4C4	4C6
μ_e	≤ 1	0.1	≥ 530	≥ 1310	≥ 1310	≥ 94	
	≤ 1	0.1	≤ 29.9	≤ 19.0	≤ 19.0	≤ 71.1	
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	≤ 1	0.1	≤ 8	≤ 5	≤ 5		
	≤ 1	0.5	≤ 14				
	≤ 1	1	≤ 30				
		2					≤ 45
		5					≤ 60
		10					≤ 100
$q_{2-24-100}$	3-12	0.1	≤ 3.0				
	15-30	0.004		≤ 1.8	≤ 1.8		

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 2....
Without nut, catalog number = 4322 022 0....

Weight			6.4 g
Mean length of lines of force	l_e	=	2.58 cm
	$\Sigma \frac{l_e}{A_e}$	=	5.97 cm^{-1}
Effective volume	V_e	=	1.12 cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 2 for potcores with nut, insert 0 for potcores without nut.
   Examples of catalog number:
   μ_e = 15, grade 4C4, potcore with nut, catalog number = 4322 022 22610
   A_L = 100, grade 3B7, potcore without nut, catalog number = 4322 022 05040
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
15	178	± 1	–	–	–	.2610
22	147	± 1	–	–	–	.2620
33	120	± 1	.4030	.4230	.4430	.2630
47	100.5	± 1	.4040	.4240	.4440	–
68	83.6	± 1	.4050	.4250	.4450	–
100	68.9	± 1.5	.4060	.4260	–	–
150	56.3	± 2	.4070	.4270	–	–
220	46.5	± 3	.4080	.4280	–	–
705	25.9	± 25	–	–	04400	–
1750	16.5	± 25	04000	04200	–	–

Number of turns $N = \alpha\sqrt{L}$ (L in 10^{-3} H)

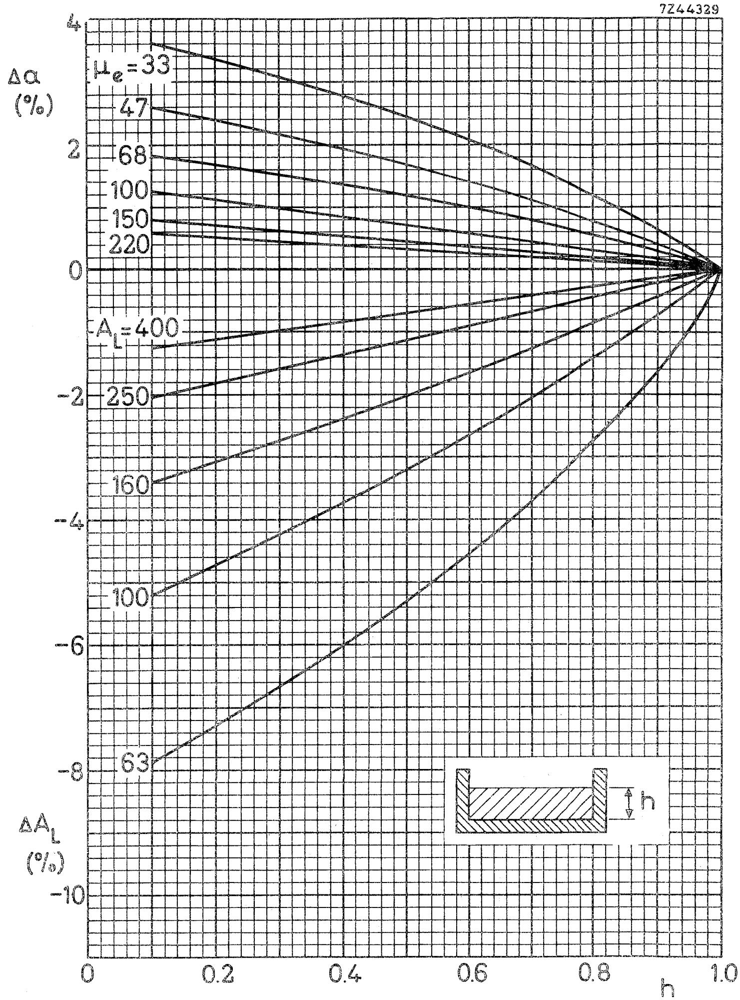
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
25	11.9	± 1	–	–	–	.3610
40	19.0	± 1	–	–	.5420	.3620
63	30	± 1	.5030	.5230	.5430	.3630
100	47.5	± 1	.5040	.5240	.5440	–
160	76	± 1	.5050	.5250	.5450	–
250	119	± 1.5	.5060	.5260	–	–
315	149	± 2	.5070	.5270	–	–
400	190	± 2	.5080	.5280	–	–
630	298	± 3	.5100	.5300	–	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

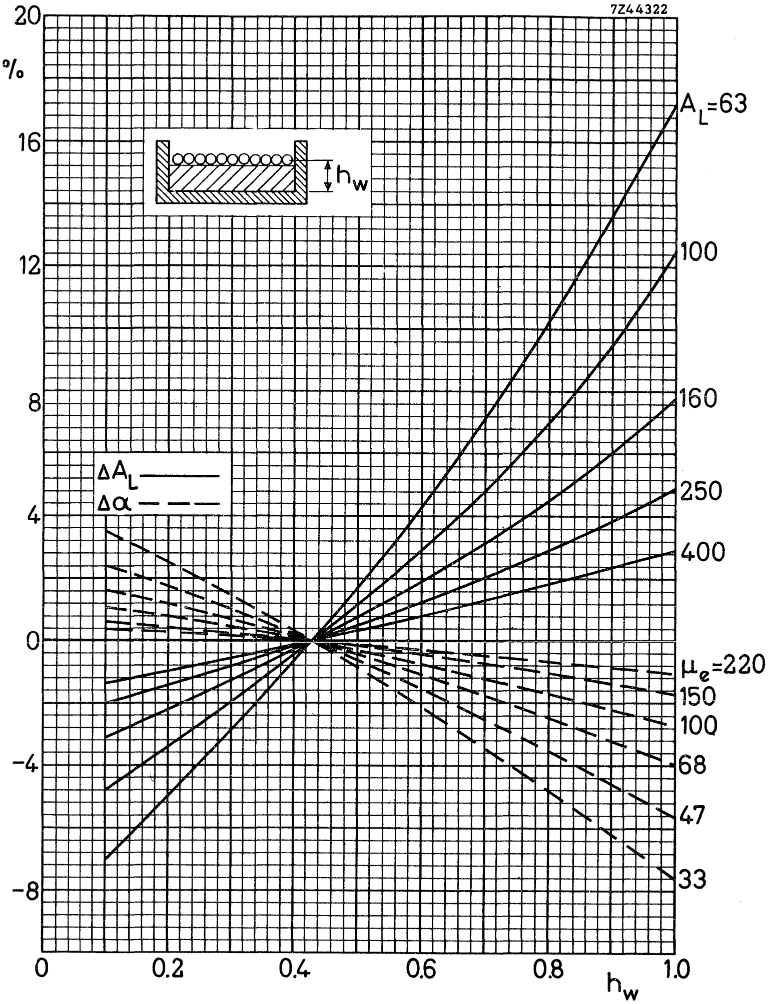
1) See Notes on the previous page.

DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.
Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: Of a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 83.6 + 1.30 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_w on a single-section coil former.
Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 83.6 - 1.7 %.

COIL FORMERS

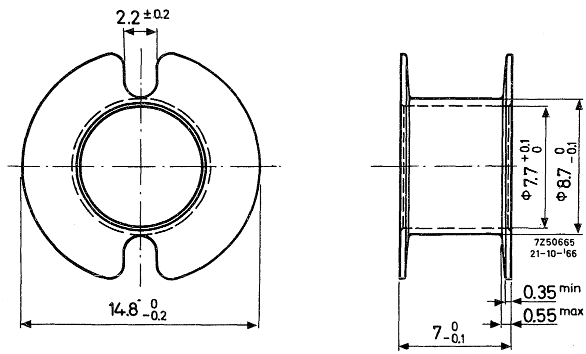
GENERAL

Four types of coil former can be supplied:

- with one section
- with two sections
- with three sections
- with one section and with soldering pins to fit 0.1" and 2.50 mm grid.

The dimensions conform with the following specifications: I.E.C.133 (international), C.C.T.U.0.6-02 (France) and D.I.N.41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



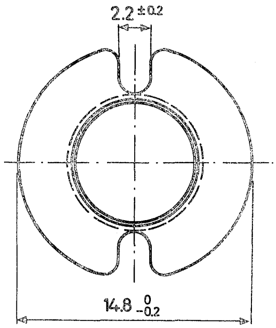
Catalog number	4322 021 30270
Material	polycarbonate K486
Window area	18 mm^2
Mean length of turn	3.7 cm
Max. temperature	130 °C

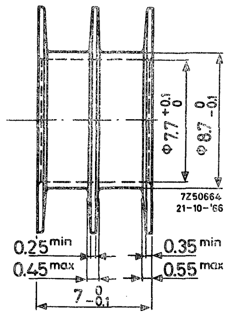
D.C. losses

$$\frac{R_0}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 16.4 \times 10^3 \quad \Omega/H$$

Weight 0.35 g

TWO-SECTION
COIL FORMER





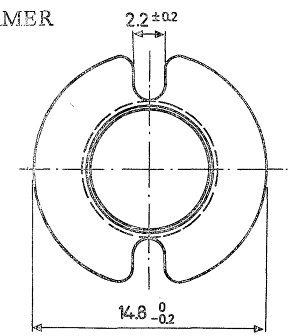
Catalog number	4322 021 30270
Material	polycarbonate K486
Window area	2 x 8.7 mm^2
Mean length of turn	3.7 cm
Max. temperature	130 °C

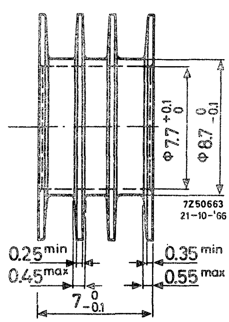
D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 17.2 \times 10^3 \quad \Omega/H$$

Weight 0.35 g

THREE-SECTION
COIL FORMER





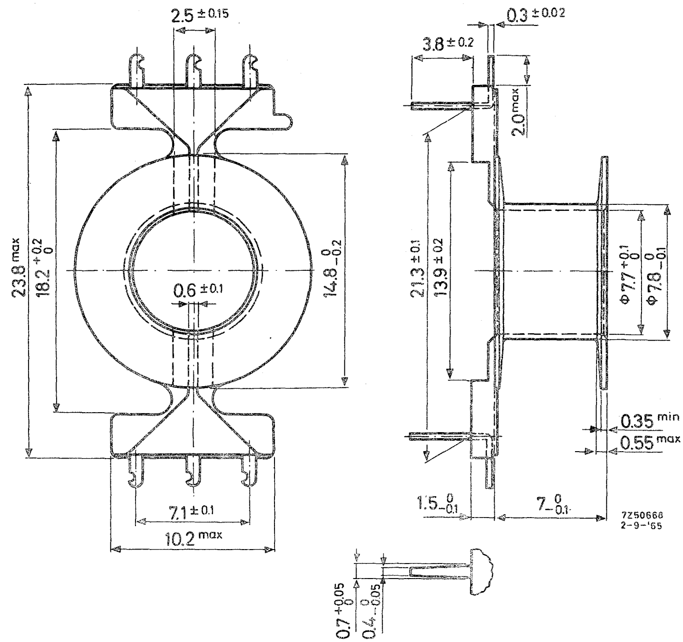
Catalog number	4322 021 30290
Material	polycarbonate K486
Window area	3 x 5.4 mm^2
Mean length of turn	3.7 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 18.4 \times 10^3 \quad \Omega/H$$

Weight 0.4 g

SINGLE-SECTION COIL FORMER WITH SOLDERING PINS



Catalog number 4322 021 30090

Material: reinforced polyester with brass dipsoldered pins

Window area 18 mm^2

Mean length of turn 3.7 cm

Max. temperature 130 ^{o}C

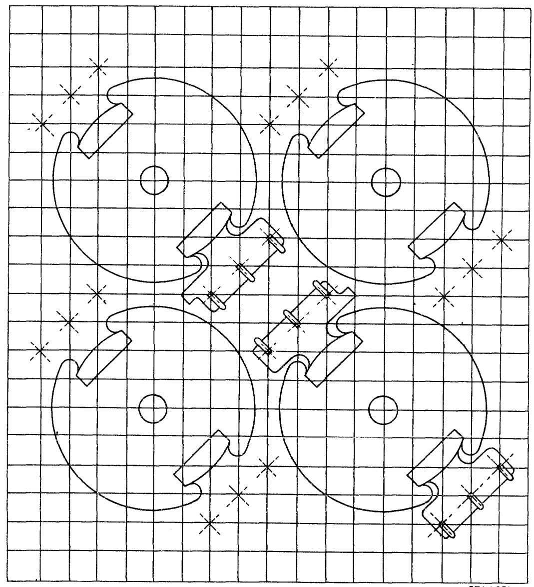
Max. dipsolder temperature for 5 - 6 s 280 ^{o}C

D.C. losses

$$\frac{R_0}{L} = \frac{1}{\mu_c} \times \frac{1}{f_{cu}} \times 16.4 \times 10^3\ \Omega/H$$

Weight 0.45 g

The soldering pins are so arranged as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes 1.3 + 0.1 mm diameter.
For this coil former the potcore halves must be cemented together, and it is recommended to cement the coil former to the lower potcore half.



7Z44851

INDUCTANCE ADJUSTMENT

ADJUSTORS

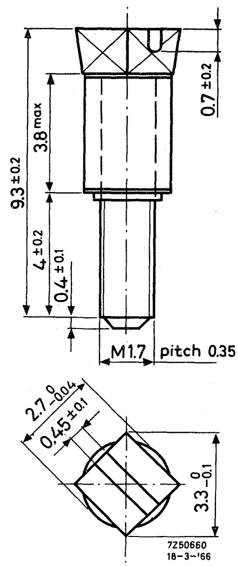


Fig.A

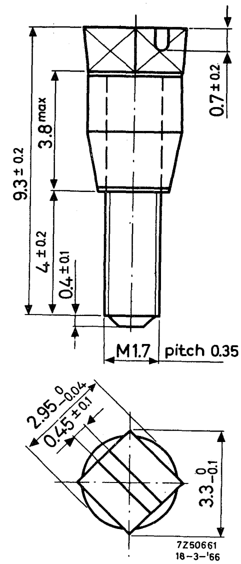


Fig.B

The tolerances on inductance of the pre-adjusted potcores (without adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.03 % by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.
The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.
The influence of the adjustors on the variability of the inductance is negligible.
The maximum permissible temperature is 110 °C.
Table II shows the type of adjustor recommended for different potcores.

Table I, available types:

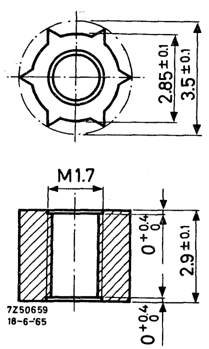
Fig.	colour	catalog number
A	brown	4322 021 30730
A	green	4322 021 30760
A	red	4322 021 30770
B	yellow	4322 021 30960
B	white	4322 021 30970
B	grey	4322 021 31080

Table II, recommended application:

μ_e	A_L	3B7/3H1/3D3	4C4
		cat.number 4322 021	
15		-	30760
	25	-	30760
	40	-	30770
22		-	30770
	63	30760	-
33		30760	30970
	100	30770	
47		30770	
68		30960	
	160	30960	
	250	30970	
100		30970	
150		30730	
	400	31080	
220		31080	

NUT FOR ADJUSTOR

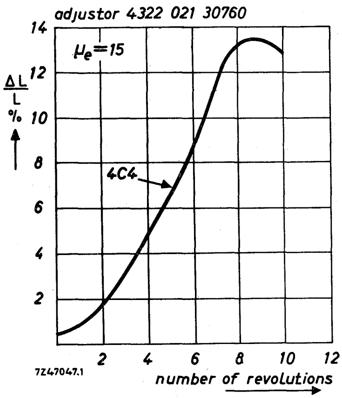
These data are given for those manufacturers who prefer to insert the nut themselves.

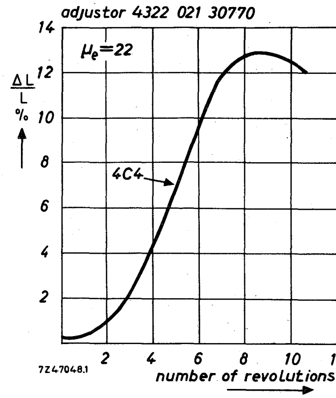


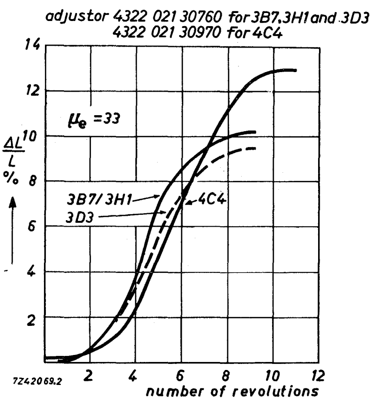
Catalog number	4322 021 30140
Material	polycarbonate
Max. impregnation temperature during 24 hours	120 °C
Recommended distance from mating surface to nut	2.3 ± 0.15 mm

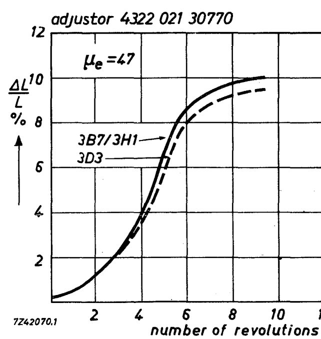
For more information see Potcores General, Inductance adjustment.

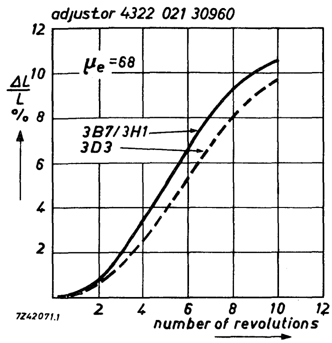
ADJUSTMENT CURVES

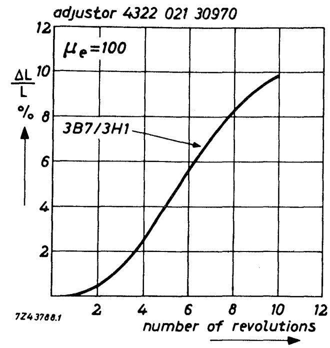


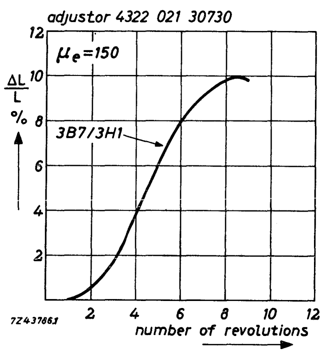


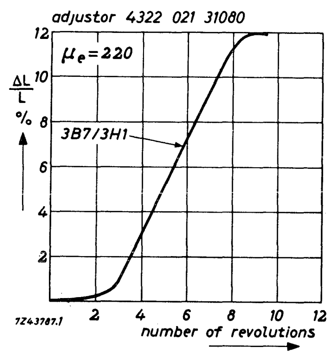





adjustor 4322 021 30960
$\mu_e = 68$
$\frac{\Delta L}{L}$ %
3B7/3H1
3D3
number of revolutions
7Z42071.1

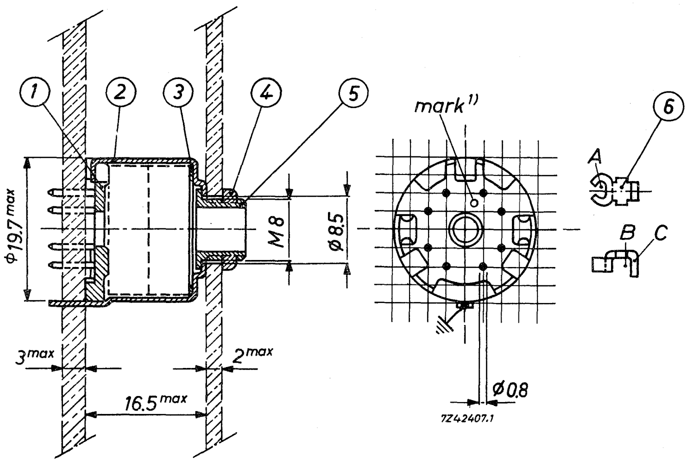

adjustor 4322 021 30970
$\mu_e = 100$
$\frac{\Delta L}{L}$ %
3B7/3H1
number of revolutions
7Z43788.1


adjustor 4322 021 30730
$\mu_e = 150$
$\frac{\Delta L}{L}$ %
3B7/3H1
number of revolutions
7Z43786.1


adjustor 4322 021 31080
$\mu_e = 220$
$\frac{\Delta L}{L}$ %
3B7/3H1
number of revolutions
7Z43787.1

MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30450	(4) nut	4322 021 30710
(2) brass container	4322 021 30530	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30640	(6) soldering spring	4322 021 30700 (8x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The eight soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness up to 3 mm. The board should be provided with holes of 1.3+0.1 mm diameter.

---

[1]) There is another mark hole in a similar position on the top of the container.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

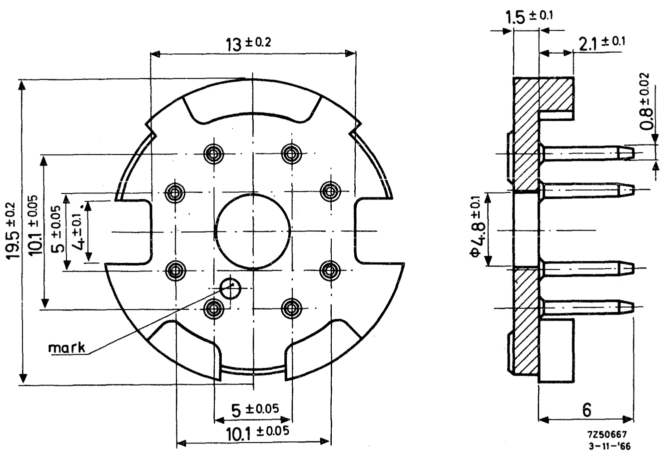
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 100 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

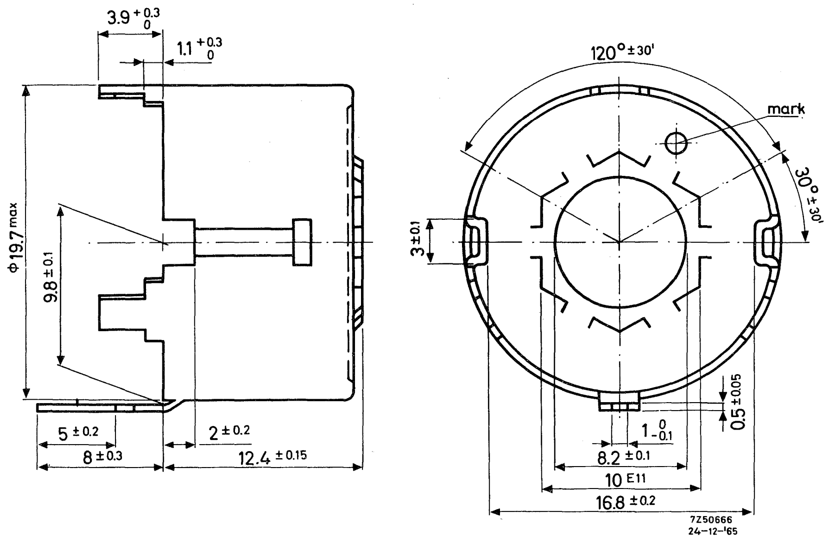
(1) Tag plate 4322 021 20450

Plate : reinforced polyester
Pins : phosphorbronze, dipsoldered



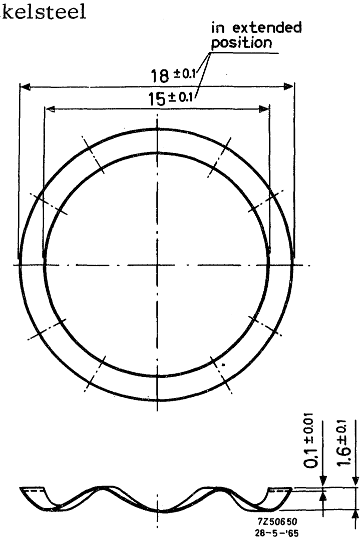
(2) Container 4322 021 30530

Material : brass, nickel plated



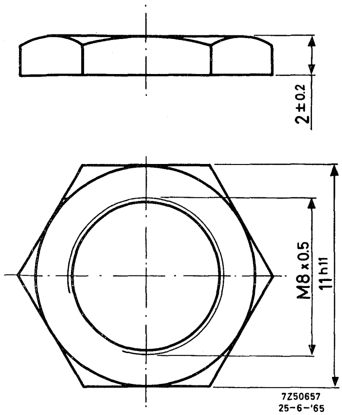
(3) Spring 4322 021 30640

Material : chrome-nickelsteel



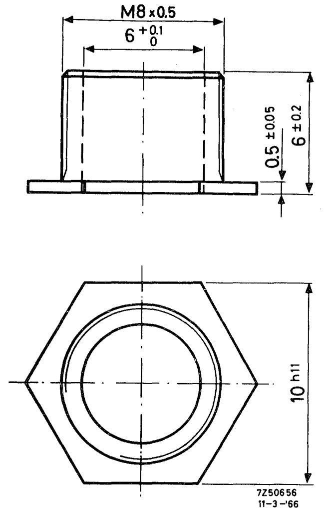
(4) Nut 4322 021 30710

Material : brass, nickel plated



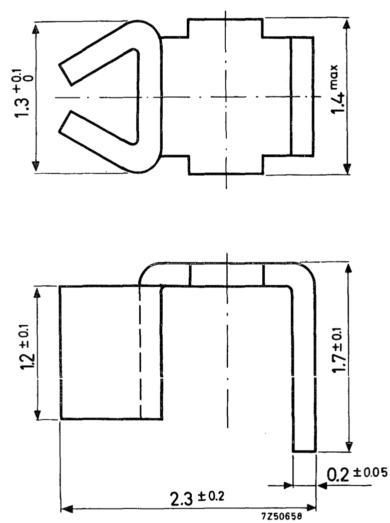
(5) Fixing bush 4322 021 30720

Material : aluminium



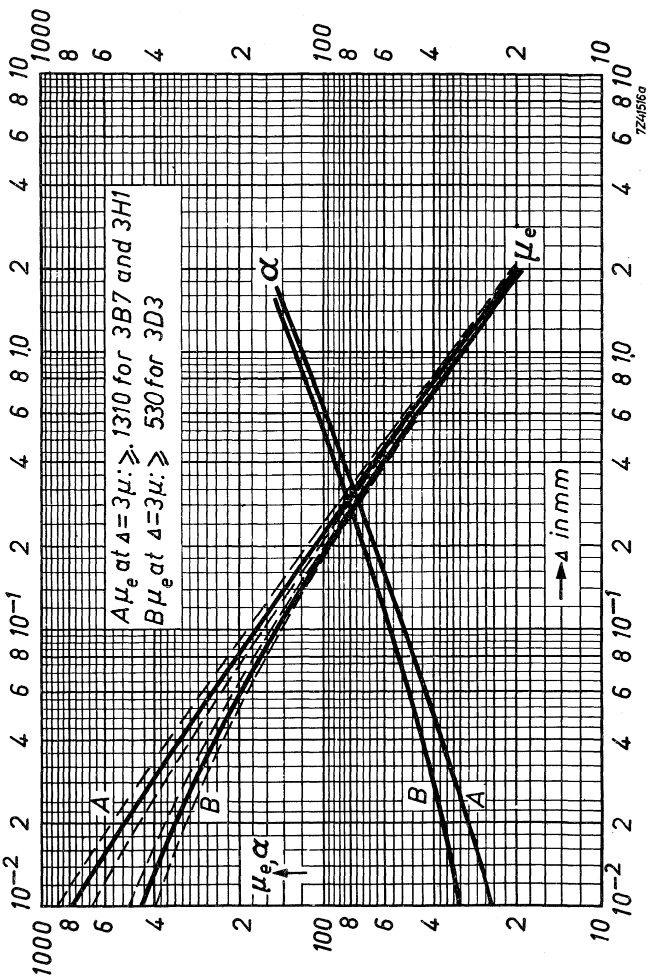
(6) Soldering spring 4322 021 30700

Material : brass, dipsoldered



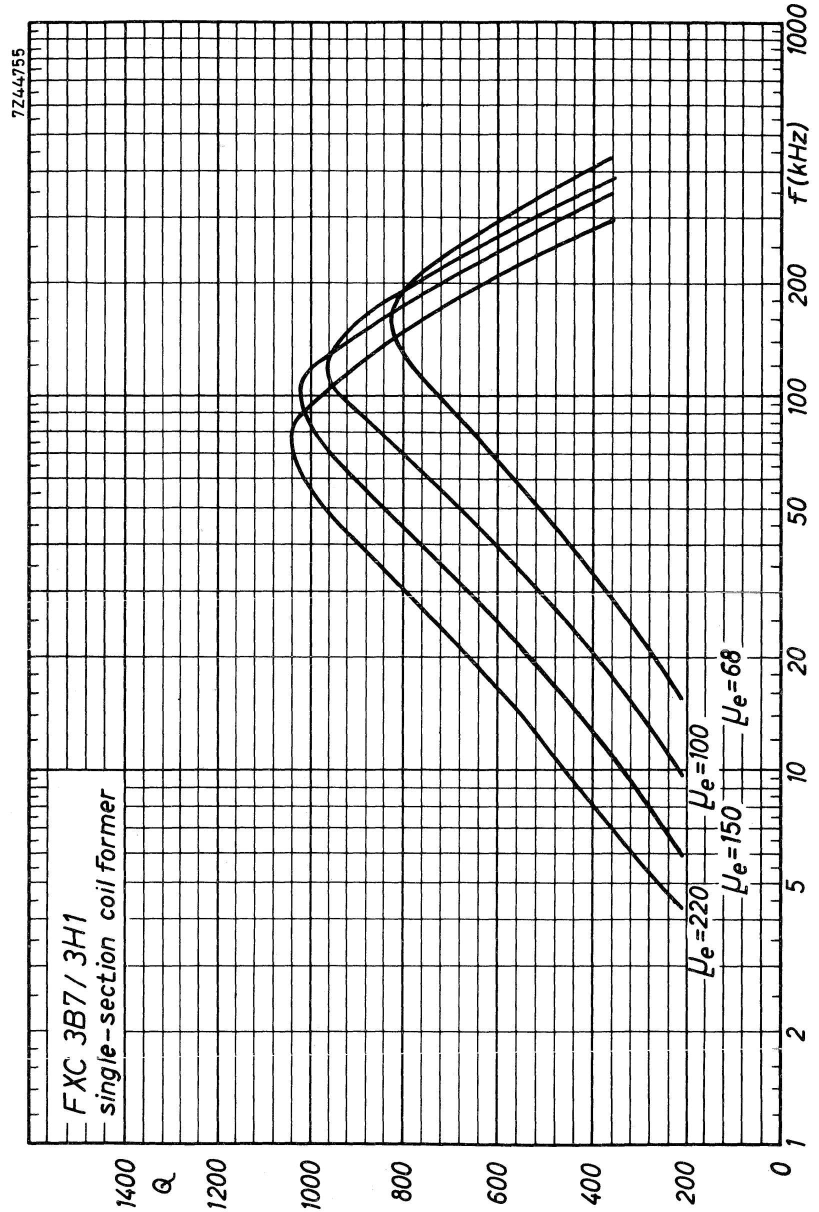
CHARACTERISTIC CURVES

μ_e - α CURVES

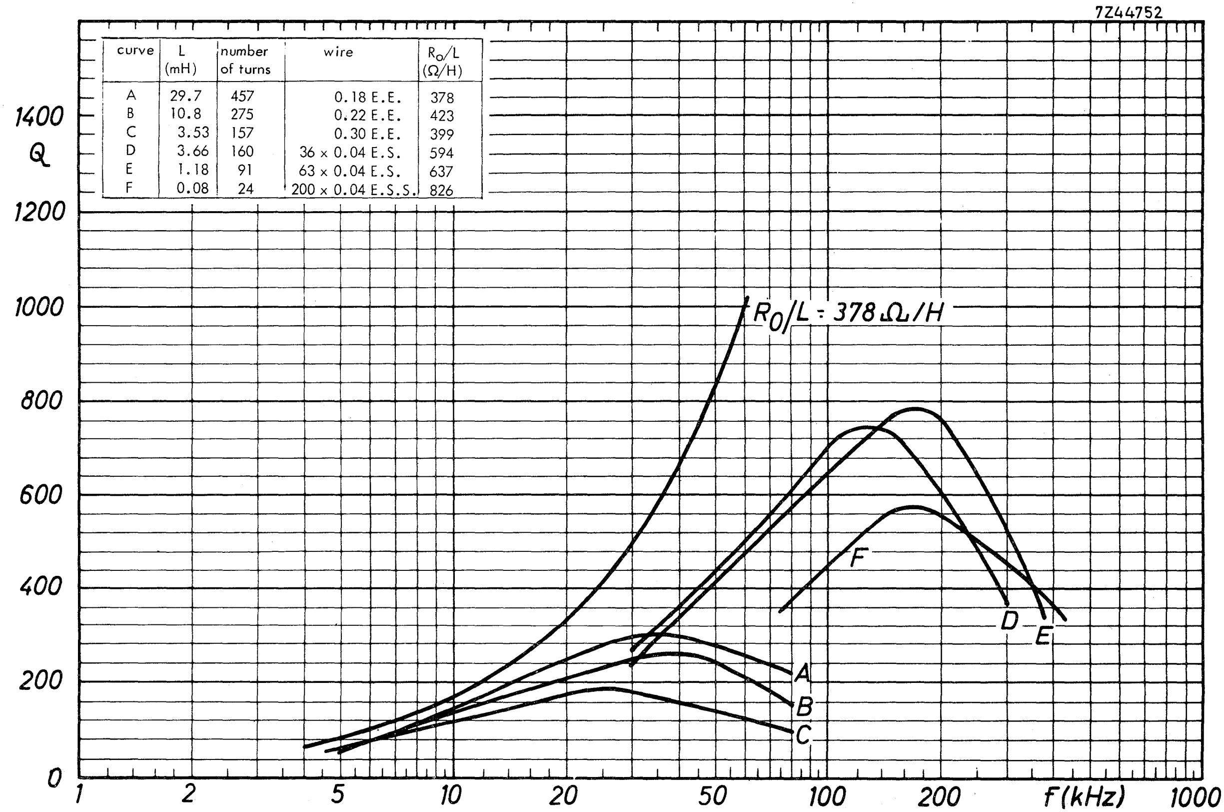


Effective permeability and turn factor for 1 mH as a function of the air gap length

TYPICAL Q-CURVES FOR FXC 3B7/3H1

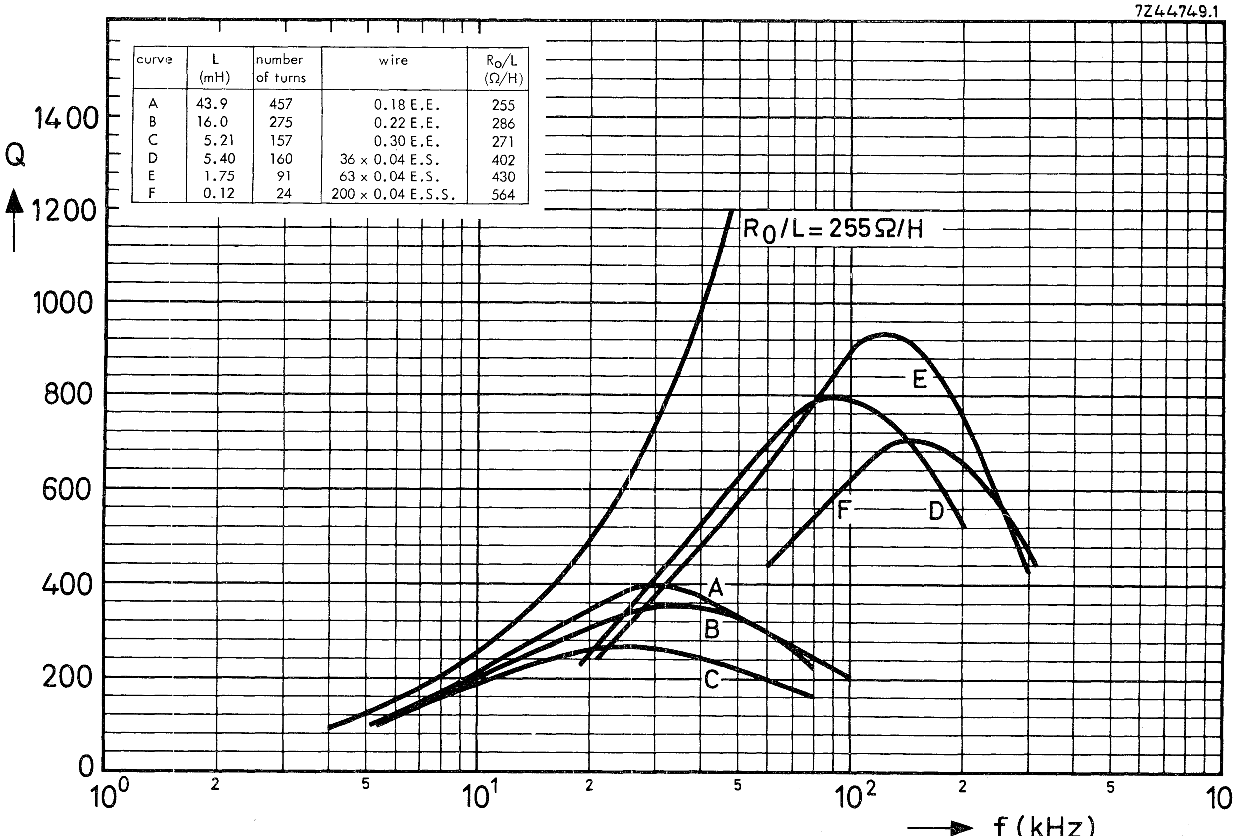


Enveloping curves



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	29.7	457	0.18 E.E.	378
B	10.8	275	0.22 E.E.	423
C	3.53	157	0.30 E.E.	399
D	3.66	160	36 × 0.04 E.S.	594
E	1.18	91	63 × 0.04 E.S.	637
F	0.08	24	200 × 0.04 E.S.S.	826

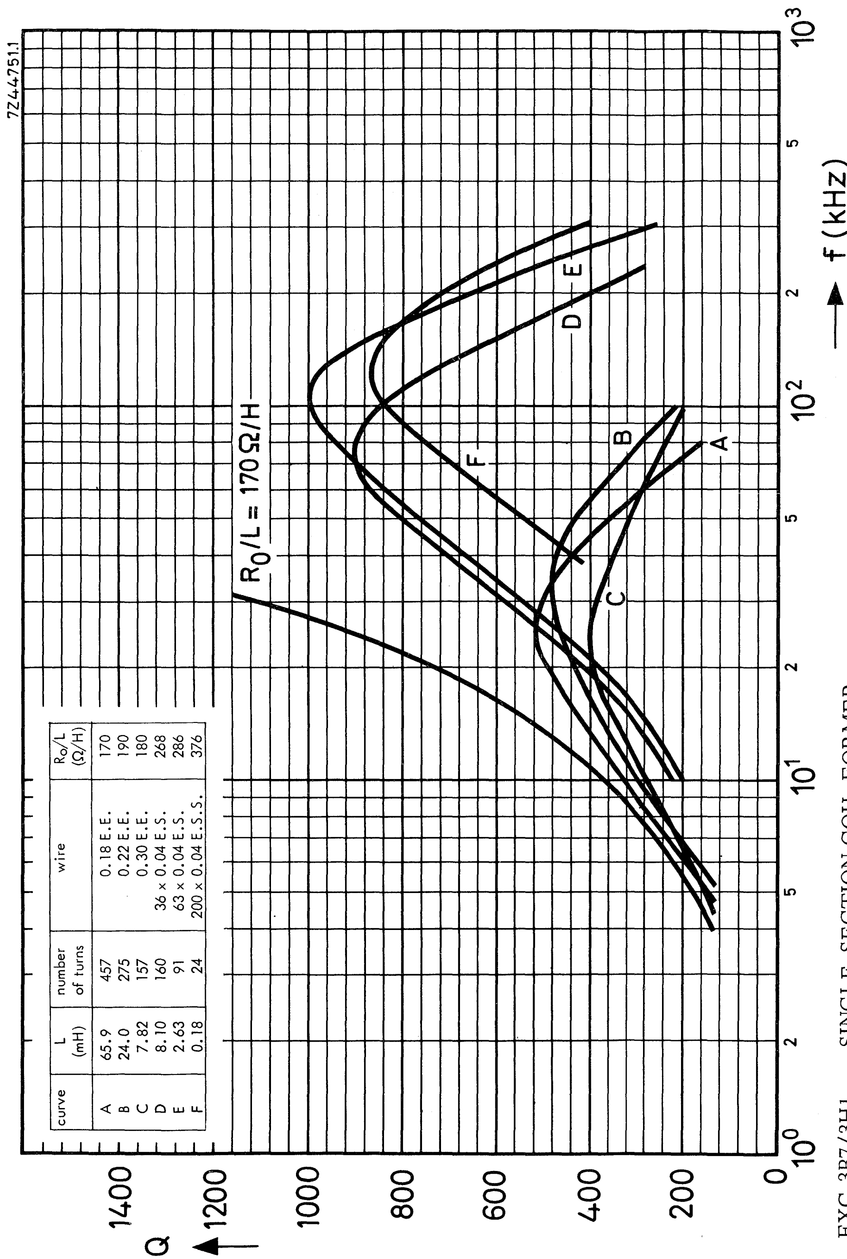
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 68$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	43.9	457	0.18 E.E.	255
B	16.0	275	0.22 E.E.	286
C	5.21	157	0.30 E.E.	271
D	5.40	160	36 x 0.04 E.S.	402
E	1.75	91	63 x 0.04 E.S.	430
F	0.12	24	200 x 0.04 E.S.S.	564

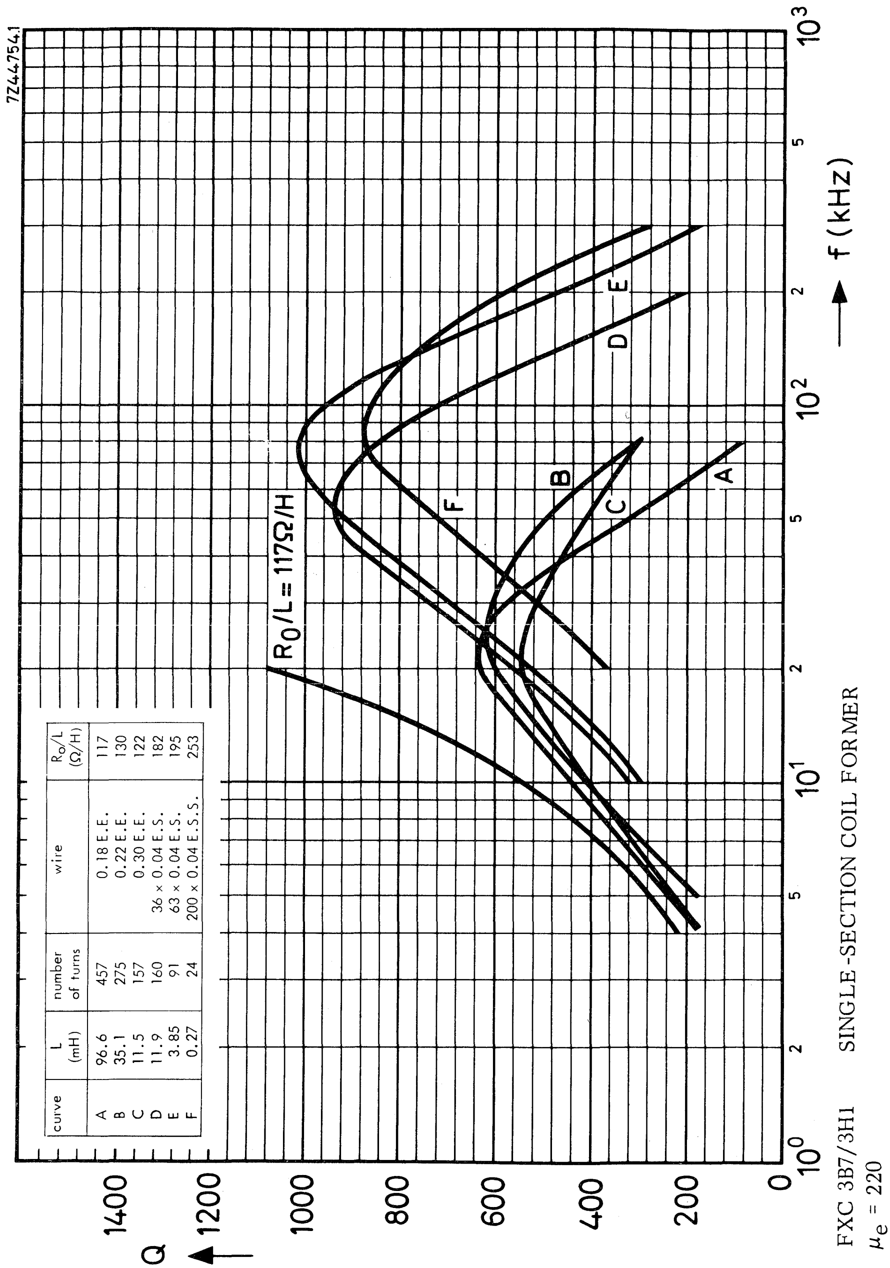
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

$\mu_e = 100$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	65.9	457	0.18 E.E.	170
B	24.0	275	0.22 E.E.	190
C	7.82	157	0.30 E.E.	180
D	8.10	160	36 × 0.04 E.S.	268
E	2.63	91	63 × 0.04 E.S.	286
F	0.18	24	200 × 0.04 E.S.S.	376

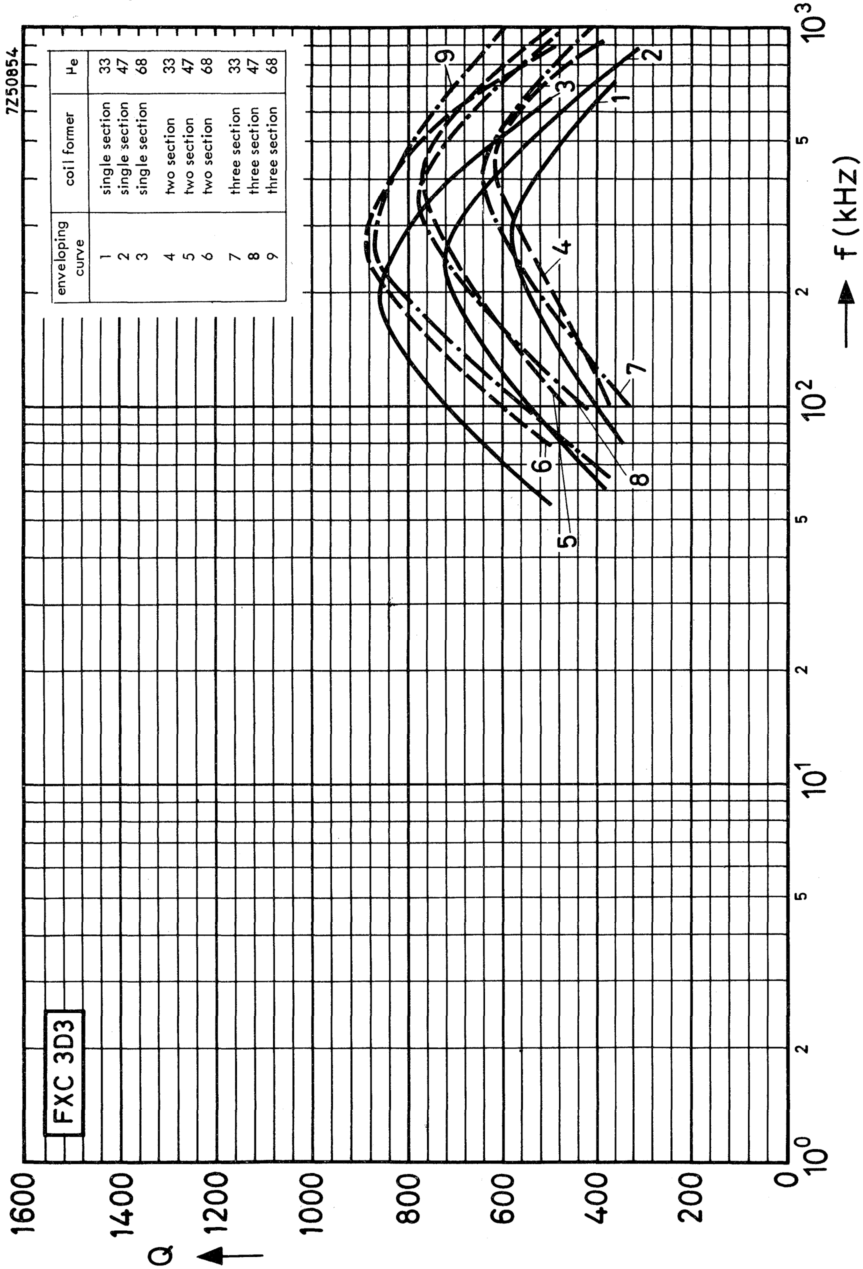
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 150$



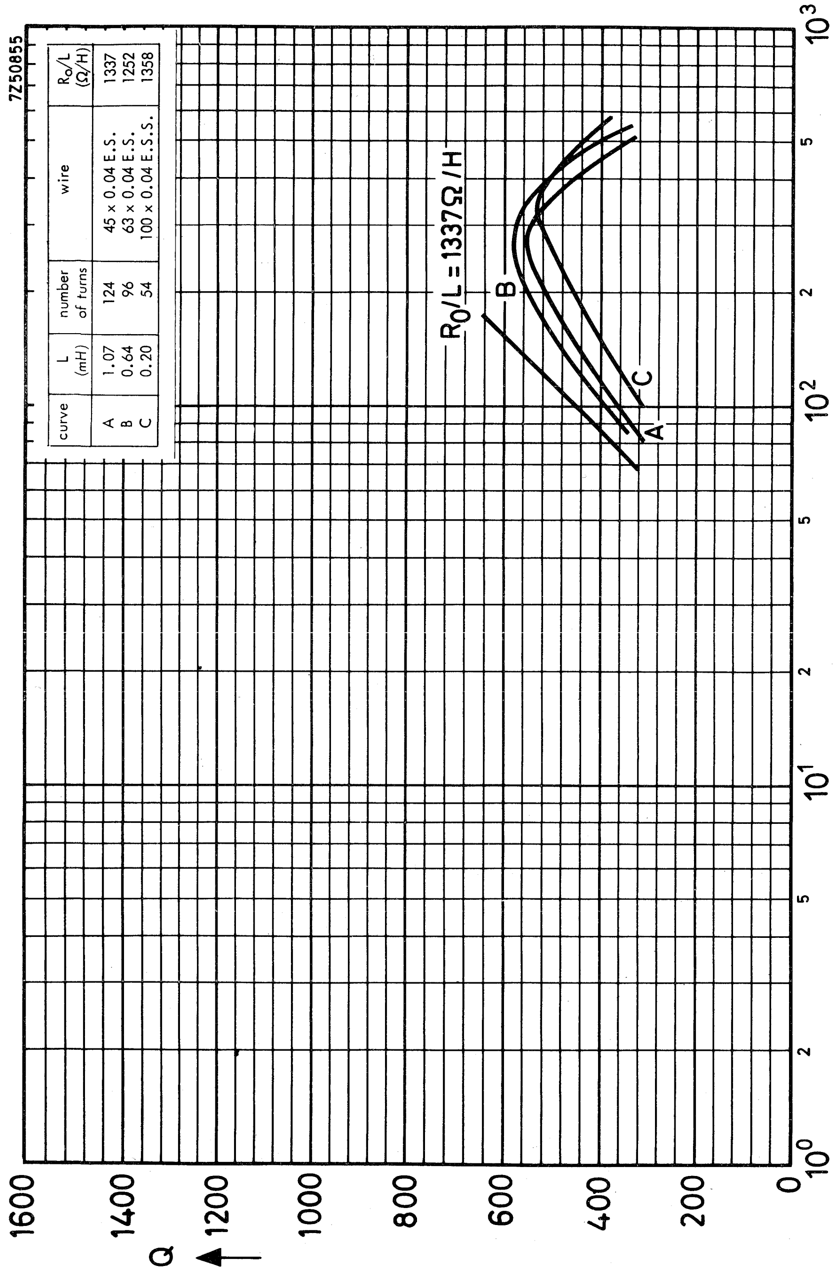
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	96.6	457	0.18 E.E.	117
B	35.1	275	0.22 E.E.	130
C	11.5	157	0.30 E.E.	122
D	11.9	160	36 × 0.04 E.S.	182
E	3.85	91	63 × 0.04 E.S.	195
F	0.27	24	200 × 0.04 E.S.S.	253

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 220$

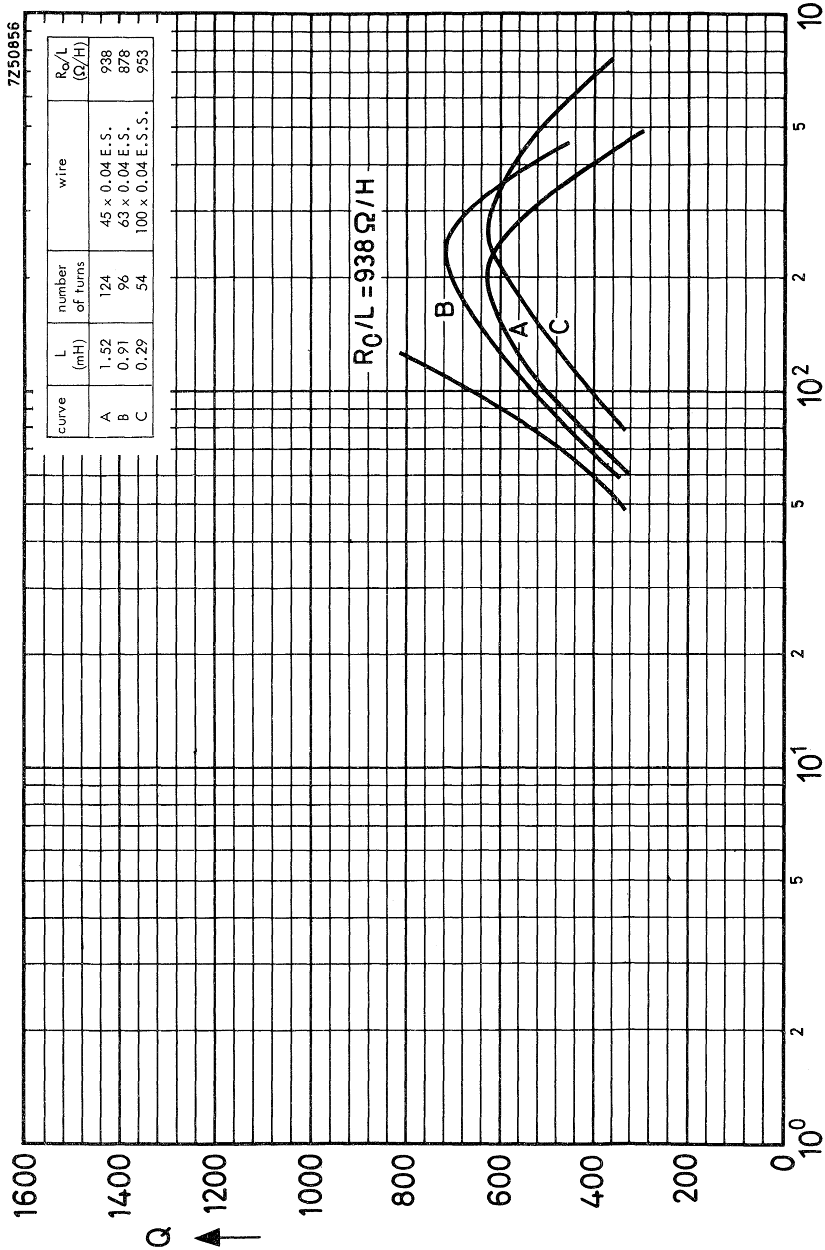
TYPICAL Q-CURVES FOR FXC 3D3



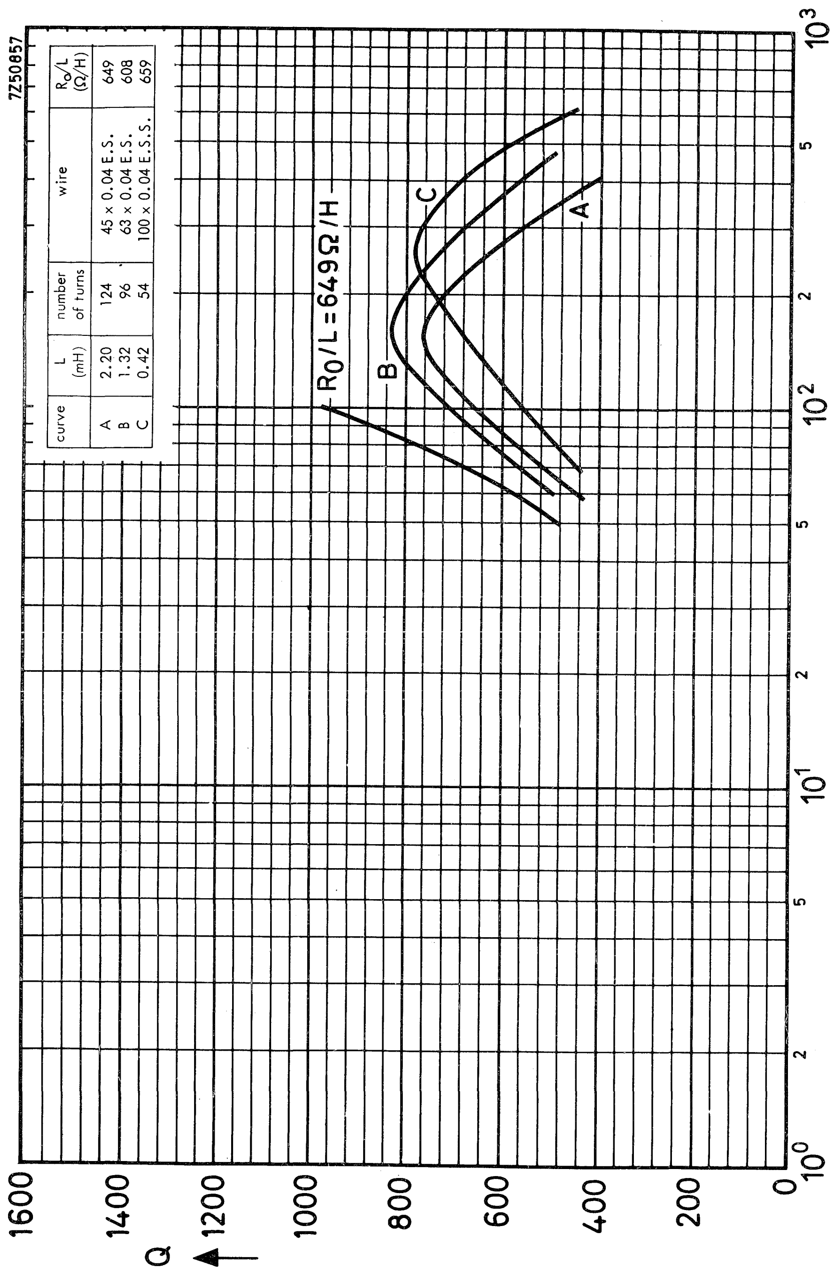
Enveloping curves



FXC 3D3
$\mu_e = 33$
SINGLE-SECTION COIL FORMER

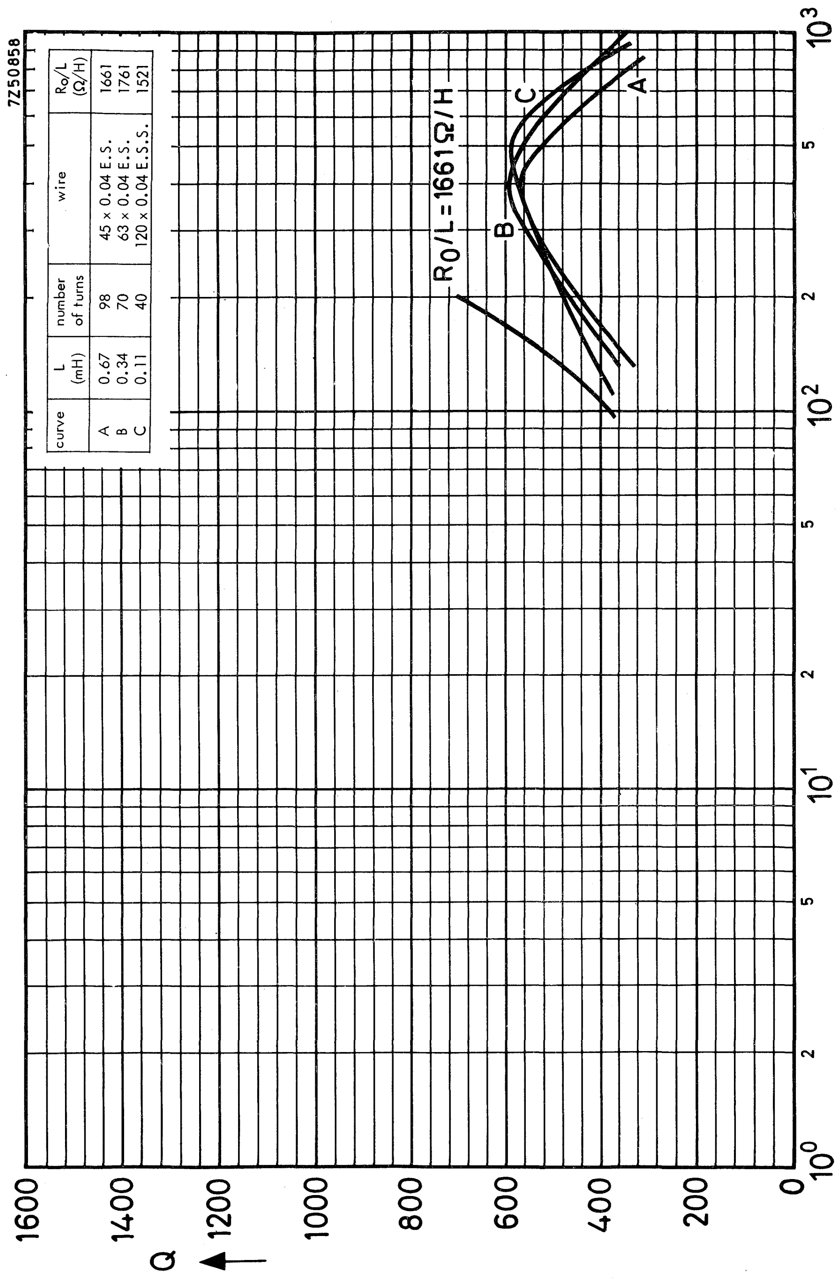


FXC 3D3 SINGLE-SECTION COIL FORMER
$\mu_e = 47$



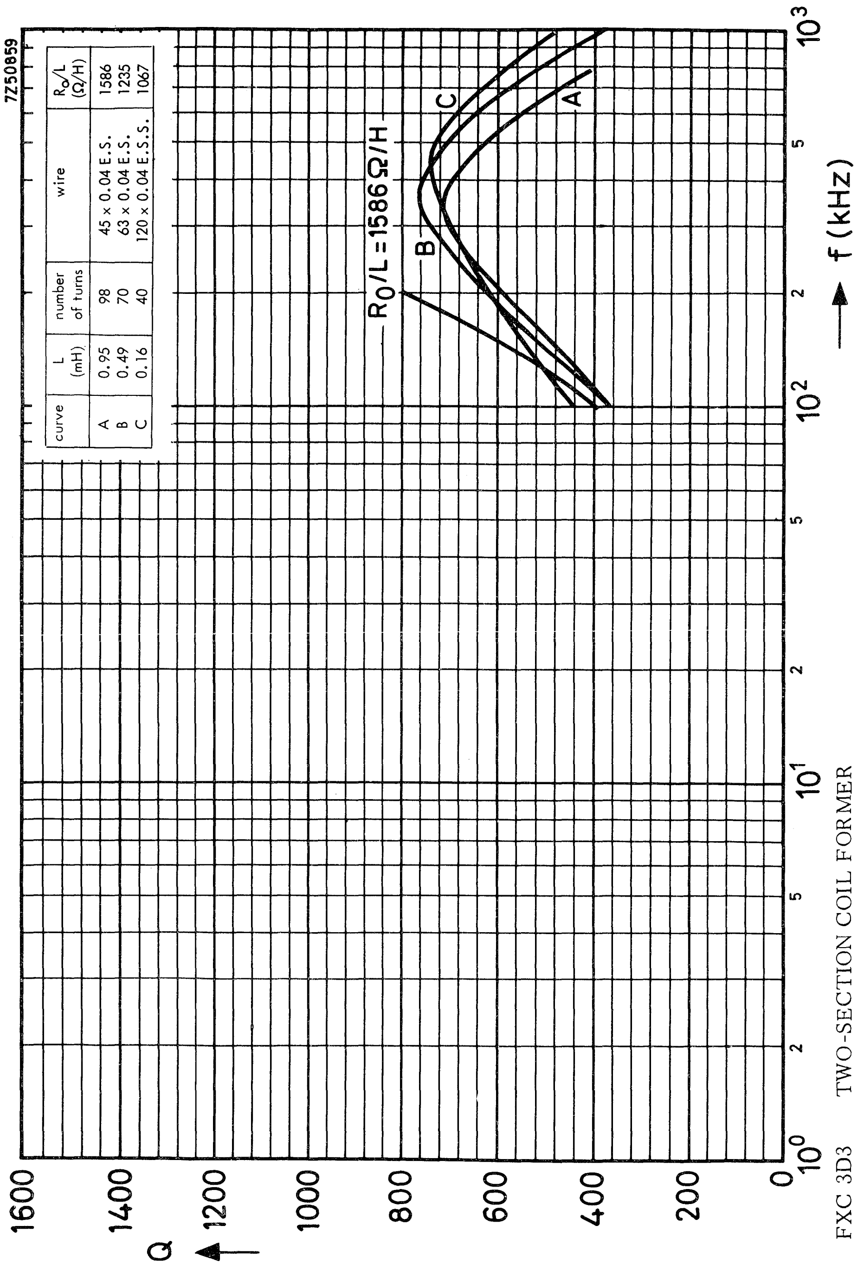
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	2.20	124	45 × 0.04 E.S.	649
B	1.32	96	63 × 0.04 E.S.	608
C	0.42	54	100 × 0.04 E.S.S.	659

FXC 3D3 SINGLE-SECTION COIL FORMER
$\mu_e = 68$

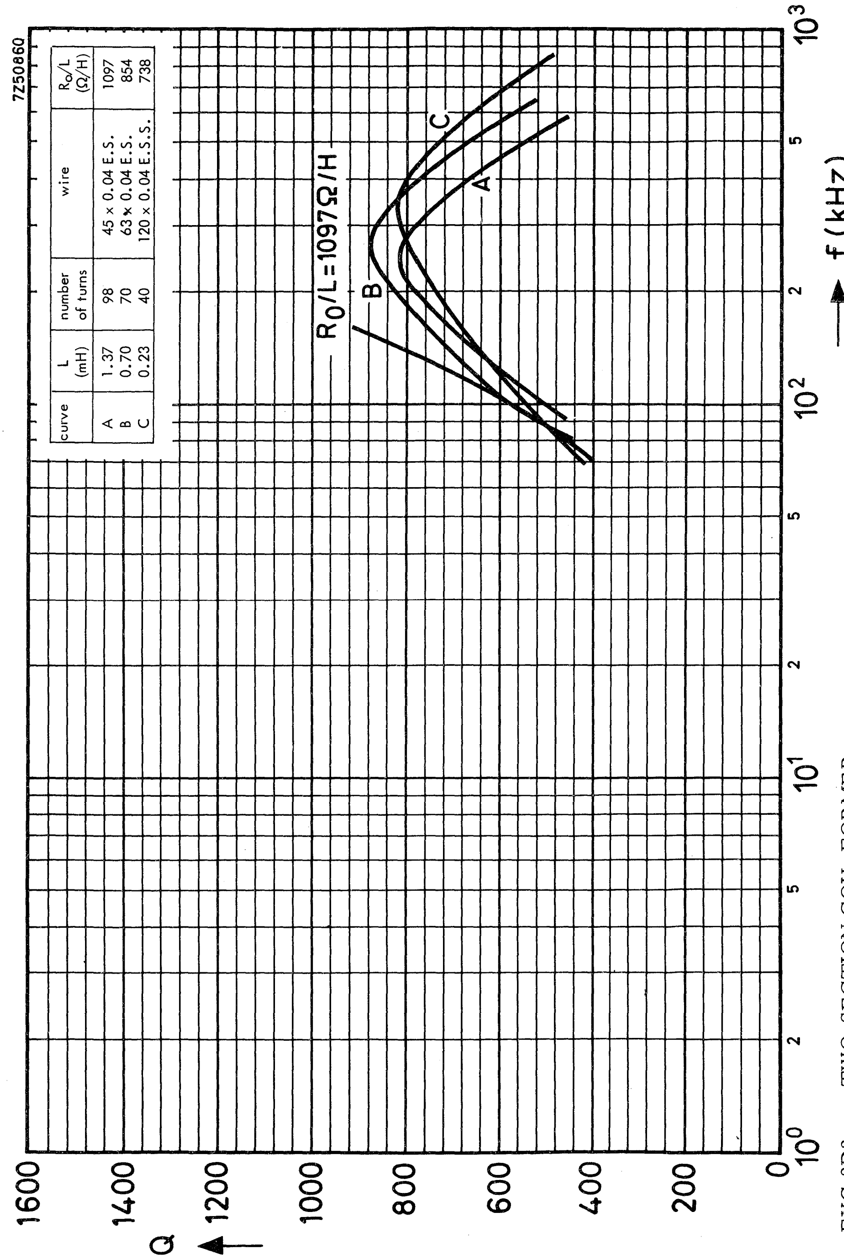


FXC 3D3 TWO-SECTION COIL FORMER

$\mu_e = 33$

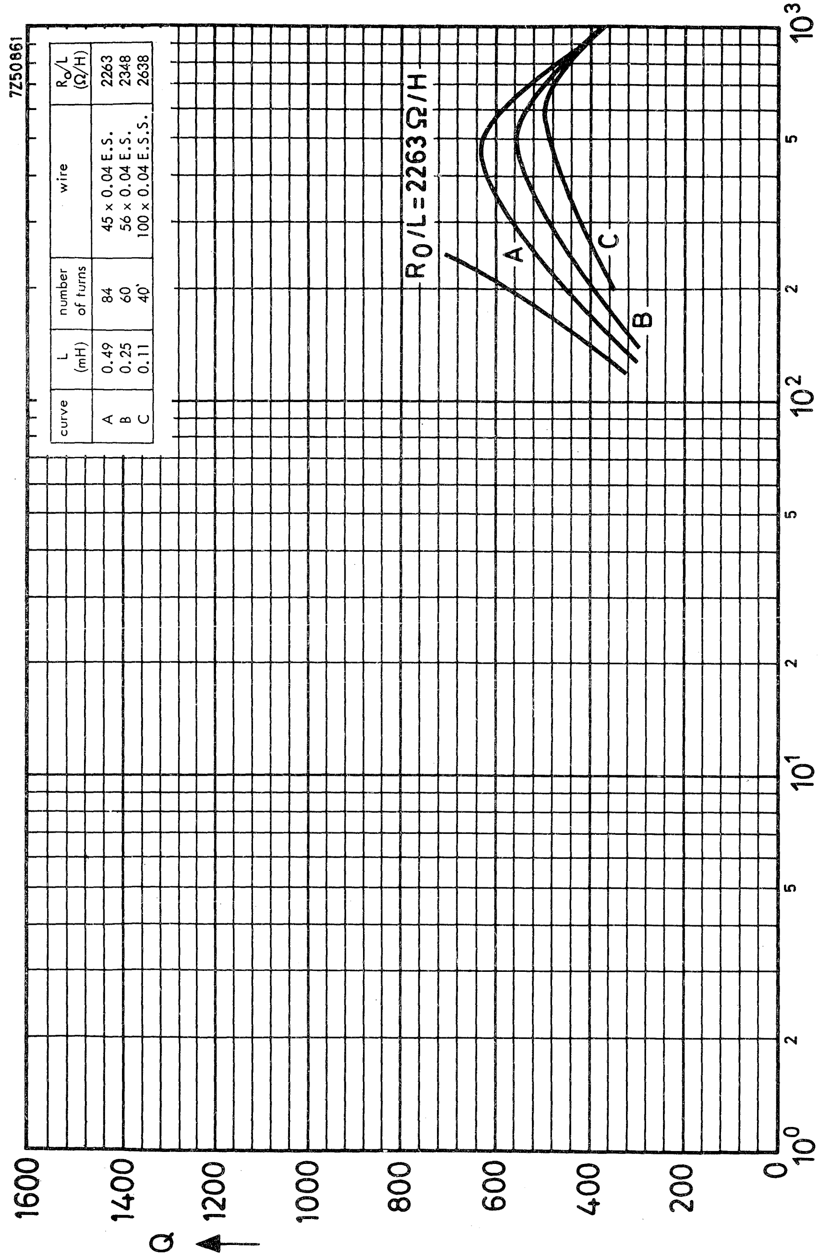


FXC 3D3 TWO-SECTION COIL FORMER
$\mu_e = 47$



FXC 3D3
$\mu_e = 68$

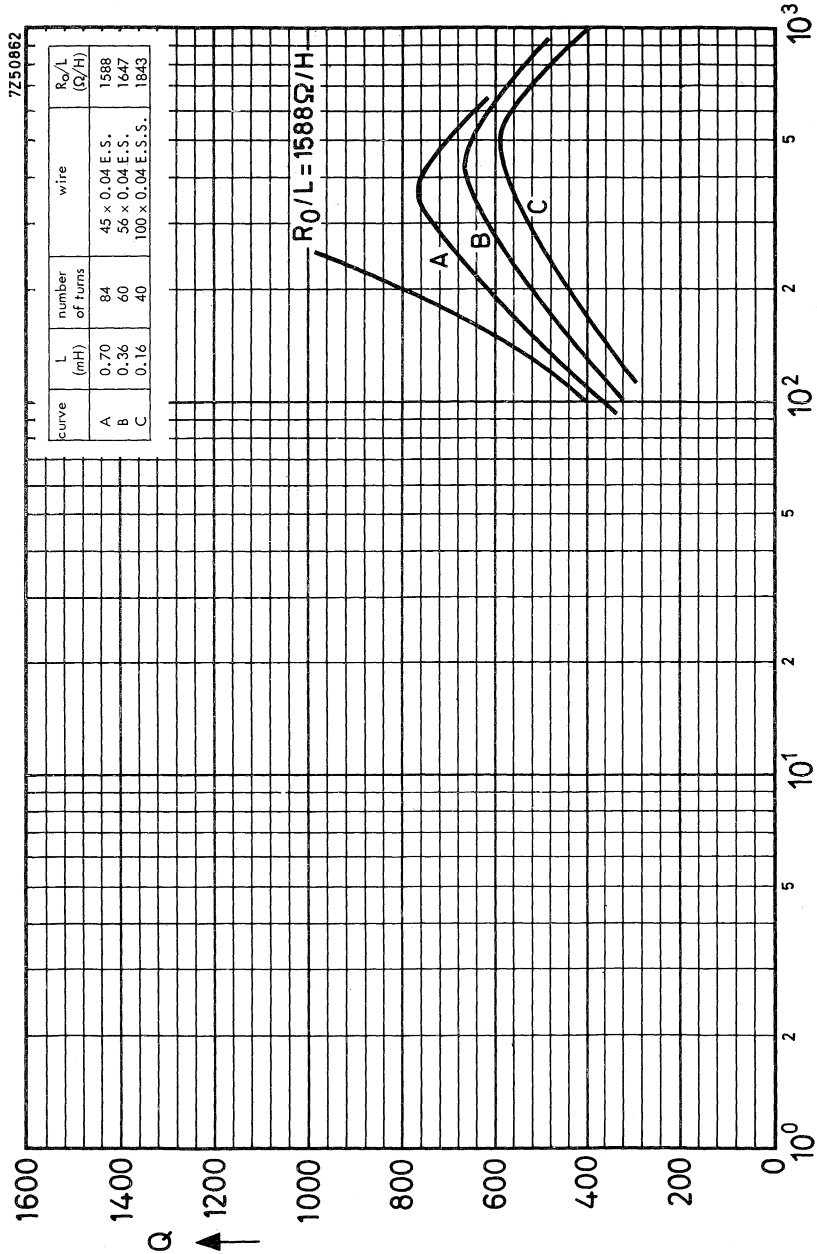
TWO-SECTION COIL FORMER



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	0.49	84	45 × 0.04 E.S.	2263
B	0.25	60	56 × 0.04 E.S.	2348
C	0.11	40	100 × 0.04 E.S.S.	2638

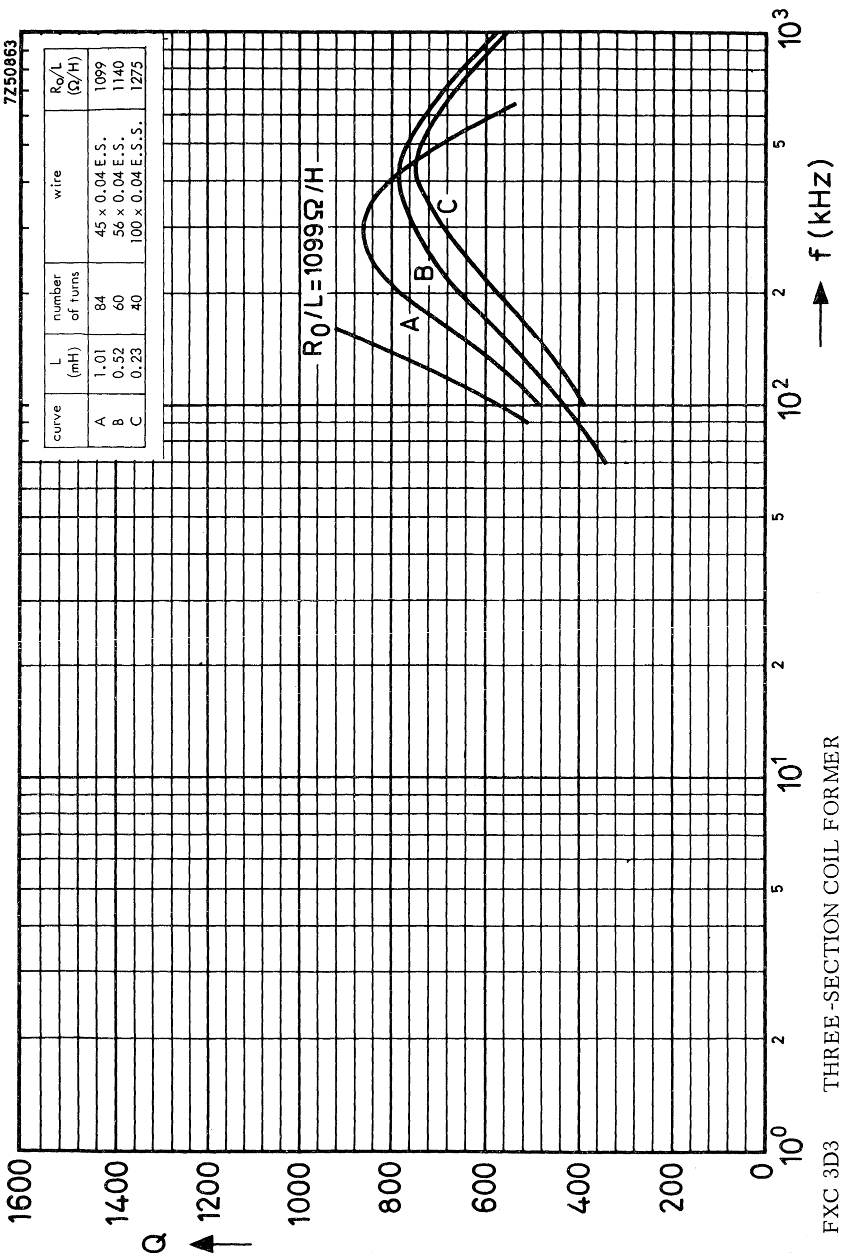
FXC 3D3 THREE-SECTION COIL FORMER

$\mu_e = 33$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	0.70	84	45 × 0.04 E.S.	1588
B	0.36	60	56 × 0.04 E.S.	1647
C	0.16	40	100 × 0.04 E.S.S.	1843

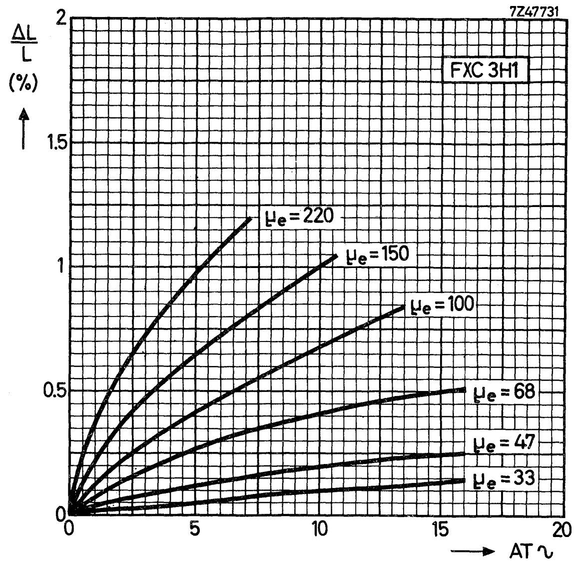
FXC 3D3 THREE-SECTION COIL FORMER
$\mu_e = 47$

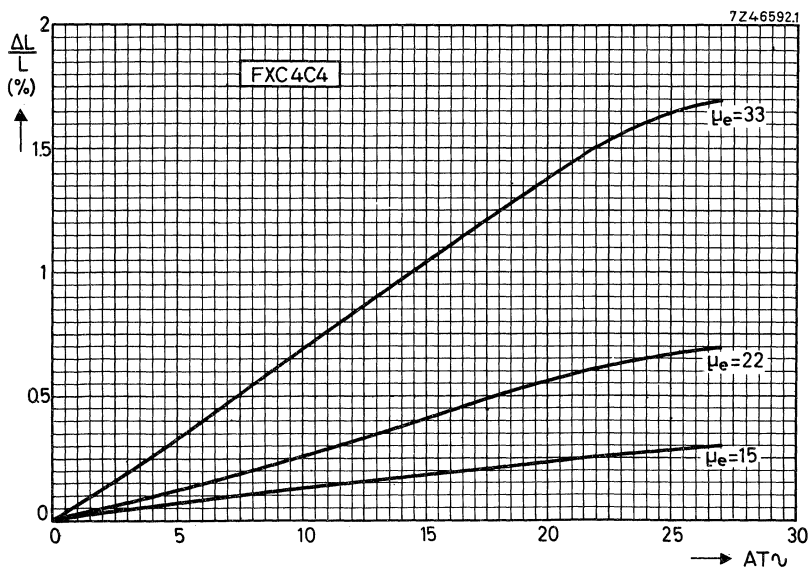


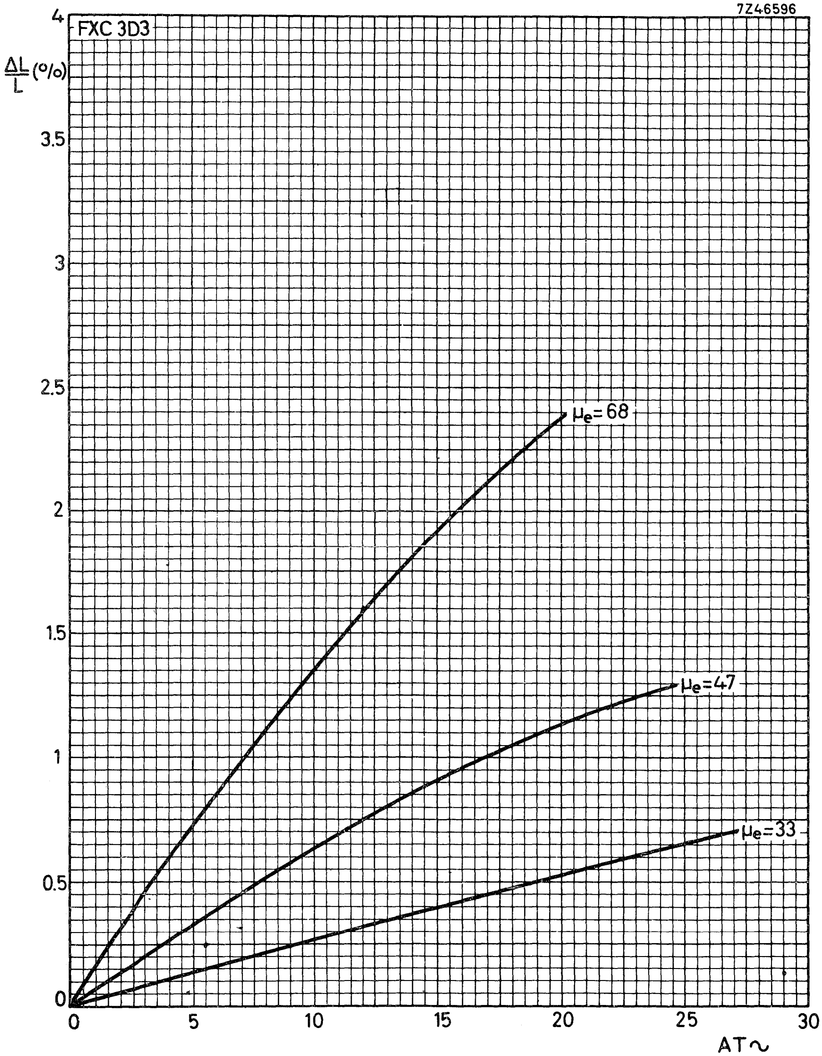
FXC 3D3 THREE-SECTION COIL FORMER

$\mu_e = 68$

INDUCTANCE VARIATION AS A FUNCTION OF AT∼

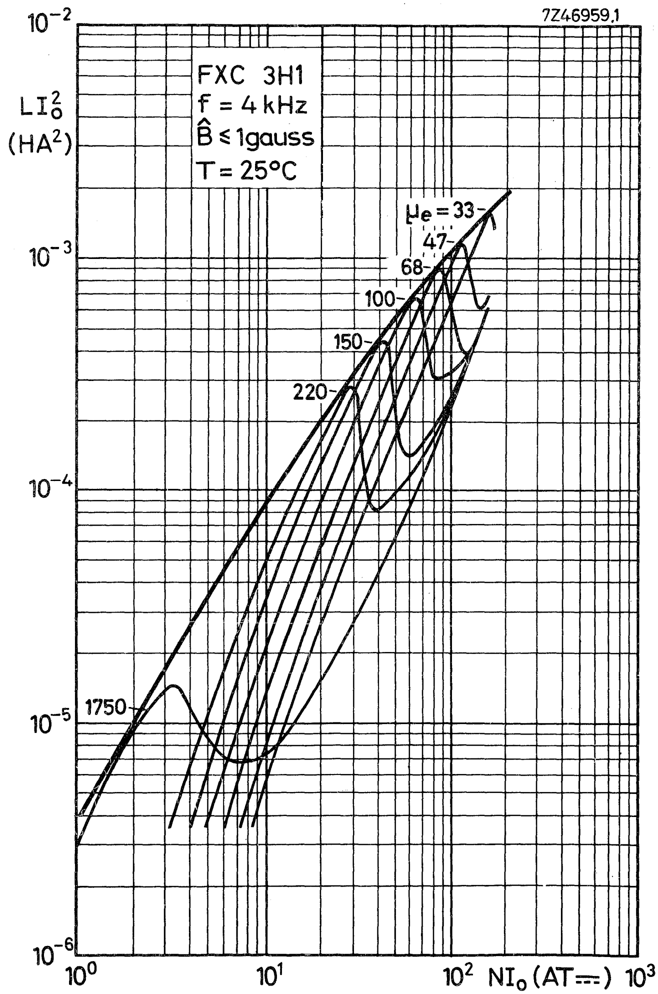


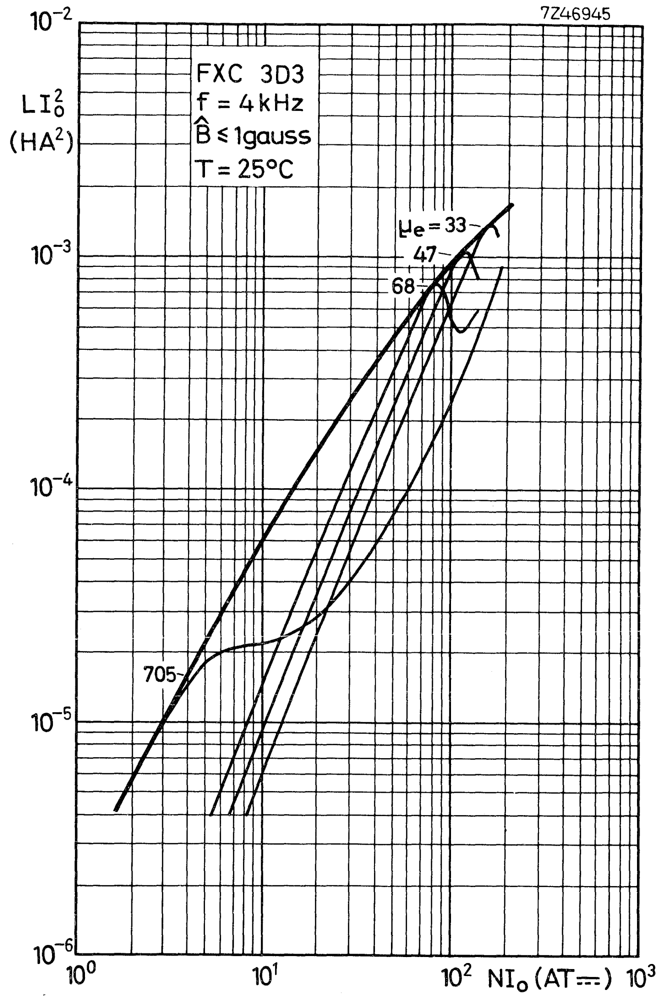



7Z46596
FXC 3D3
ΔL/L (%)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
AT~
μe=68
μe=47
μe=33

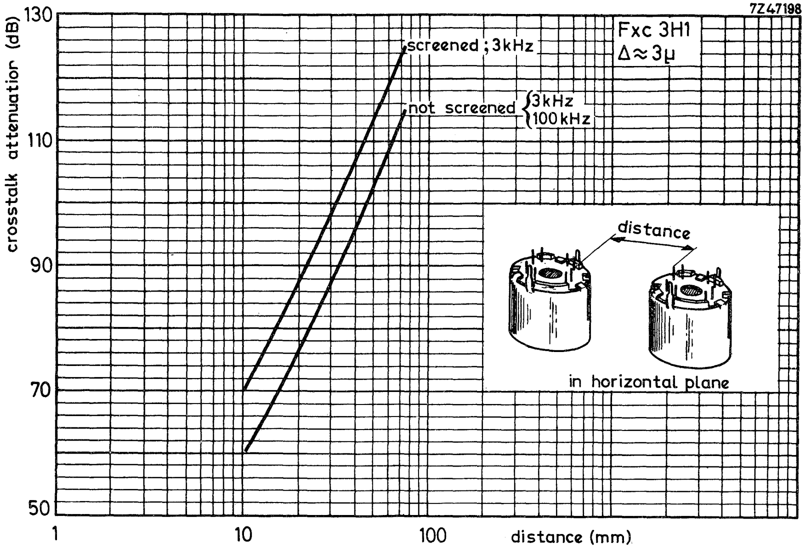
HANNA CURVES (typical values)

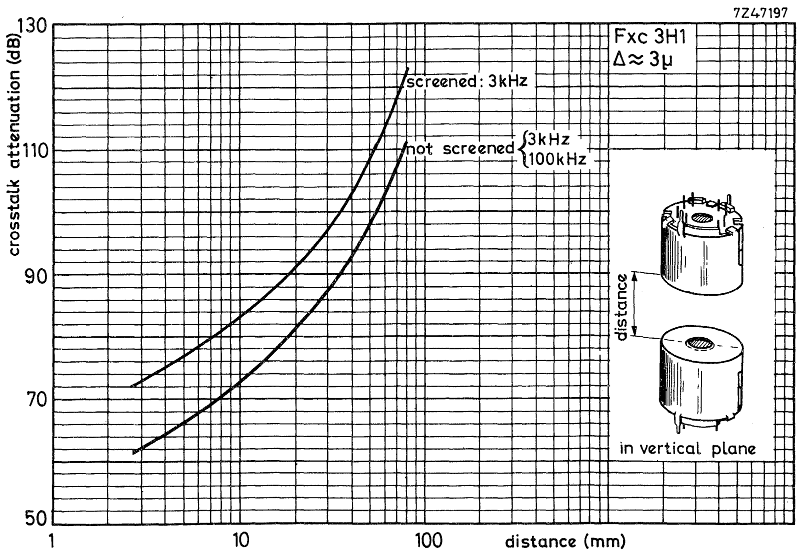
These curves indicate the optimum inductance for a certain μ_e-value and direct current.

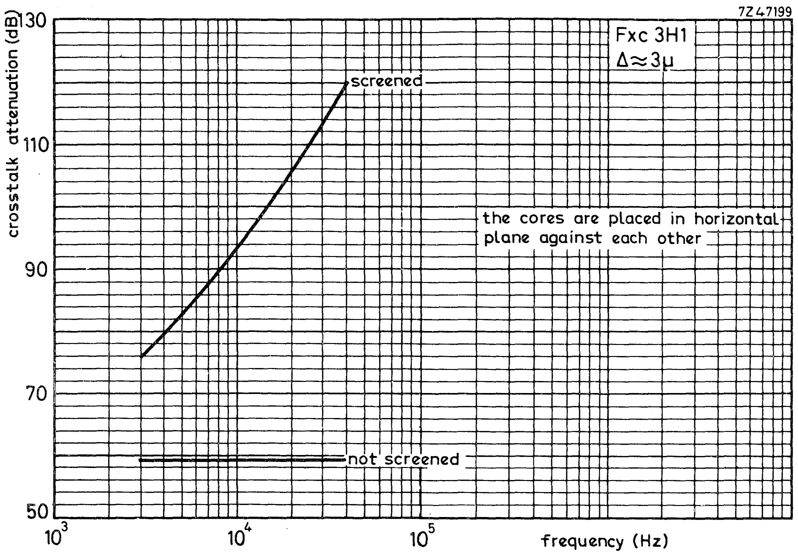



7Z46945
FXC 3D3
f = 4 kHz
$\hat{B}$ ≤ 1 gauss
T = 25°C
LI_o^2
(HA^2)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
μ_e = 33
47
68
705
10^0
10^1
10^2
NI_o (AT ⎓)
10^3

CROSSTALK ATTENUATION






7Z47199
Fxc 3H1
Δ≈3μ
screened
the cores are placed in horizontal plane against each other
not screened
crosstalk attenuation (dB)
130
110
90
70
50
10^3
10^4
10^5
frequency (Hz)

POTCORES

INTRODUCTION

Three types of core can be supplied:

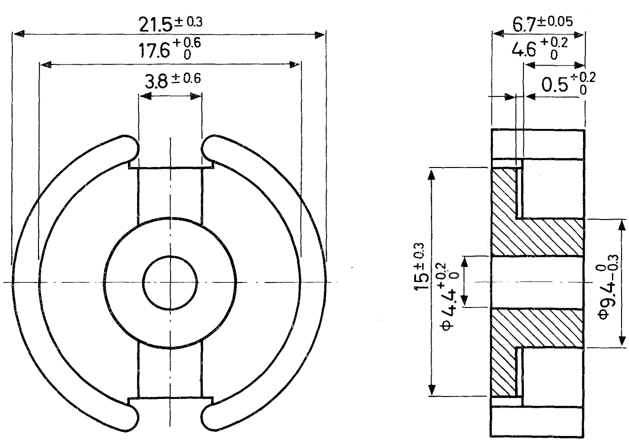
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C.133 (international), C.C.T.U.06-02 (France) and D.I.N.41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number. Quantity: a primary pack contains 20 potcore halves or 10 pieces of pre-adjusted potcore, so please order in multiples of these quantities.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 21750
3H1	4322 020 21760
3D3	4322 020 21770
4C4	4322 020 21780
4C6	

Properties

For toroidally wound core halves the values in Table I are guaranteed.

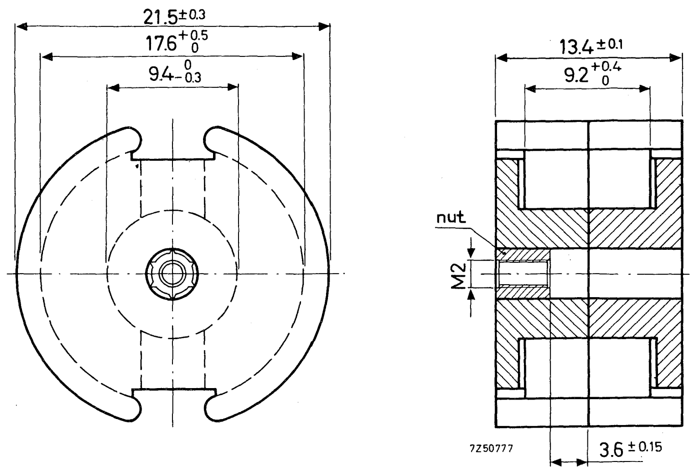
Table I	temp. (^oC)	grade				
		3B7	3H1	3D3	4C4	4C6
T.F. x 10^6	+5 to +23	–	–	–	–	−2 to +4
	+23 to +55	–	–	–	−10 to 0	0 to +6
	+23 to +70	−0.6 to +0.6	+0-6 to +1.8	0 to 2	–	–
D.F. x 10^6 (10-100 min)	23 ± 1	≤4.3	≤4.3	≤15	≤33	≤10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 140 Newton, the values in Table II are guaranteed at 25±10 °C.

Table II	$\hat{B}$ gauss	freq. kHz	3B7	3H1	3D3	4C4	4C6
μ_e	≤1	4	≥1400	≥1400		≥94	
	≤1	100			≥540		
α	≤1	4	≤16.8	≤16.8		≤64.7	
	≤1	100			≤27.0		
$\frac{\tan\delta}{\mu_i}$ x 10^{-6}	≤1	4	≤1.2	≤1.2			
	≤1	100	≤5	≤5	≤8		
	≤1	500			≤14		
	≤1	1 000			≤30		
		2 000					≤45
		5 000					≤60
		10 000					≤100
$q_{2-24-100}$	15-30	4	≤1.8	≤1.8			
	3-12	100			≤3.0		

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 .....
Without nut, catalog number = 4322 022 .....

Weight			12	g
Mean length of lines of force	l_e	=	3.15	cm
	$\Sigma \frac{l_e}{A_e}$	=	4.97	cm^{-1}
Effective volume	V_e	=	2.00	cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 2 for potcores with nut, insert 0 for potcores without nut.
   Examples of catalog number:
   μ_e = 15, grade 4C4, potcore with nut, catalog number = 4322 022 26610
   A_L = 100, grade 3B7, potcore without nut, catalog number = 4322 022 07040
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
15	162	± 1	–	–	–	.6610
22	134	± 1	–	–	–	.6620
33	109.4	± 1	–	–	.6430	.6630
47	91.7	± 1	–	–	.6440	–
68	76.2	± 1	.6050	.6250	.6450	–
100	62.8	± 1.5	.6060	.6260	–	–
150	51.3	± 2	.6070	.6270	–	–
220	42.4	± 3	.6080	.6280	–	–
330	34.6	± 3	.6090	.6290	–	–
720	23.4	±25	–	–	06400	–
1840	14.6	±25	06000	06200	–	–

Number of turns $N = \alpha\sqrt{L}$ (L in 10^{-3} H)

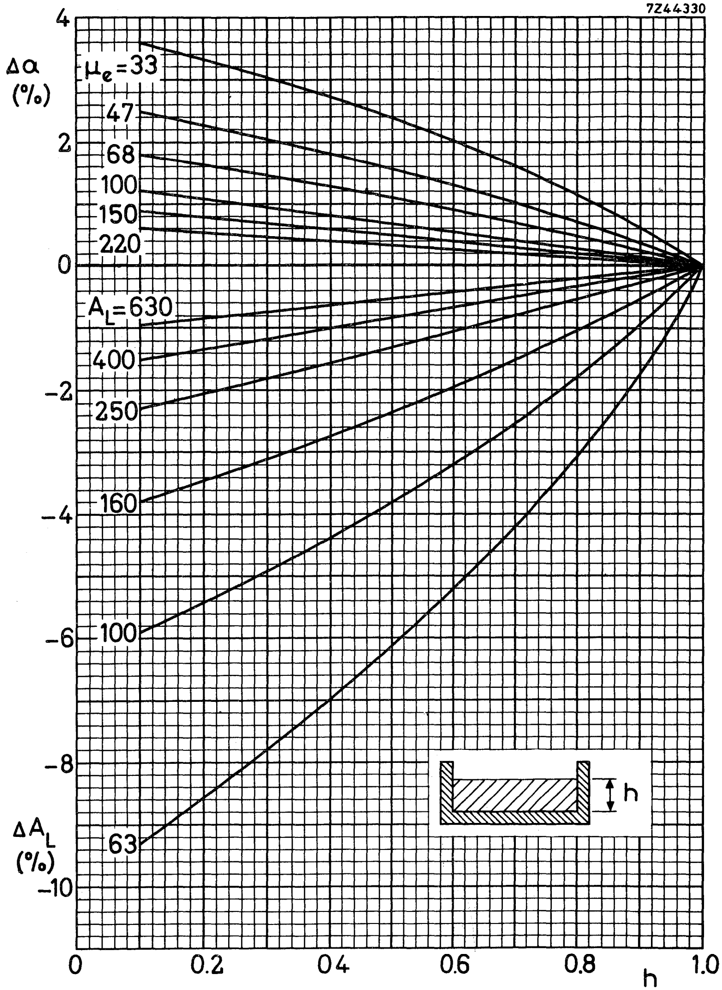
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
40	15.8	± 1	–	–	–	.7620
63	25	± 1	–	–	.7430	.7630
100	39.5	± 1	.7040	.7240	.7440	–
160	63.5	± 1	.7050	.7250	.7450	–
250	99	± 1.5	.7060	.7260	–	–
315	124.5	± 2	.7070	.7270	–	–
400	158	± 2	.7080	.7280	–	–
630	249	± 3	.7100	.7300	–	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

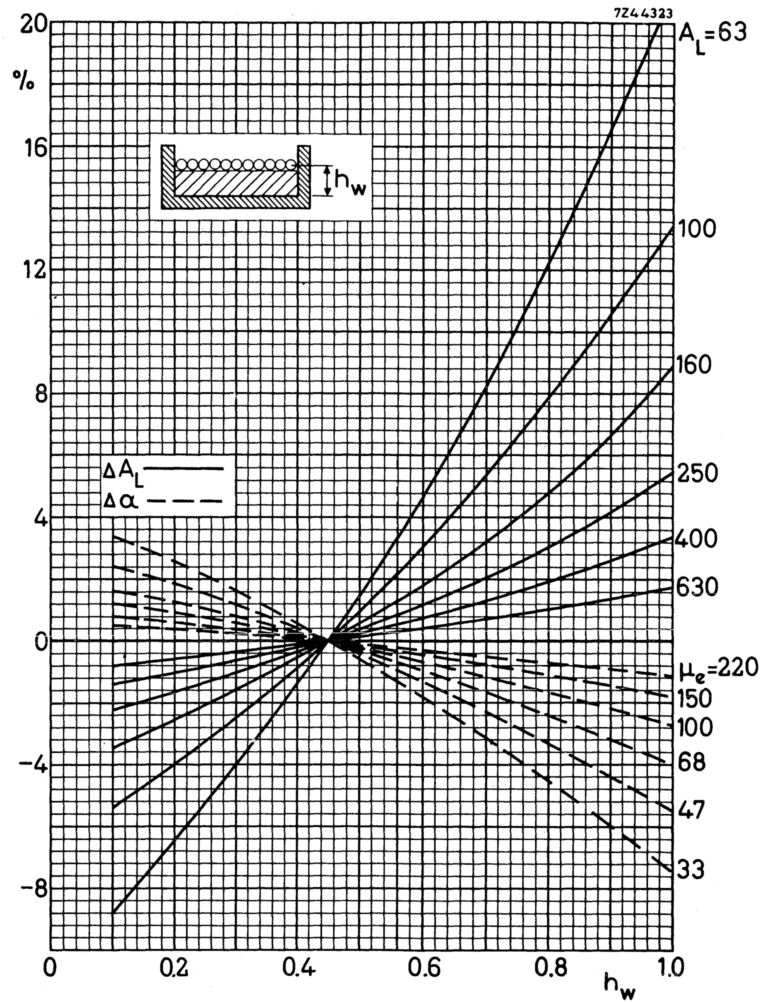
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 76.2 + 1.25 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_w on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 76.2 - 1.7 %.

COIL FORMERS

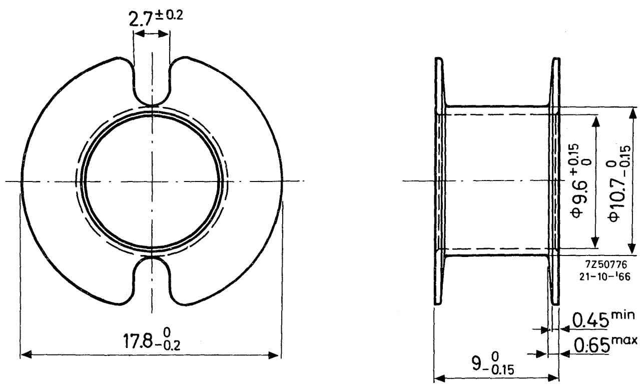
GENERAL

Four types of coil former can be supplied:

- with one section
- with two sections
- with three sections
- with one section and with soldering pins to fit 0.1" and 2.50 mm grid.

The dimensions conform with the following specifications: I.E.C.133 (international), C.C.T.U.06-02 (France) and D.I.N.41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



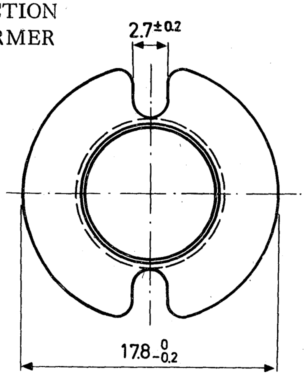
Catalog number	4322 021 30300
Material	polycarbonate K486
Window area	28 mm^2
Mean length of turn	4.4 cm
Max. temperature	130 ^{o}C

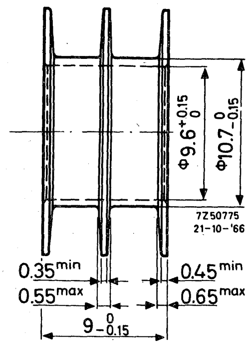
D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 11.0 \times 10^3 \quad \Omega/H$$

Weight 0.35 g

TWO-SECTION COIL FORMER





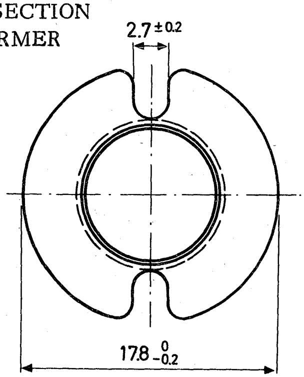
Catalog number	4322 021 30310
Material	polycarbonate K486
Window area	2 x 13 mm^2
Mean length of turn	4.4 cm
Max. temperature	130 ^oC

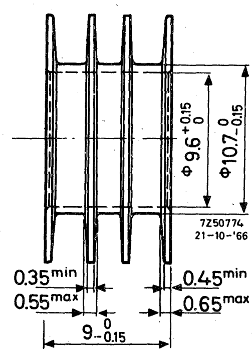
D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 11.6 \times 10^3 \quad \Omega/H$$

Weight 0.4 g

THREE-SECTION COIL FORMER





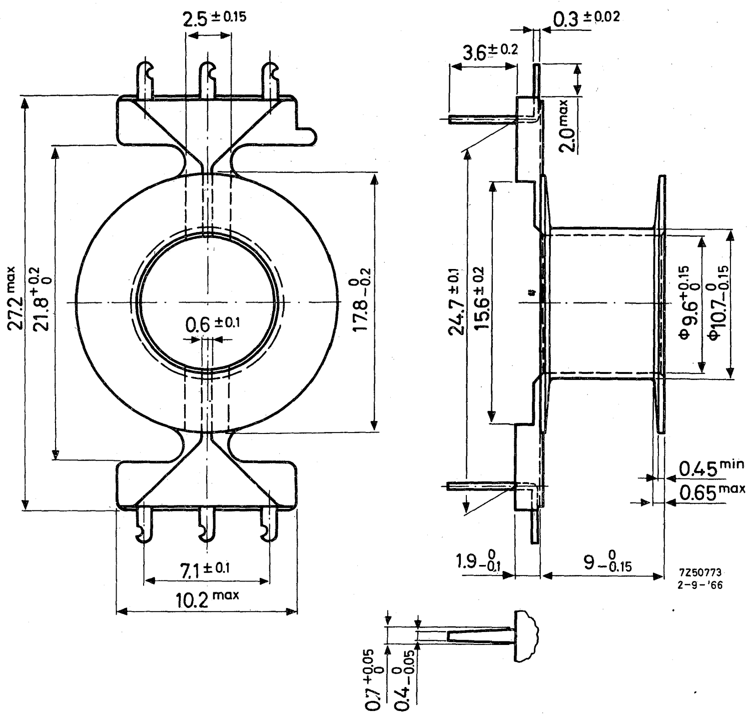
Catalog number	4322 021 30320
Material	polycarbonate K486
Window area	3 x 8.2 mm
Mean length of turn	4.4 mm^2
Max. temperature	130 ^oC

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 12.4 \times 10^3 \quad \Omega/H$$

Weight 0.45 g

SINGLE-SECTION COIL FORMER WITH SOLDERING PINS



Catalog number	4322 021 30110
Material	reinforced polyester with brass dip-soldered pins
Window area	28 mm^2
Mean length of turn	4.4 cm
Max. temperature	130 ^{o}C

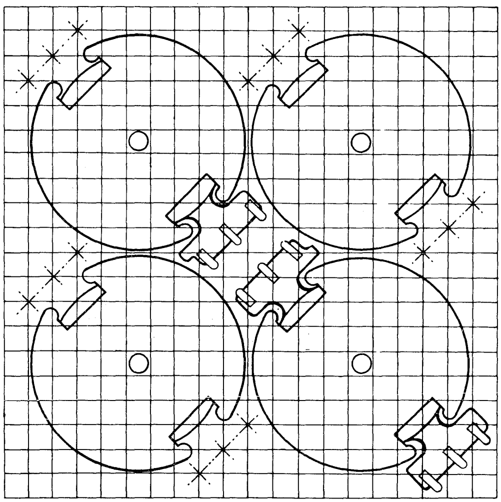
Max. dipsolder temperature for 5 - 6 s	280	^{o}C

D.C. losses:

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 11.0 \times 10^3 \quad \Omega/H$$

Weight	0.45	g

The soldering pins are so arranged as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes 1.3 ± 0.1 mm diameter.
For this coil former the potcore halves must be cemented together, and it is recommended to cement the coil former to the lower potcore half.



7Z47202

INDUCTANCE ADJUSTMENT

ADJUSTORS

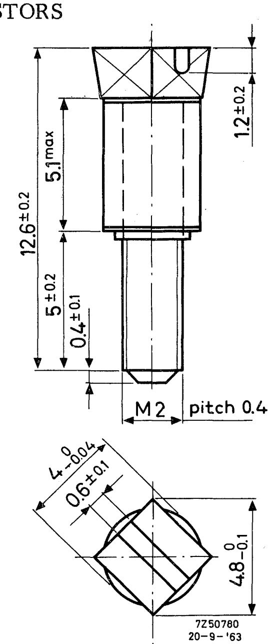


Fig. A

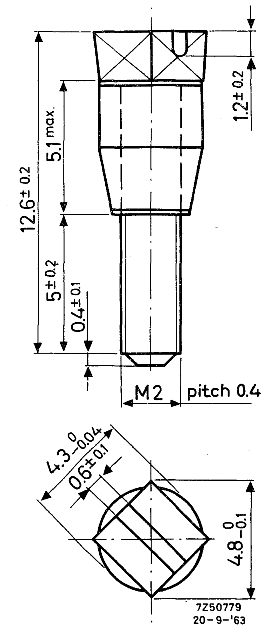


Fig. B

The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.3 ⁰/oo by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.

The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.

The influence of the adjustors on the variability of the inductance is negligible.

The maximum permissible temperature is 110 °C.

Table II shows the type of adjustor recommended for different potcores.

Table I, available types

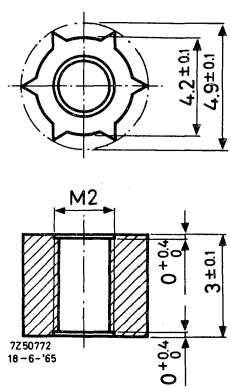
Fig.	colour	catalog number
B	yellow	4322 021 31000
B	white	4322 021 31020
B	green	4322 021 31040
B	red	4322 021 31060
A	brown	4322 021 31100
B	black	4322 021 31240

Table II, recommended application

μ_e	A_L	3B7/3H1/3D3	4C4
		cat. number 4322 021	
15		–	31060
	40	–	31060
22		–	31000
	63	31040	31000
33		31040	31020
	100	31060	–
47		31060	–
68		31000	–
	160	31000	–
	250	31020	–
100		31020	–
150		31100	–
	400	31100	–
220		31100	–
	630	31100	–
330		31240	–

NUT FOR ADJUSTOR

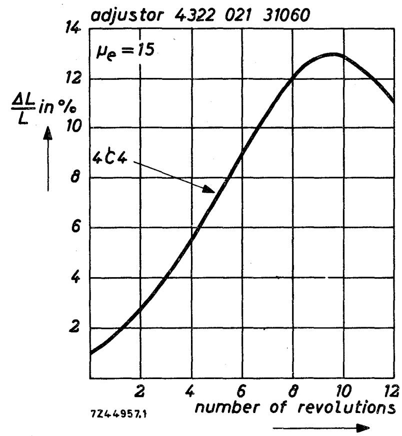
These data are given for those manufacturers who prefer to insert the nut themselves.

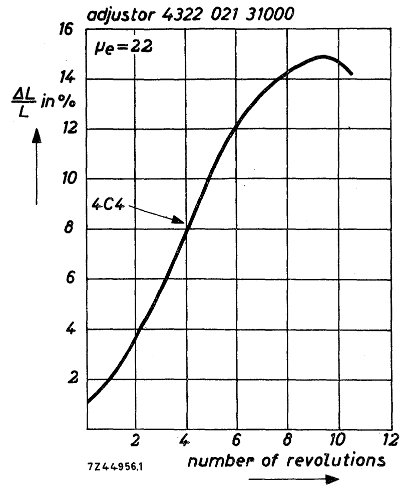


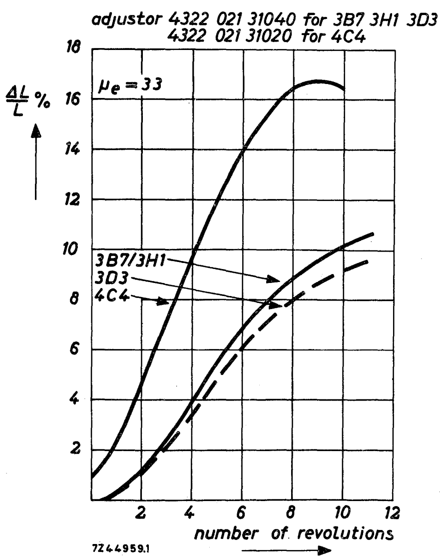
Catalog number	4322 021 30150
Material	polycarbonate
Max. impregnation temperature during 24 hours	120 °C
Recommended distance from mating surface to nut	3.6 ± 0.15 mm

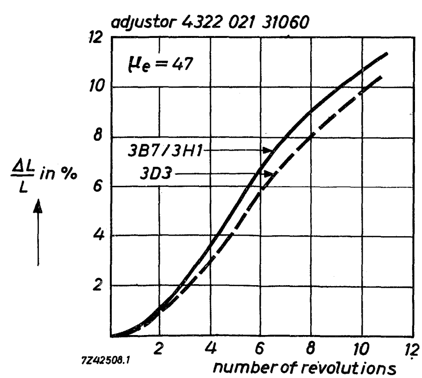
For more information see Potcores General, Inductance adjustment.

ADJUSTMENT CURVES

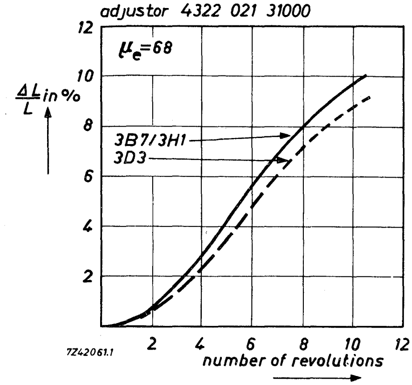




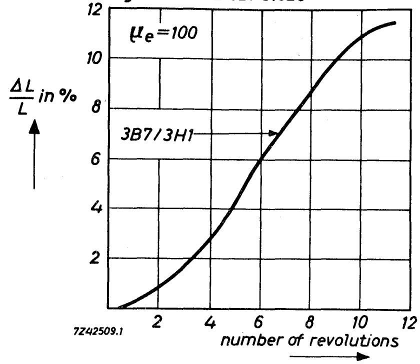




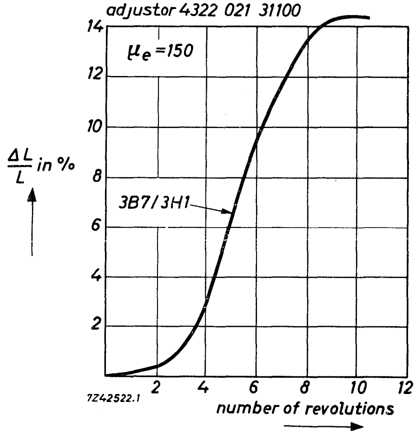
adjustor 4322 021 31000



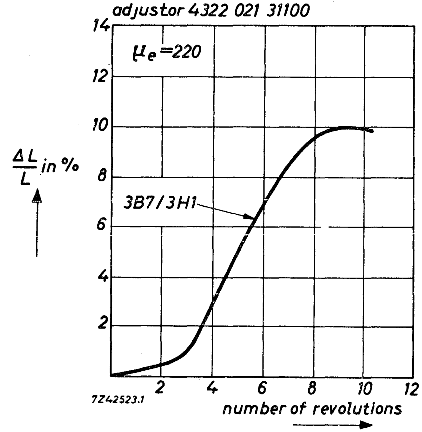
adjustor 4322 021 31020



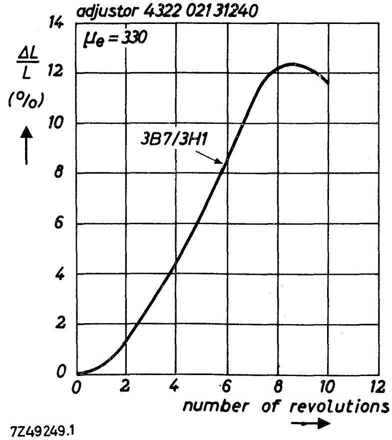
adjustor 4322 021 31100



adjustor 4322 021 31100

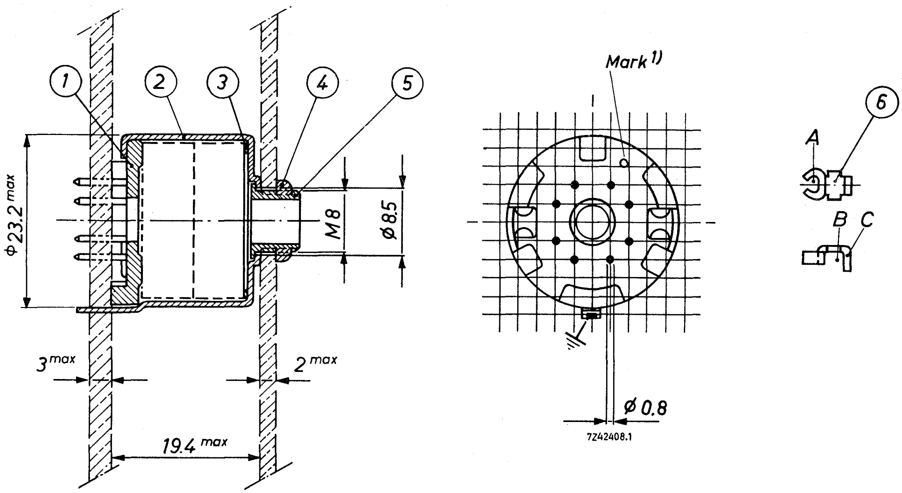


adjustor 4322 021 31240



MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30460	(4) nut	4322 021 30710
(2) brass container	4322 021 30540	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30650	(6) soldering spring	4322 021 30700 (8x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The eight soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness up to 3 mm. The board should be provided with holes of 1.3 + 0.1 mm diameter.

1) There is another mark hole in a similar position on the top of the container.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

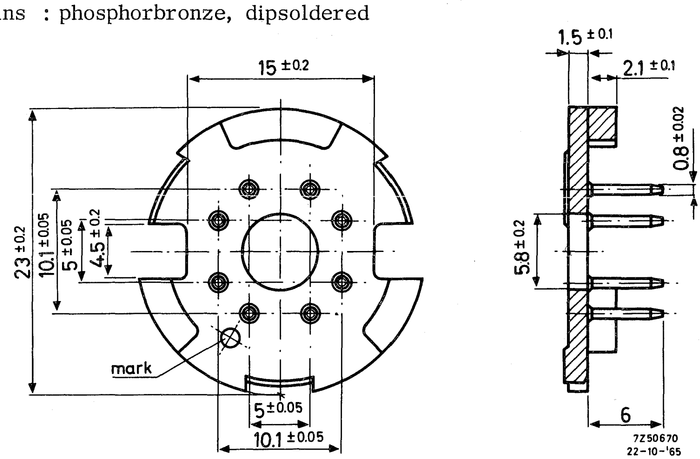
Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 140 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

(1) Tag plate 4322 021 30460

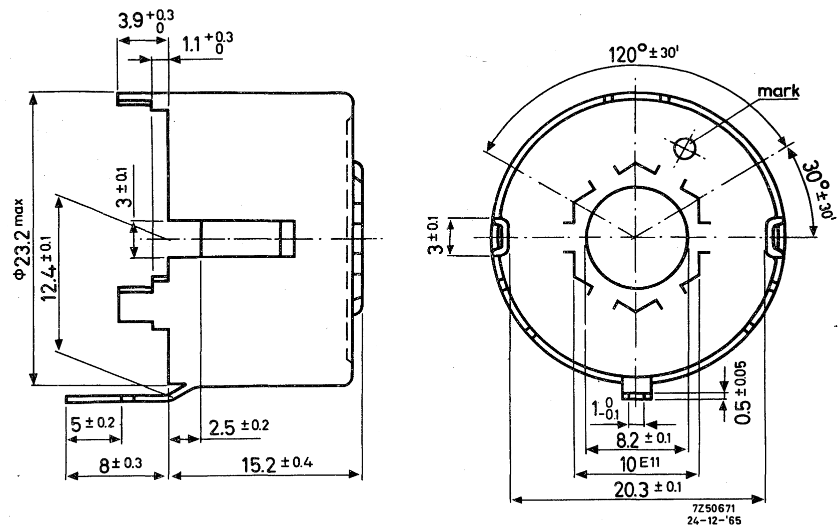
Plate : reinforced polyester

Pins : phosphorbronze, dipsoldered



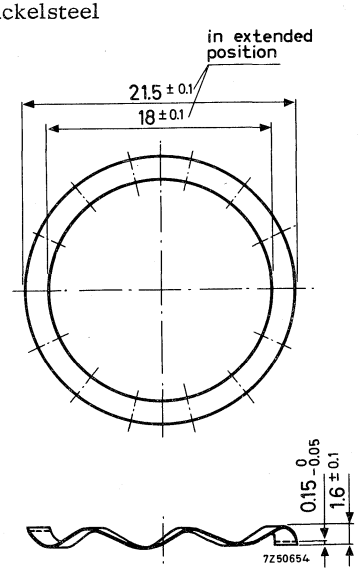
(2) Container 4322 021 30540

Material : brass, nickel plated



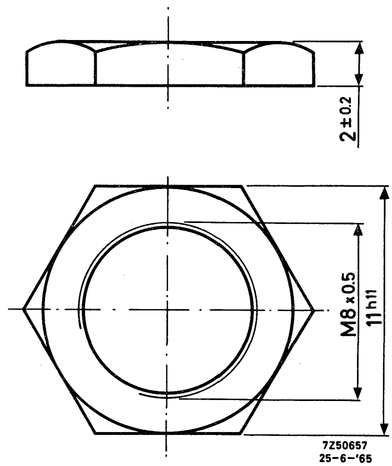
(3) Spring 4322 021 30650

Material : chrome- nickelsteel



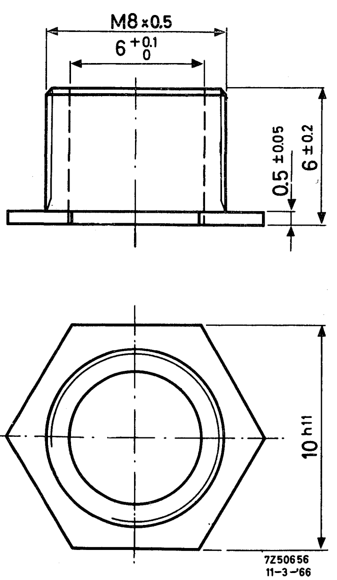
(4) Nut 4322 021 30710

Material: brass, nickel plated



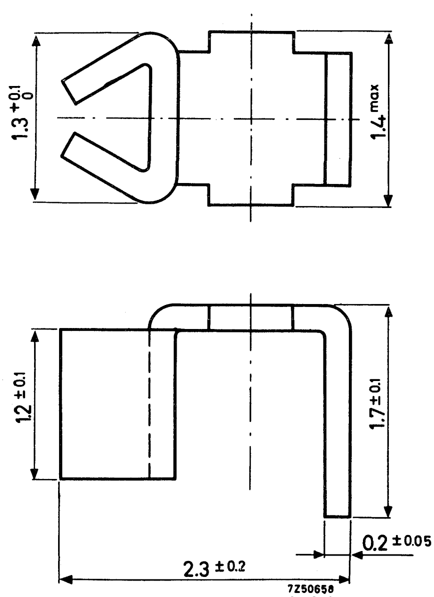
(5) Fixing bush 4322 021 30720

Material: aluminium



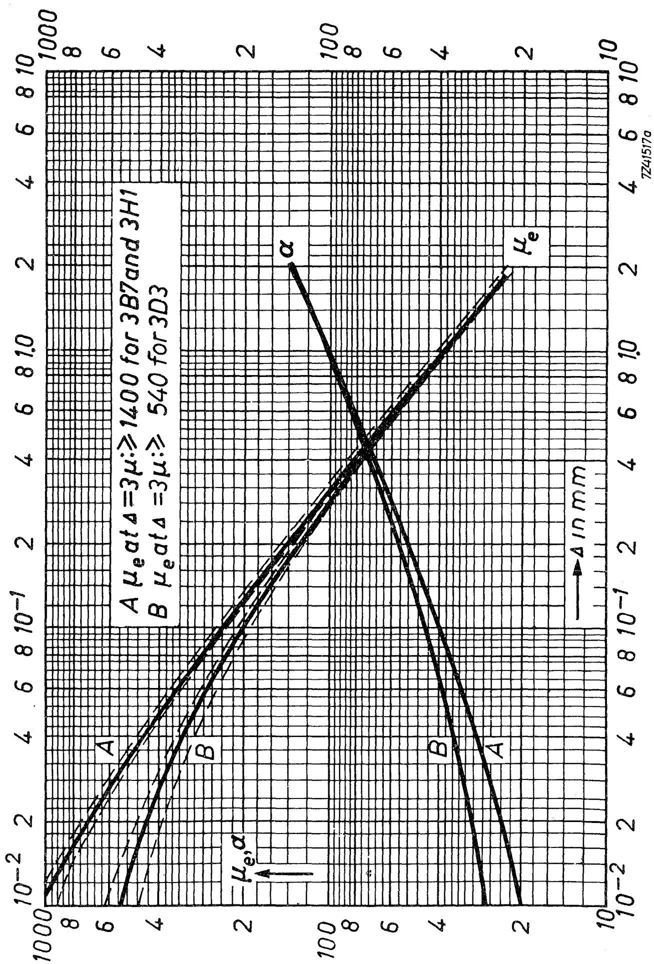
(6) Soldering spring 4322 021 30700

Material: brass, dipsoldered



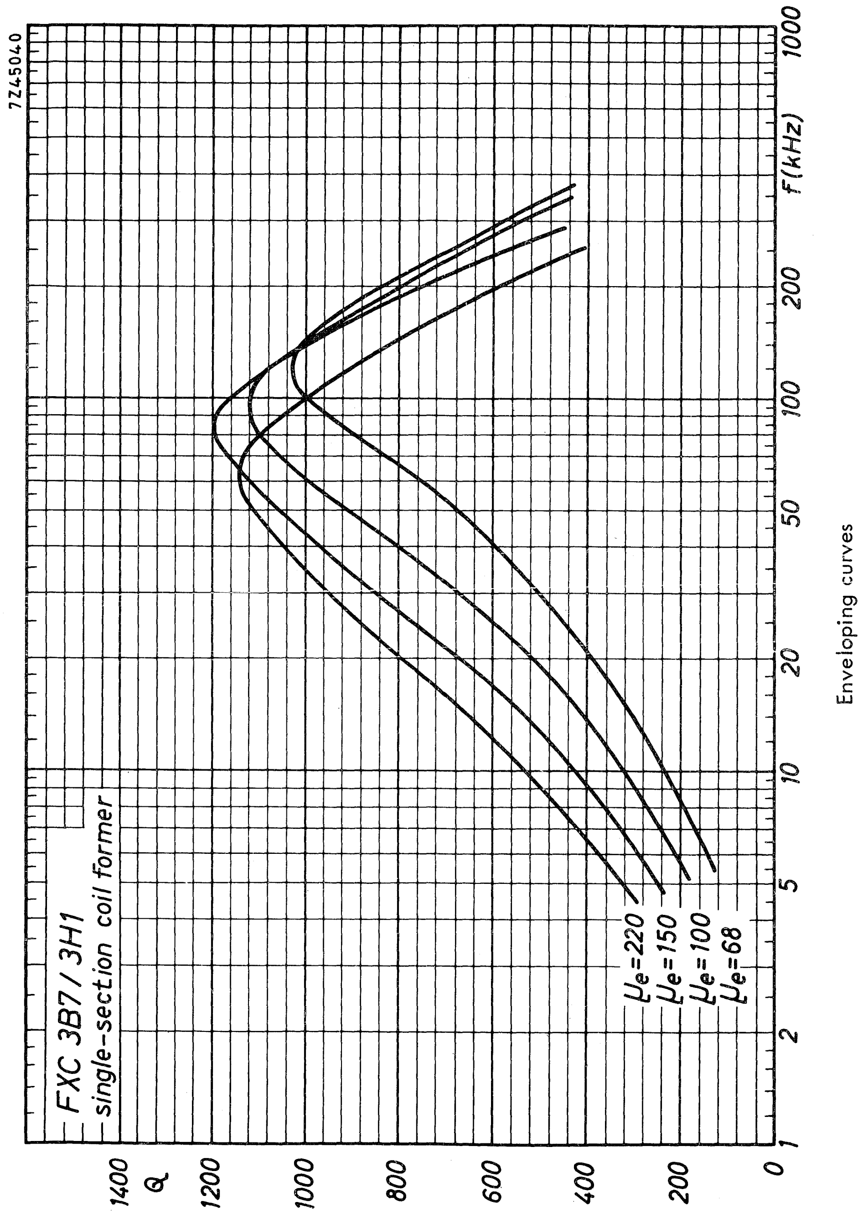
CHARACTERISTIC CURVES

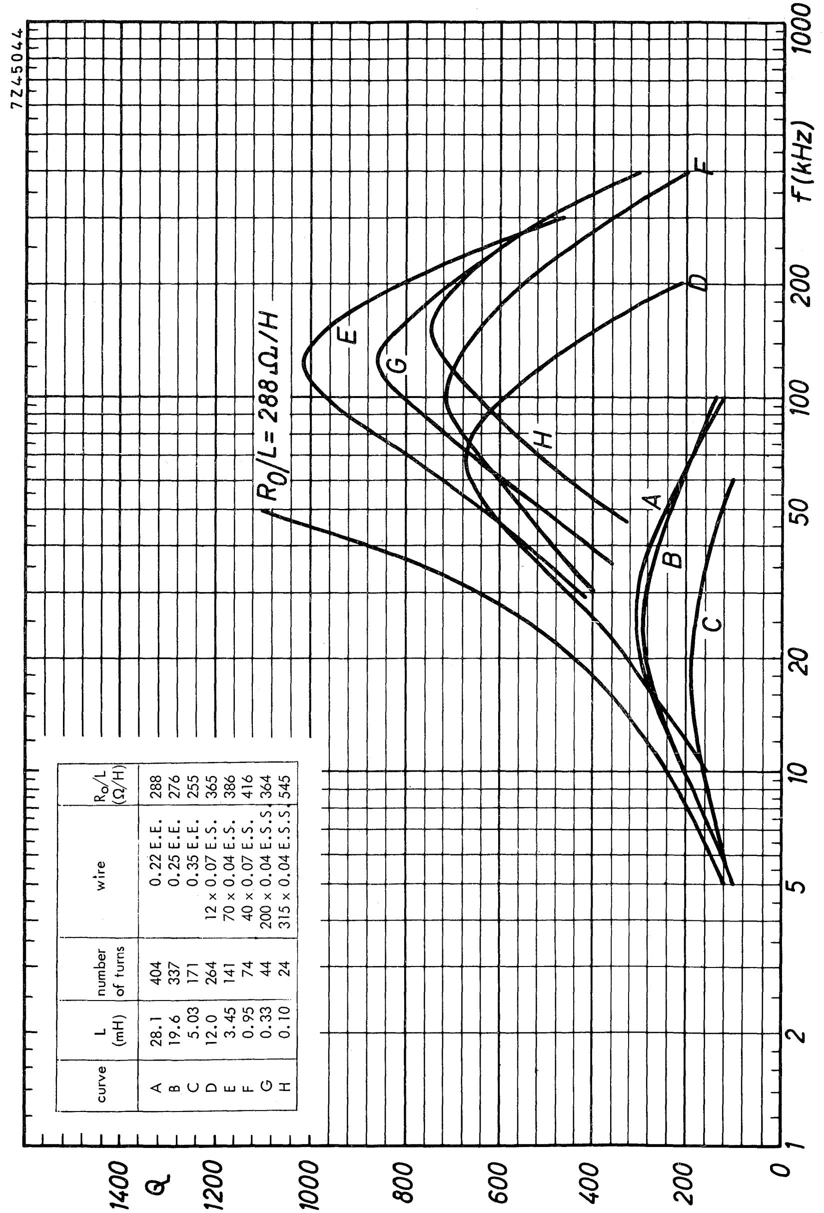
μ_e - α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length

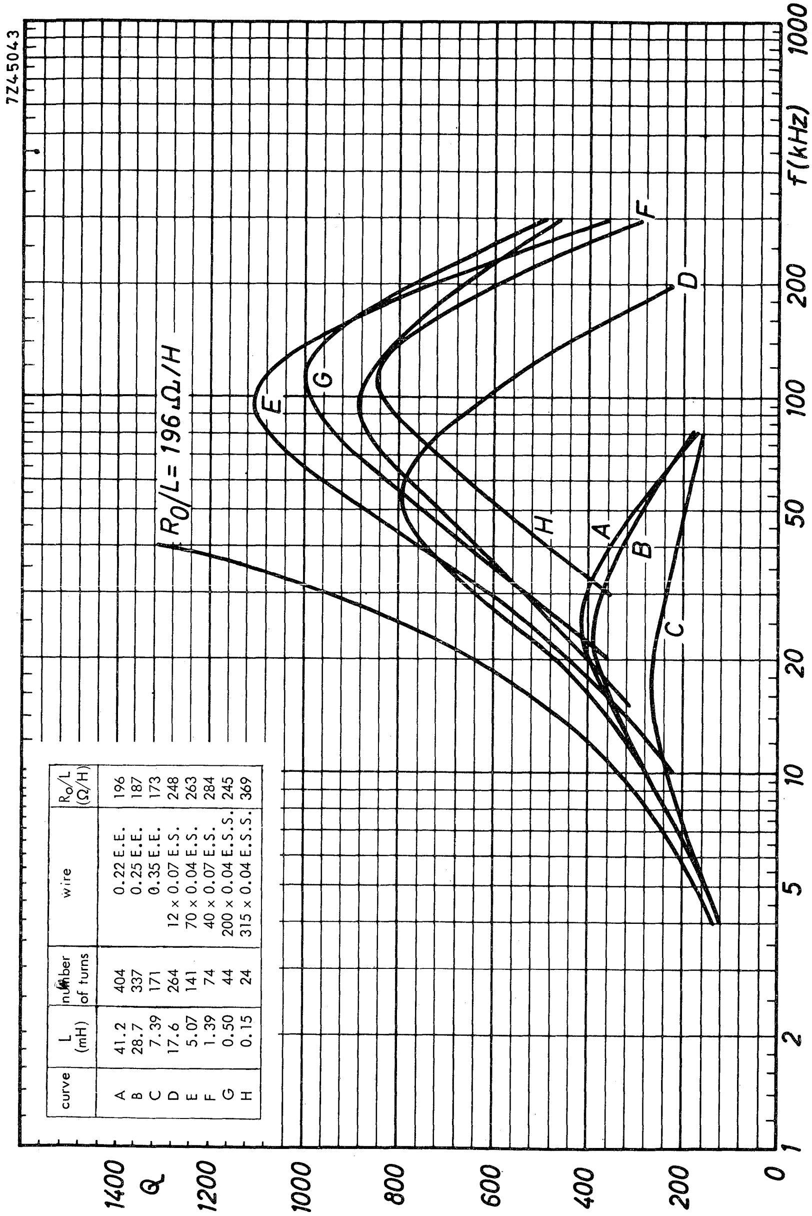
TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1





curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	28.1	404	0.22 E.E.	288
B	19.6	337	0.25 E.E.	276
C	5.03	171	0.35 E.E.	255
D	12.0	264	12 × 0.07 E.S.	365
E	3.45	141	70 × 0.04 E.S.	386
F	0.95	74	40 × 0.07 E.S.	416
G	0.33	44	200 × 0.04 E.S.S.	364
H	0.10	24	315 × 0.04 E.S.S.	545

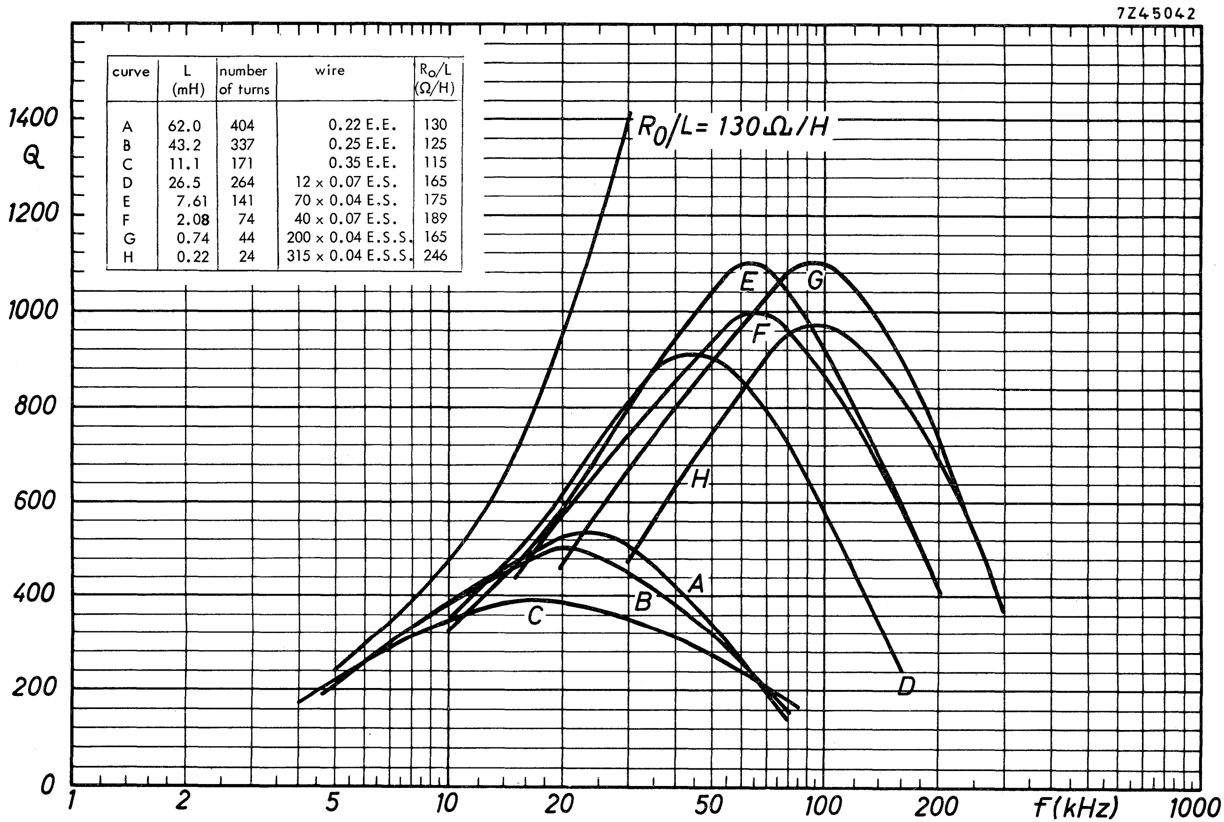
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 68$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	41.2	404	0.22 E.E.	196
B	28.7	337	0.25 E.E.	187
C	7.39	171	0.35 E.E.	173
D	17.6	264	12 × 0.07 E.S.	248
E	5.07	141	70 × 0.04 E.S.	263
F	1.39	74	40 × 0.07 E.S.	284
G	0.50	44	200 × 0.04 E.S.S.	245
H	0.15	24	315 × 0.04 E.S.S.	369

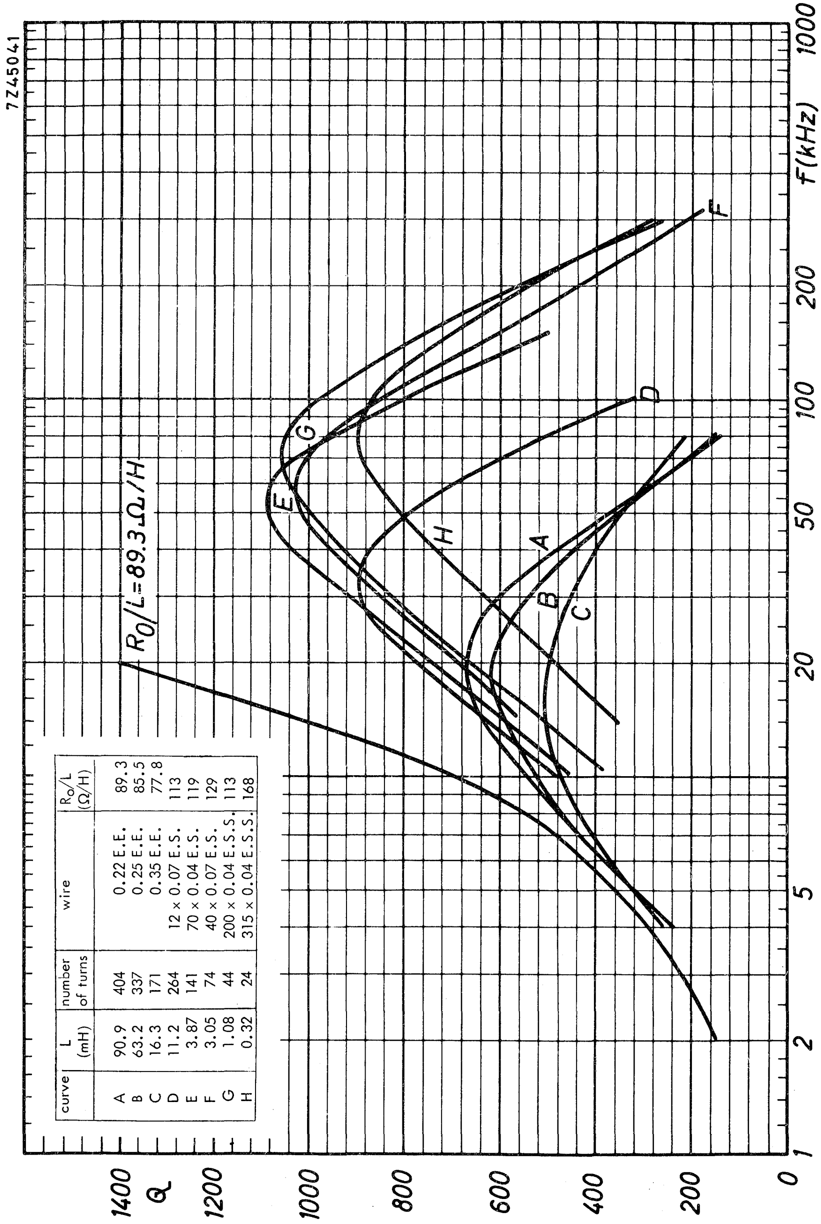
SINGLE-SECTION COIL FORMER

FXC 3B7/3H1
$\mu_e = 100$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	62.0	404	0.22 E.E.	130
B	43.2	337	0.25 E.E.	125
C	11.1	171	0.35 E.E.	115
D	26.5	264	12 × 0.07 E.S.	165
E	7.61	141	70 × 0.04 E.S.	175
F	2.08	74	40 × 0.07 E.S.	189
G	0.74	44	200 × 0.04 E.S.S.	165
H	0.22	24	315 × 0.04 E.S.S.	246

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 150$

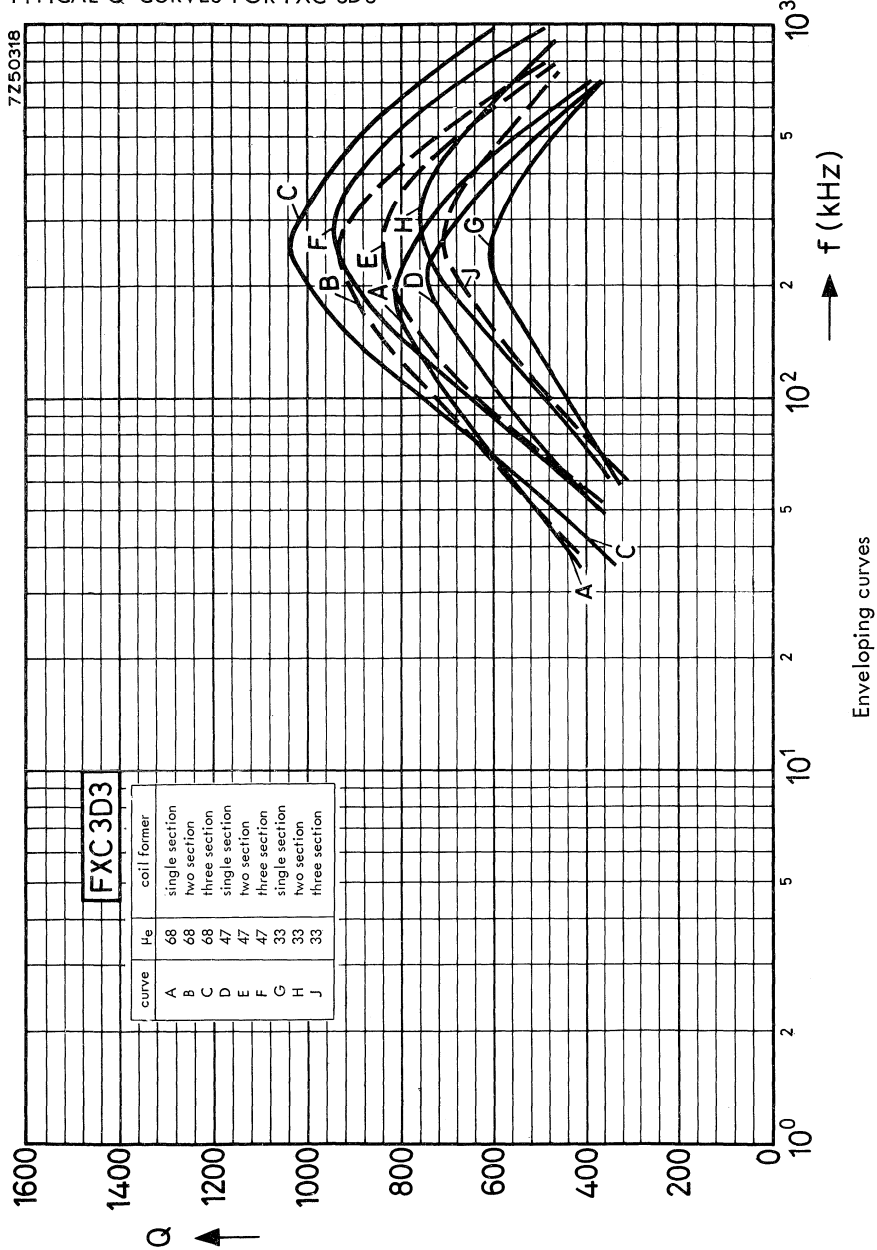


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	90.9	404	0.22 E.E.	89.3
B	63.2	337	0.25 E.E.	85.5
C	16.3	171	0.35 E.E.	77.8
D	11.2	264	12 × 0.07 E.S.	113
E	3.87	141	70 × 0.04 E.S.	119
F	3.05	74	40 × 0.07 E.S.	129
G	1.08	44	200 × 0.04 E.S.S.	113
H	0.32	24	315 × 0.04 E.S.S.	168

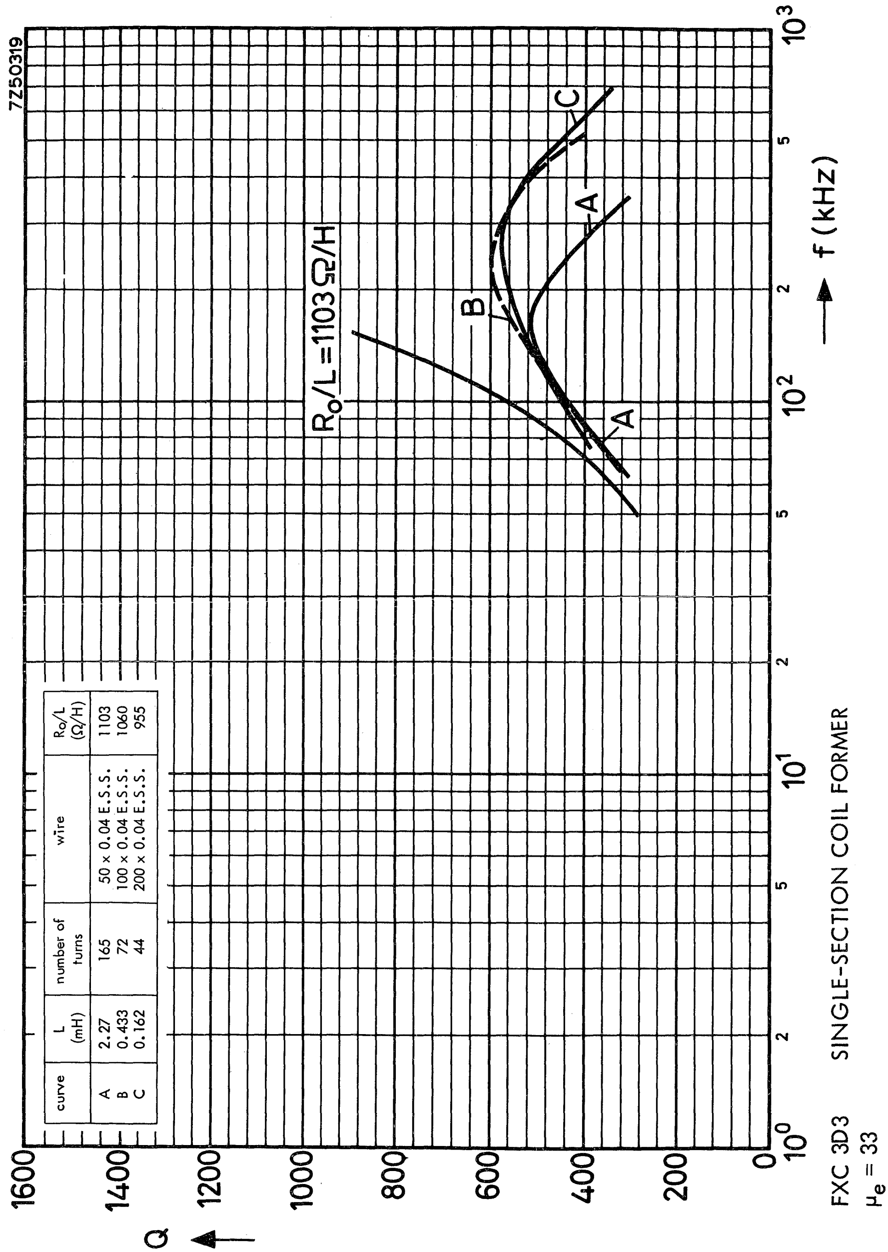
SINGLE-SECTION COIL FORMER

FXC 3B7/3H1
$\mu_e = 220$

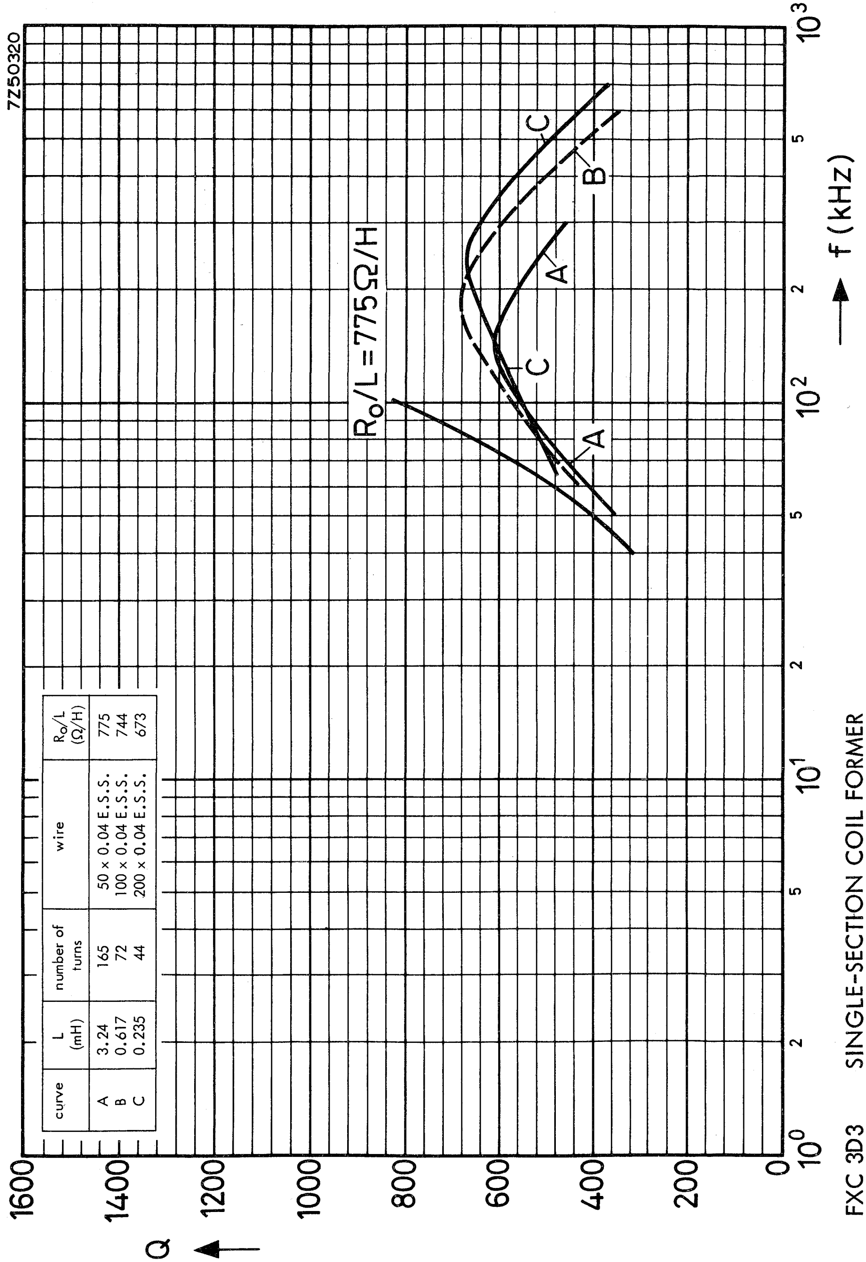
TYPICAL Q-CURVES FOR FXC 3D3



curve	μe	coil former
A	68	single section
B	68	two section
C	68	three section
D	47	single section
E	47	two section
F	47	three section
G	33	single section
H	33	two section
J	33	three section

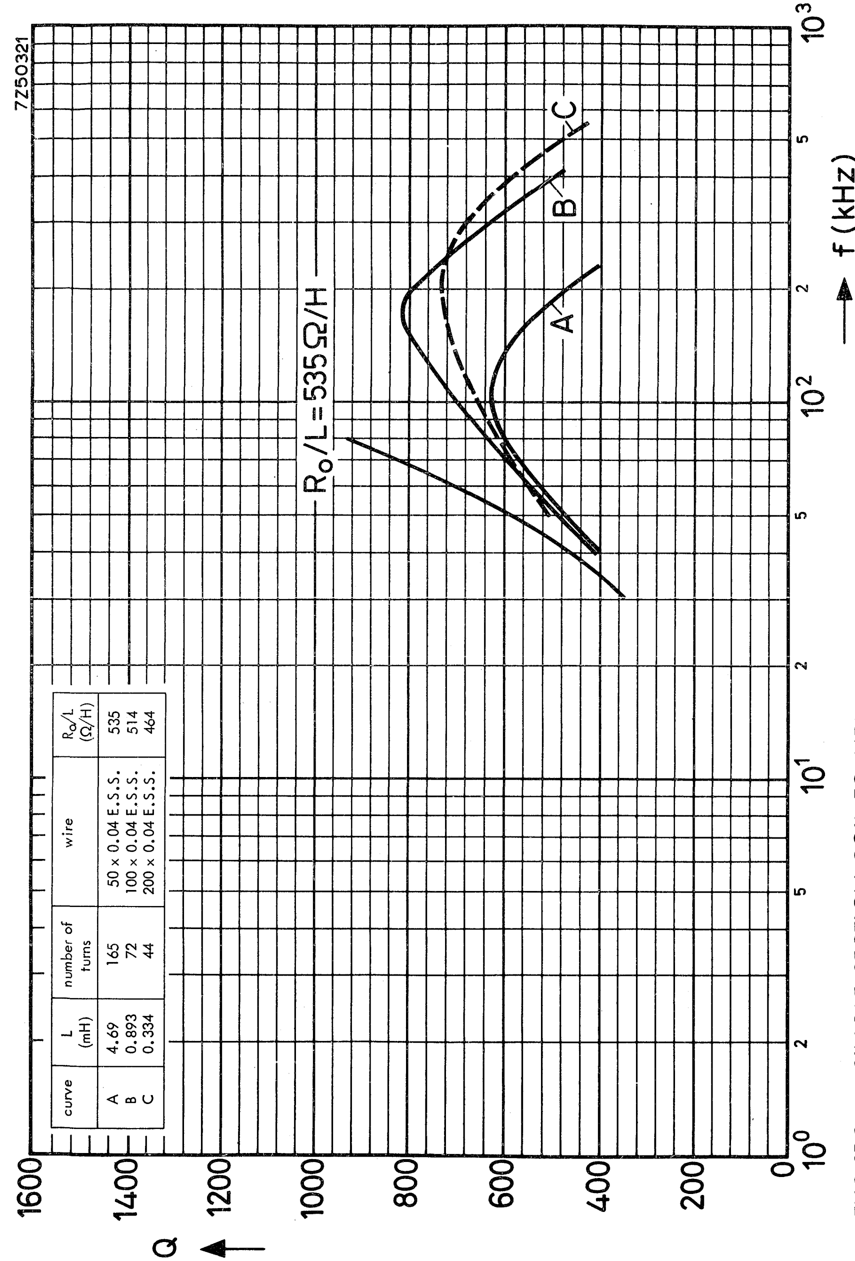


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	2.27	165	50 × 0.04 E.S.S.	1103
B	0.433	72	100 × 0.04 E.S.S.	1060
C	0.162	44	200 × 0.04 E.S.S.	955



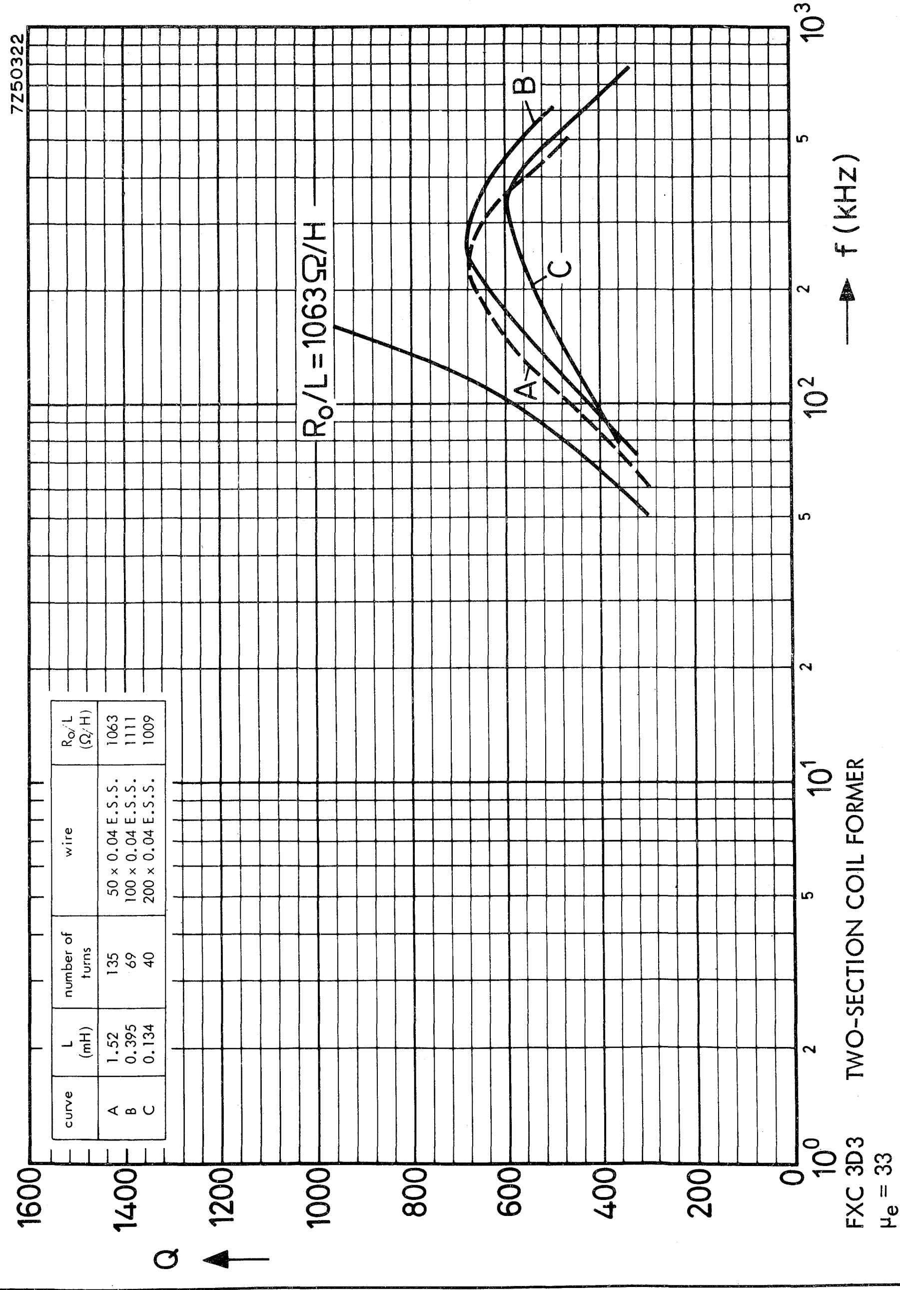
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	3.24	165	50 × 0.04 E.S.S.	775
B	0.617	72	100 × 0.04 E.S.S.	744
C	0.235	44	200 × 0.04 E.S.S.	673

FXC 3D3 SINGLE-SECTION COIL FORMER
$\mu_e = 47$

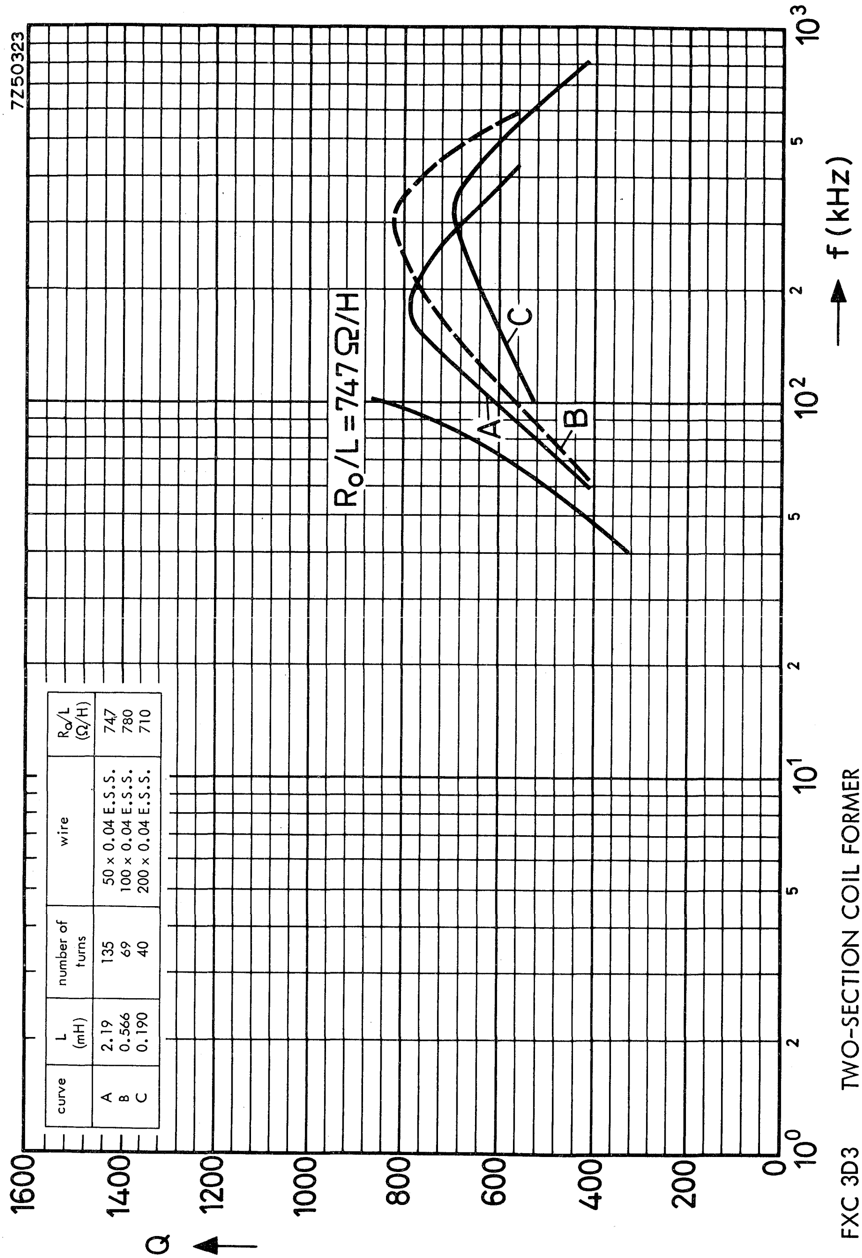


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	4.69	165	50 × 0.04 E.S.S.	535
B	0.893	72	100 × 0.04 E.S.S.	514
C	0.334	44	200 × 0.04 E.S.S.	464

FXC 3D3 SINGLE-SECTION COIL FORMER
$\mu_e = 68$



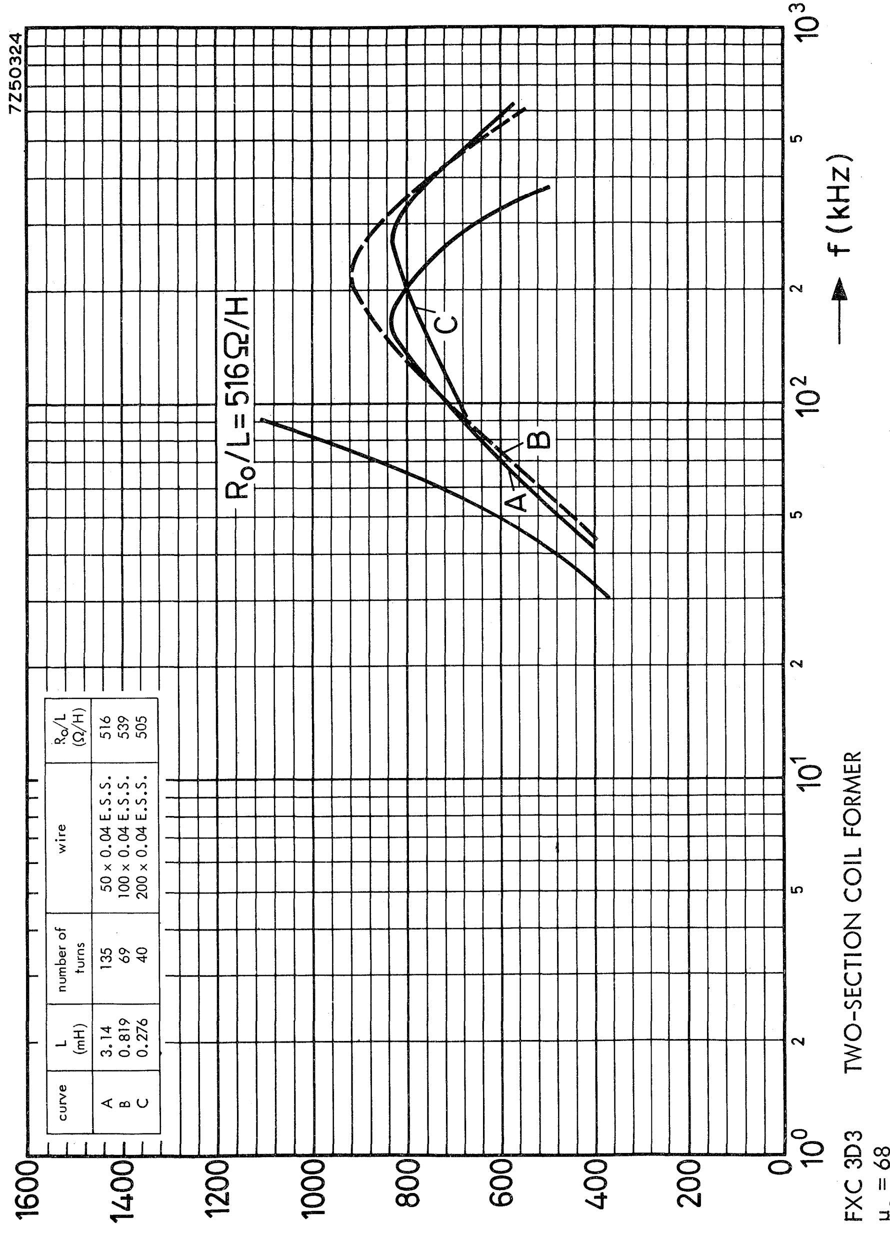
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	1.52	135	50 × 0.04 E.S.S.	1063
B	0.395	69	100 × 0.04 E.S.S.	1111
C	0.134	40	200 × 0.04 E.S.S.	1009



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	2.19	135	50 × 0.04 E.S.S.	747
B	0.566	69	100 × 0.04 E.S.S.	780
C	0.190	40	200 × 0.04 E.S.S.	710

FXC 3D3
$\mu_e = 47$

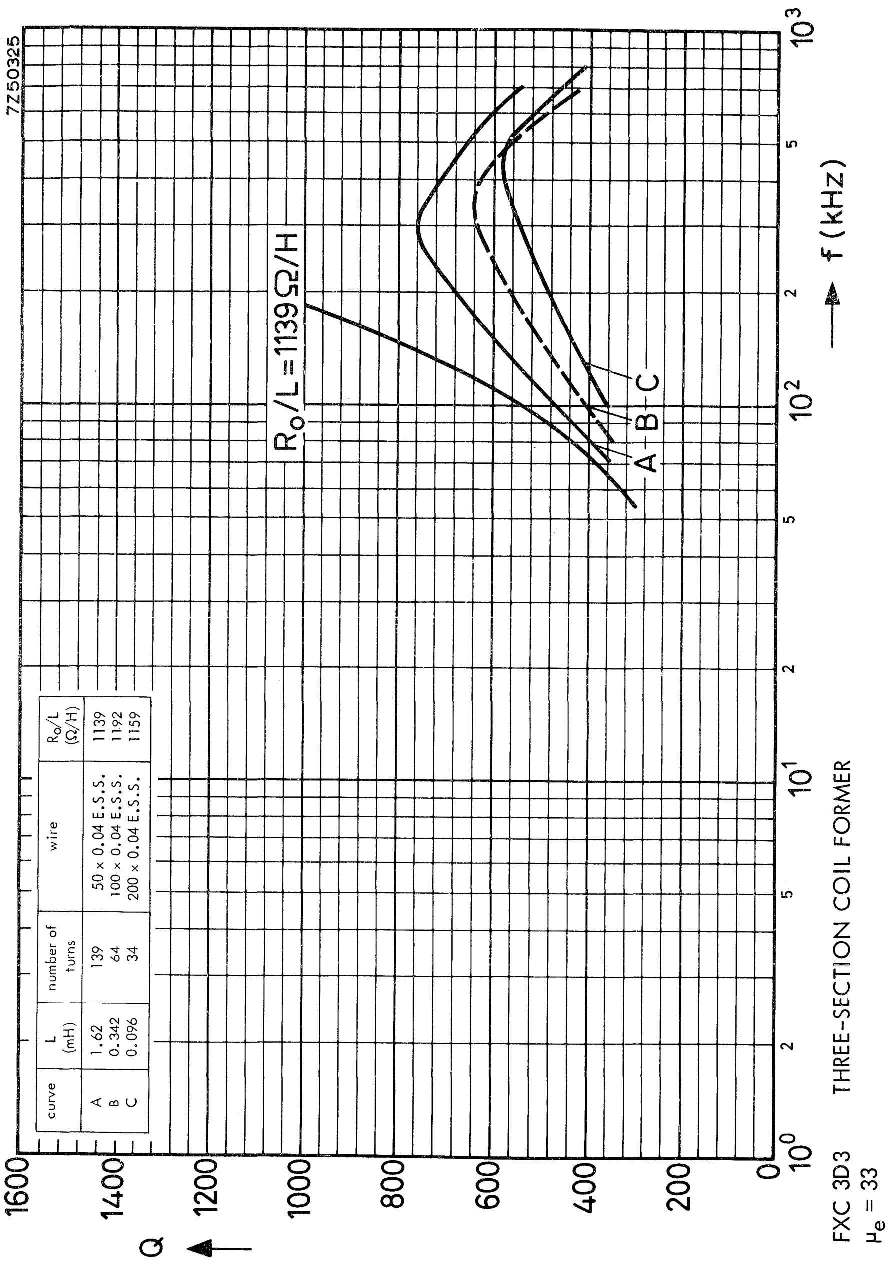
TWO-SECTION COIL FORMER



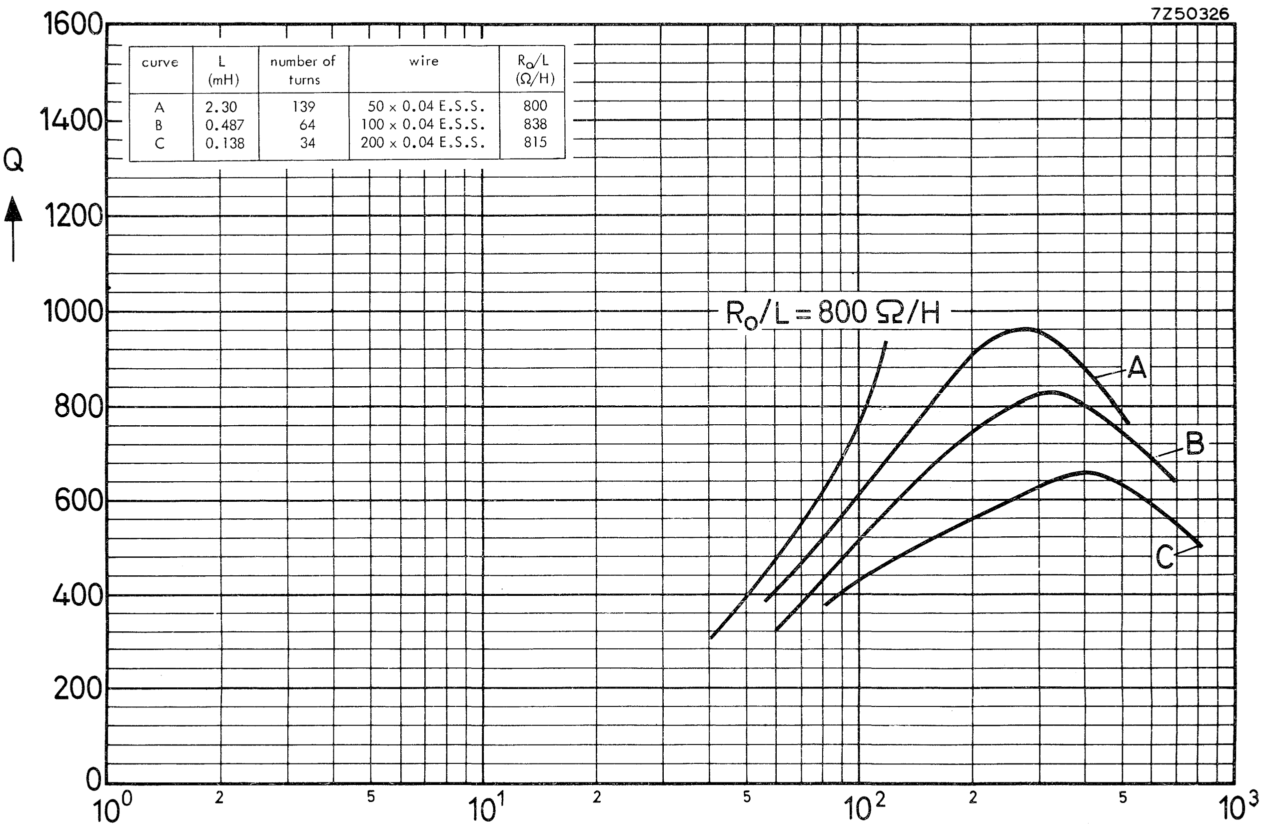
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	3.14	135	50 × 0.04 E.S.S.	516
B	0.819	69	100 × 0.04 E.S.S.	539
C	0.276	40	200 × 0.04 E.S.S.	505

FXC 3D3
$\mu_e = 68$

TWO-SECTION COIL FORMER



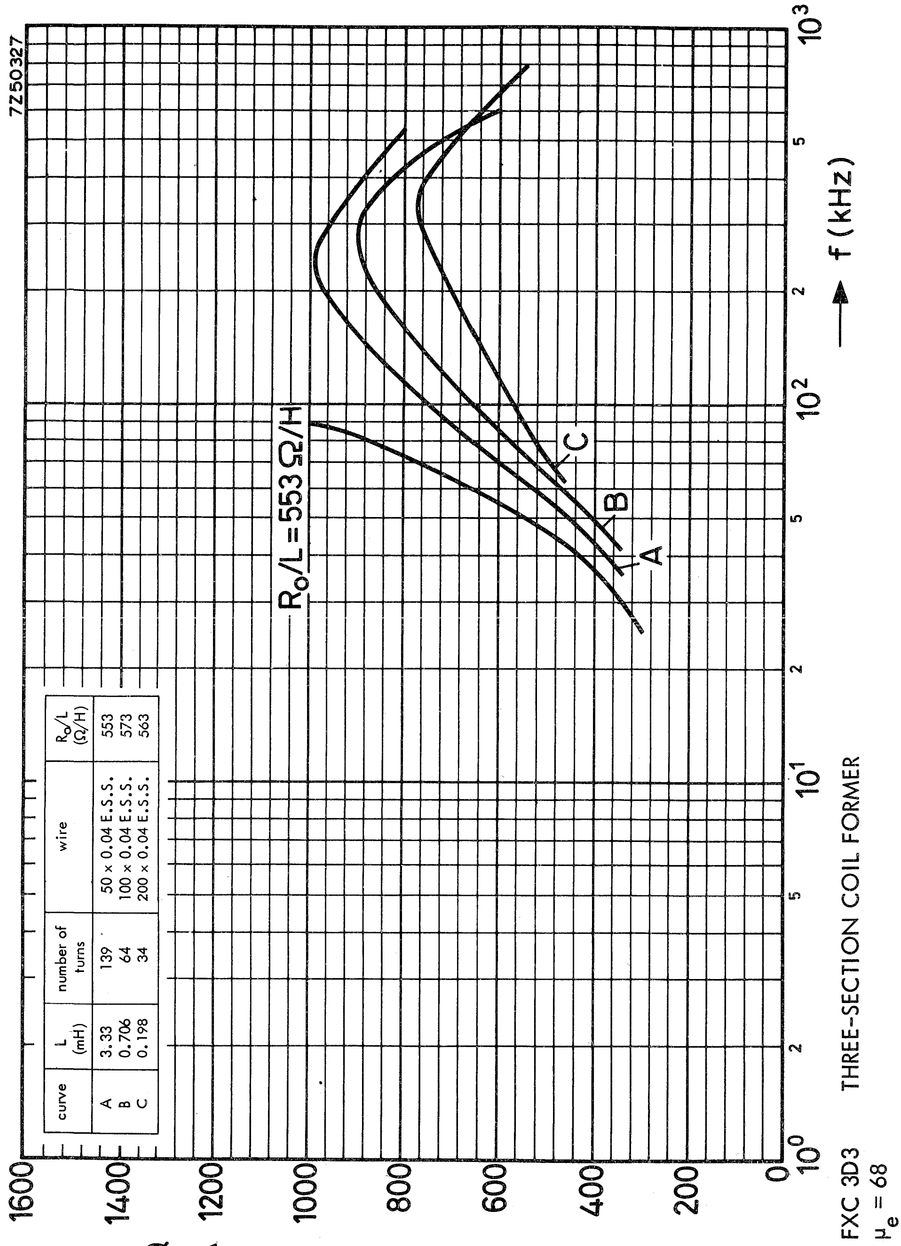
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	1.62	139	50 × 0.04 E.S.S.	1139
B	0.342	64	100 × 0.04 E.S.S.	1192
C	0.096	34	200 × 0.04 E.S.S.	1159



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	2.30	139	50 × 0.04 E.S.S.	800
B	0.487	64	100 × 0.04 E.S.S.	838
C	0.138	34	200 × 0.04 E.S.S.	815

FXC 3D3 THREE-SECTION COIL FORMER

$\mu_e = 47$

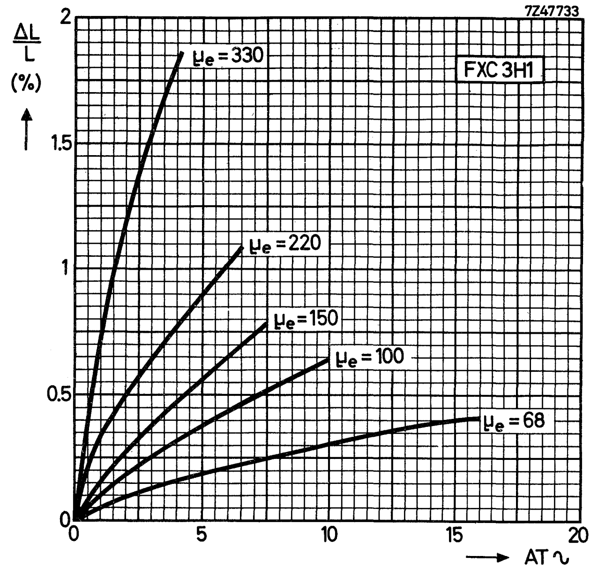


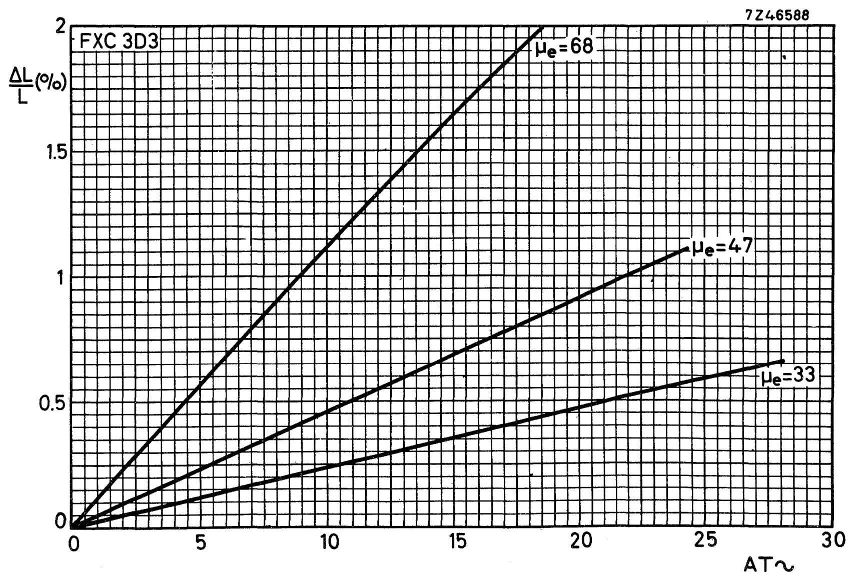
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	3.33	139	50 × 0.04 E.S.S.	553
B	0.706	64	100 × 0.04 E.S.S.	573
C	0.198	34	200 × 0.04 E.S.S.	563

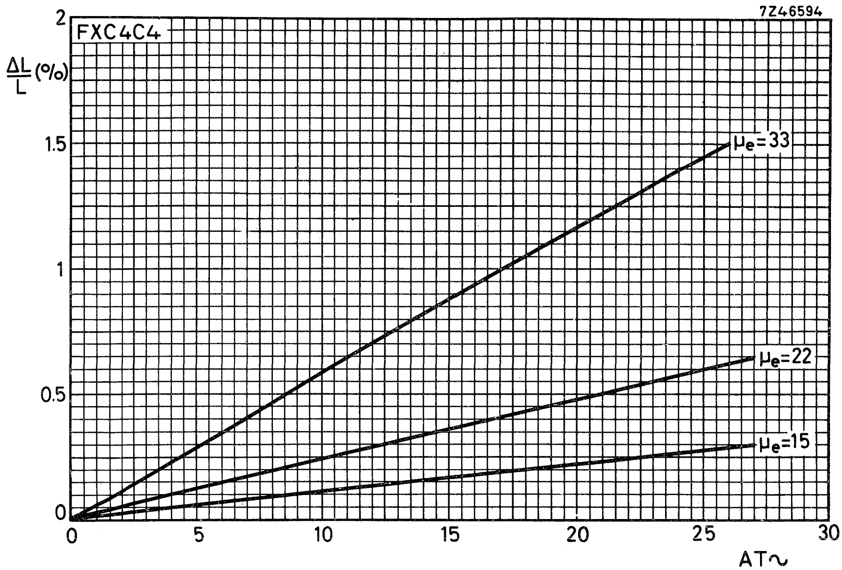
THREE-SECTION COIL FORMER

FXC 3D3
$\mu_e = 68$

INDUCTANCE VARIATION AS A FUNCTION OF AT~

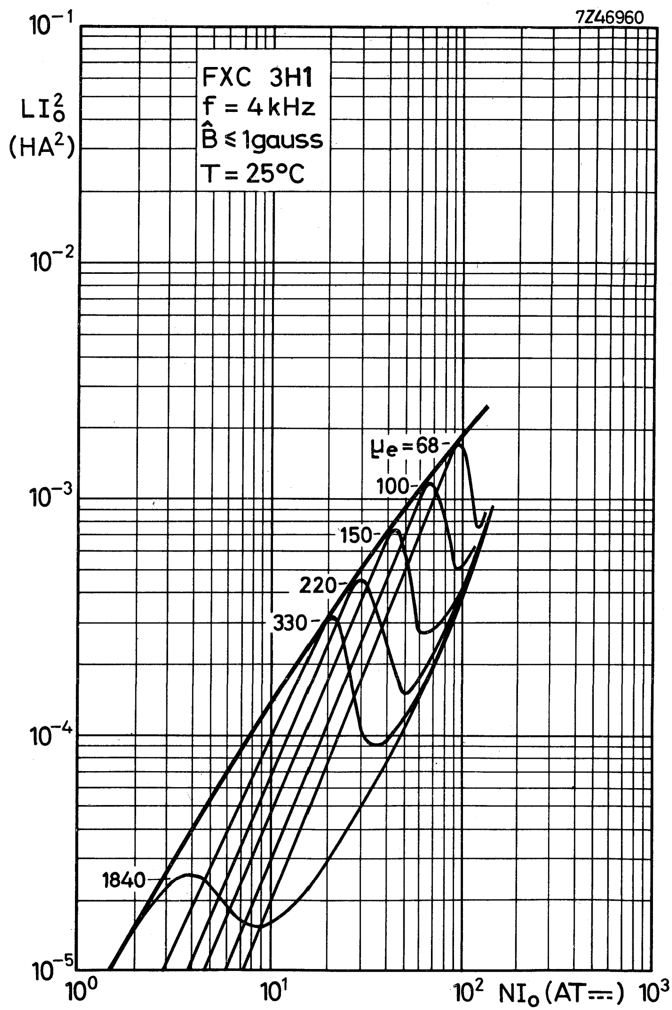




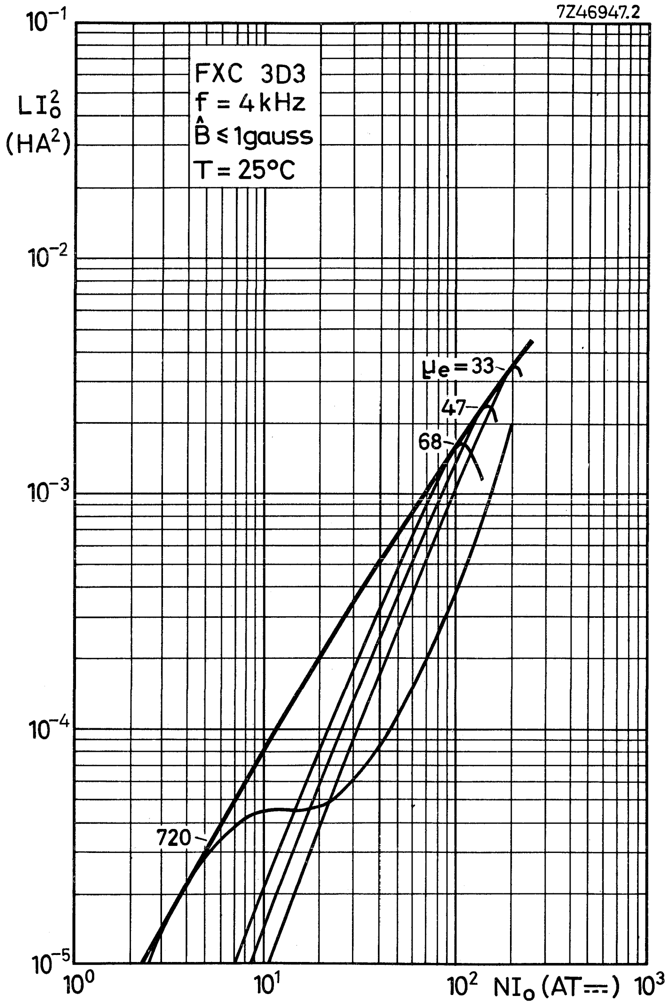

7Z46594
FXC4C4
ΔL/L (%)
2
1.5
1
0.5
0
μe=33
μe=22
μe=15
0
5
10
15
20
25
30
AT~

HANNA CURVES

Indicating optimum inductance for a certain μ_e-value and direct current.
Typical values



Typical values



POTCORES

INTRODUCTION

Three types of core can be supplied:

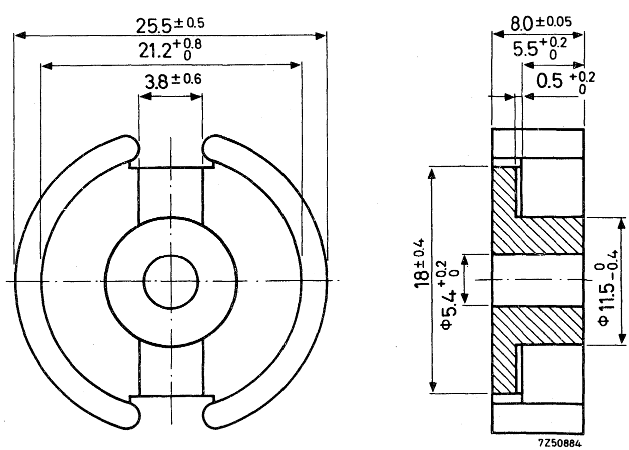
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number. Quantity: a primary pack contains 20 potcore halves or 10 pieces of pre-adjusted potcore, so please order in multiples of these quantities.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 22000
3H1	4322 020 22010
3D3	4322 020 22020
4C4	4322 020 22030
4C6	

Properties

For toroidally wound core halves the values in Table I are guaranteed.

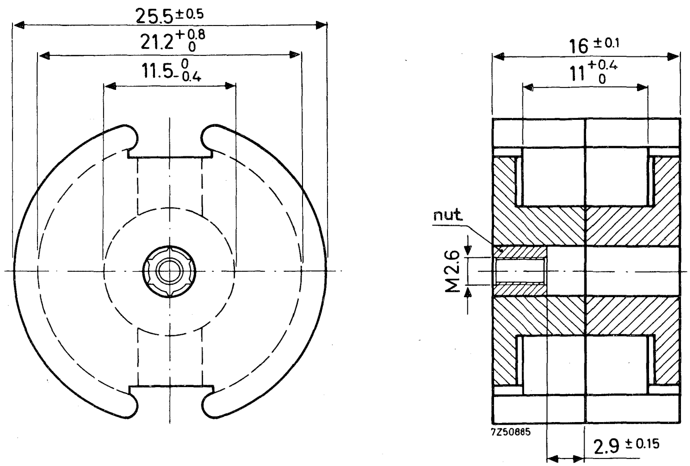
Table I	temp. (°C)	grade				
		3B7	3H1	3D3	4C4	4C6
T.F.x 10^6	+5 to +23	–	–	–	–	−2 to +4
	+23 to +55	–	–	–	−10 to 0	0 to +6
	+23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to 2	–	
D.F.x 10^6 (10-100 min)	23 ± 1	≤ 4.3	≤ 4.3	≤ 12	≤ 33	≤ 10

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 200 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (MHz)	grade				
			3B7	3H1	3D3	4C4	4C6
μ_e	≤ 1	0.004	≥ 1430	≥ 1430		≥ 94	
	≤ 1	0.1			≥ 550		
α	≤ 1	0.004	≤ 14.9	≤ 14.9		≤ 58.0	
	≤ 1	0.1			≤ 24.1		
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	≤ 1	0.004	≤ 1.2	≤ 1.2			
		0.1	≤ 5	≤ 5	≤ 8		
		0.5			≤ 14		
		1			≤ 35		
		2					≤ 45
		5					≤ 60
		10					≤ 100
$q_{2-24-100}$	15-30	0.004	≤ 1.8	≤ 1.8			
	3-12	0.1			≤ 3.0		

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 2....
Without nut, catalog number = 4322 022 0....

Weight		=	20 g
Effective length	l_e	=	3.76 cm
	$\Sigma \frac{l_e}{A_e}$	=	4.00 cm^{-1}
Effective volume	V_e	=	3.53 cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 2 for potcores with nut, insert 0 for potcores without nut.
   Examples of catalog number:
   μ_e = 15, grade 4C4, potcore with nut, catalog number = 4322 022 26610
   A_L = 100, grade 3B7, potcore without nut, catalog number = 4322 022 09040
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
15	146	± 1	–	–	–	.6610
22	120	± 1	–	–	–	.6620
33	98.2	± 1	.8030	.8230	.8430	.6630
47	82.3	± 1	.8040	.8240	.8440	–
68	68.4	± 1	.8050	.8250	.8450	–
100	56.4	± 1.5	.8060	.8260	–	–
150	46.1	± 2	.8070	.8270	–	–
220	38.1	± 3	.8080	.8280	–	–
330	31.0	± 3	.8090	.8290	–	–
730	20.8	± 25	–	–	08400	–
1910	12.9	± 25	08000	08200	–	–

Number of turns $N = \alpha\sqrt{L}$ (L in 10^{-3} H)

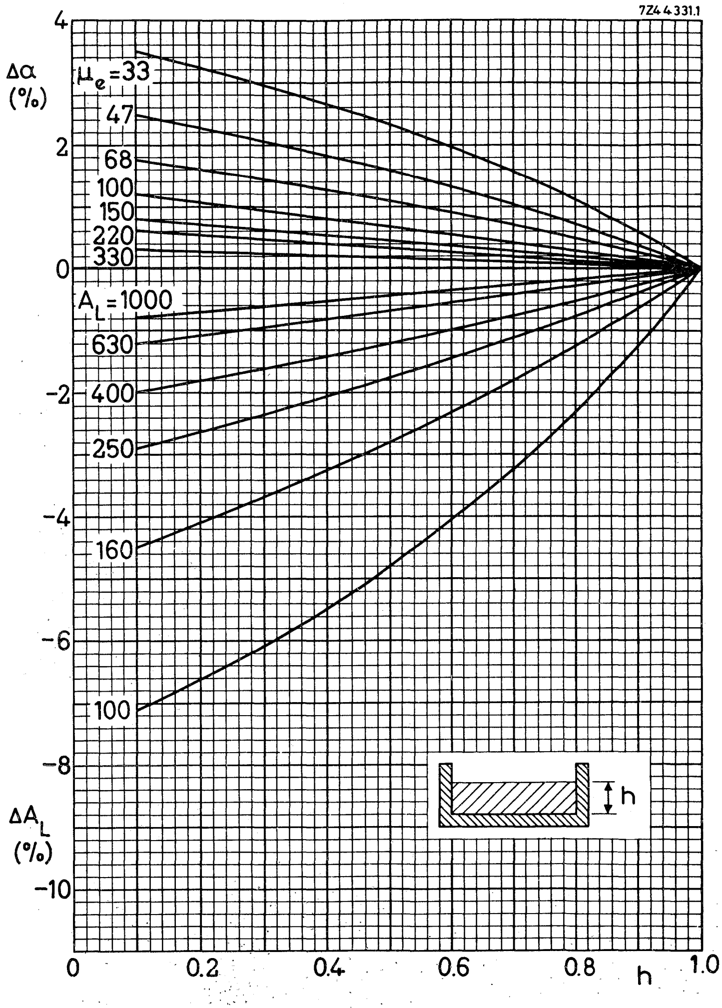
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022			
			3B7	3H1	3D3	4C4
63	20	± 1	–	–	–	.9630
100	31.8	± 1	.9040	.9240	.9440	.9640
160	51	± 1	.9050	.9250	.9450	–
250	79.5	± 1	.9060	.9260	.9460	–
315	100.2	± 1.5	.9070	.9270	–	–
400	127	± 2	.9080	.9280	–	–
630	200	± 3	.9100	.9300	–	–
1000	318	± 3	.9110	.9310	–	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

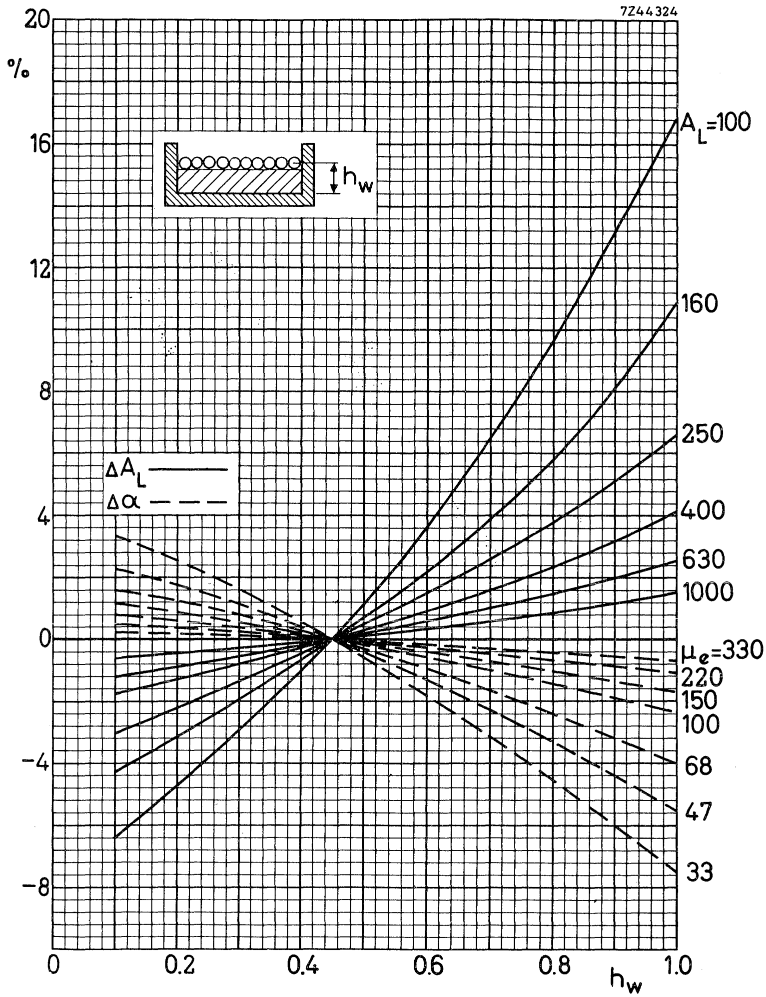
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 68.4 + 1.25 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_w on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3 only.

Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 68.4 - 1.7 %.

COIL FORMERS

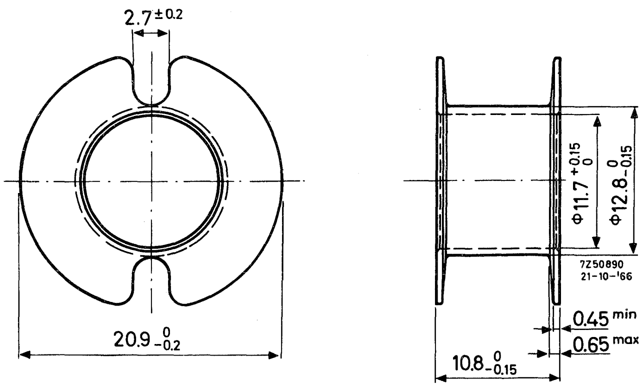
GENERAL

Four types of coil former can be supplied:

- with one section
- with two sections
- with three sections
- with one section and with soldering pins to fit 0.1" and 2.50 mm grid.

The dimensions conform with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



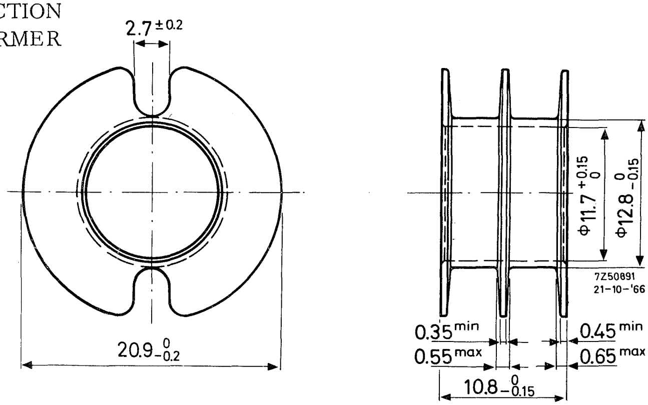
Catalog number	4322 021 30330
Material	polycarbonate K486
Window area	39 mm^2
Mean length of turn	5.3 cm
Max. temperature	130 ^{o}C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 7.42 \times 10^3 \quad \Omega/H$$

Weight 0.5 g

TWO-SECTION COIL FORMER



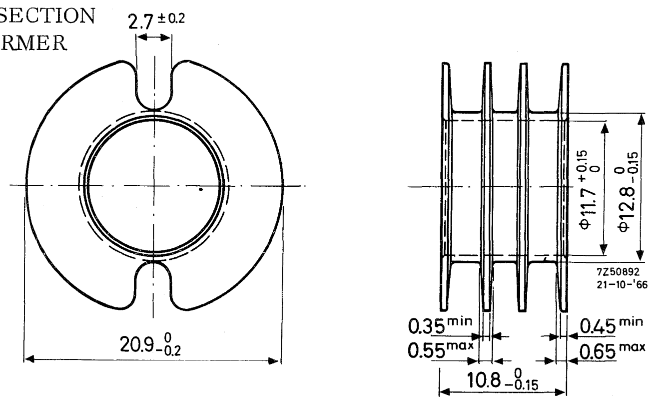
Catalog number	4322 021 30340
Material	polycarbonate K486
Window area	2 x 19 mm^2
Mean length of turn	5.3 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 7.79 \times 10^3 \ \Omega/H$$

Weight 0.6 g

THREE-SECTION COIL FORMER



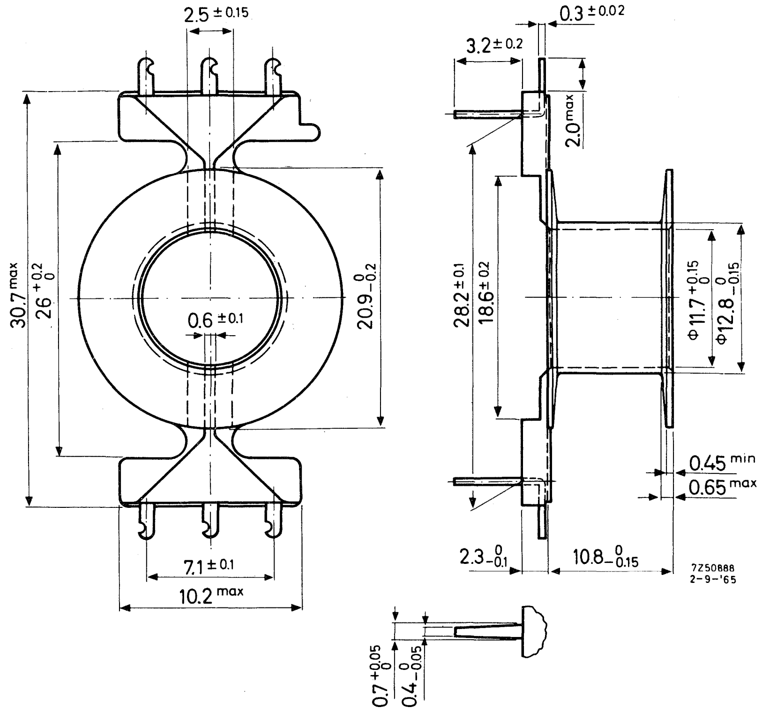
Catalog number	4322 021 30350
Material	polycarbonate K486
Window area	3 x 12 mm^2
Mean length of turn	5.3 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 8.18 \times 10^3 \ \Omega/H$$

Weight 0.7 g

SINGLE-SECTION COIL FORMER WITH SOLDERING PINS



Catalog number 4322 021 30130

Material: reinforced polyester with brass dipsoldered pins

Window area 39 mm^2

Mean length of turn 5.3 cm

Max. temperature 130 °C

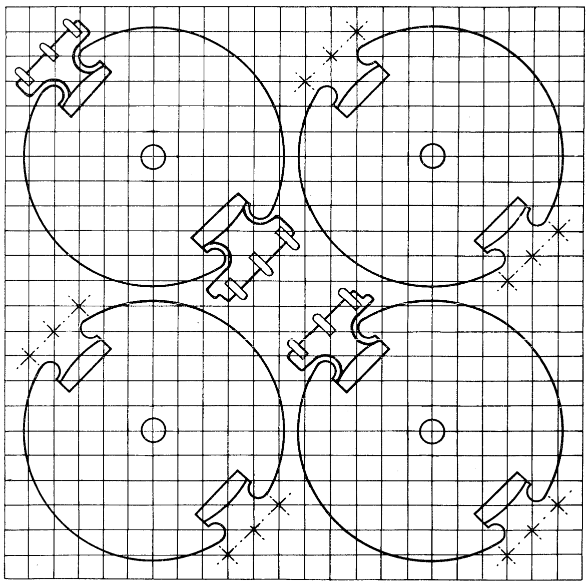
Max. dipsolder temperature for 5-6 s 280 °C

D.C. losses:

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 7.42 \times 10^3 \quad \Omega/H$$

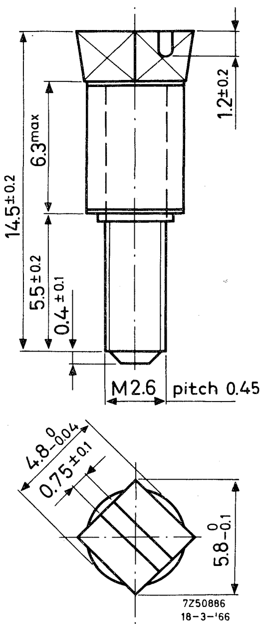
Weight 0.6 g

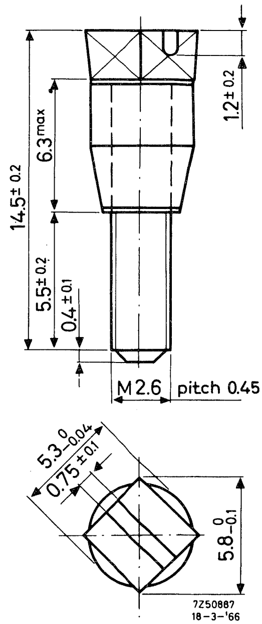
The soldering pins are so arranged as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes 1.3 ± 0.1 mm diameter.
For this coil former the potcore halves must be glued together, and it is recommended to cement the coil former to the lower potcore half.


7Z47201

INDUCTANCE ADJUSTMENT

CONTINUOUS ADJUSTORS





The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.03 % by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.

The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.

The influence of the adjustors on the variability of the inductance is negligible.

The maximum permissible temperature is 110 °C.

Table II shows the type of adjustor recommended for different potcores.

Table I, available types

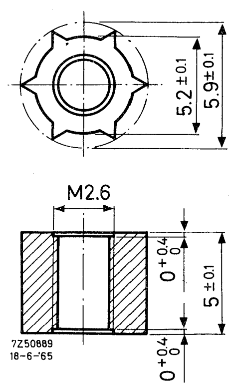
Fig.	colour	catalog number
A	green	4322 021 30780
A	yellow	4322 021 30790
A	red	4322 021 30800
A	brown	4322 021 30810
B	white	4322 021 30980
B	grey	4322 021 31090

Table II, recommended application

μ_e	A_L	3B7/3H1/3D3	4C4
		cat. number 4322 021	
15		–	30780
22		–	30780
	63	–	30780
33		30780	30790
	100	30780	30790
47		30800	
	160	30800	
68		30980	
	250	30980	
100	315	30980	
150		30810	
	400	30810	
220		30810	
	630	30810	
330		31090	
	1000	31090	

NUT FOR ADJUSTOR

These data are given for those manufacturers who prefer to insert the nut themselves.



Catalog number 4322 021 30160

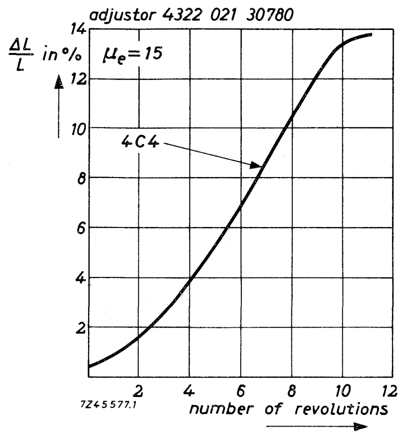
Material polycarbonate

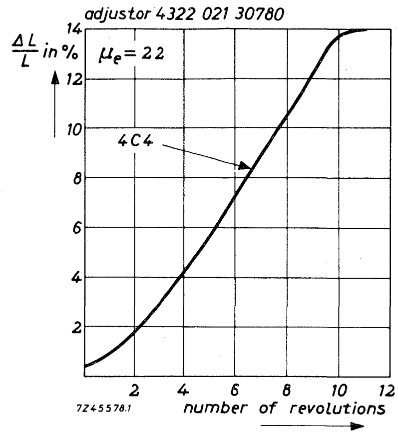
Max. impregnation temperature during 24 hours 120 °C

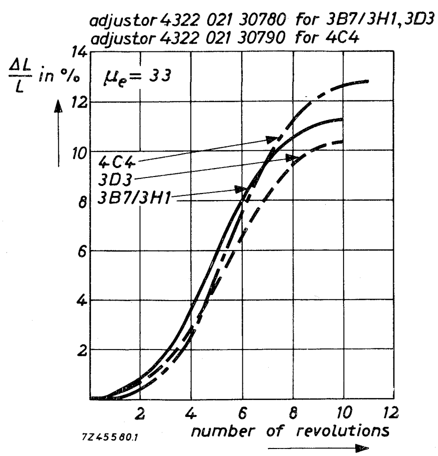
Recommended distance from mating surface to nut 2.9 ± 0.15 mm

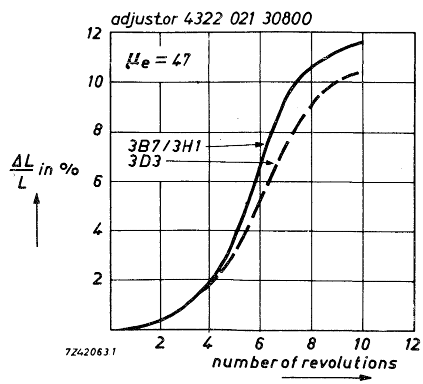
For more information see Potcores General, Mounting data

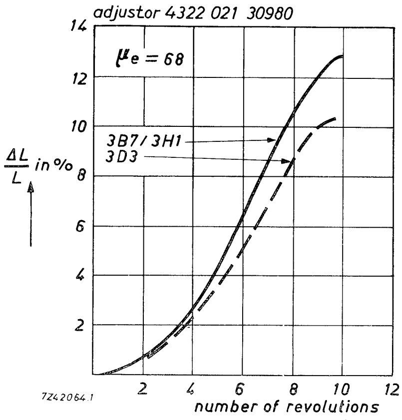
ADJUSTMENT CURVES

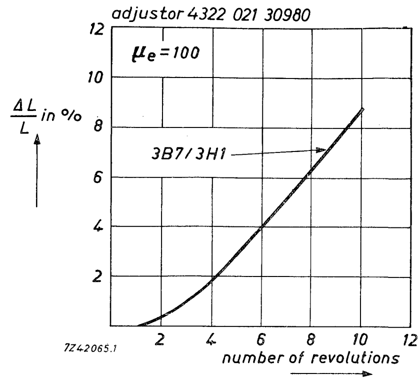


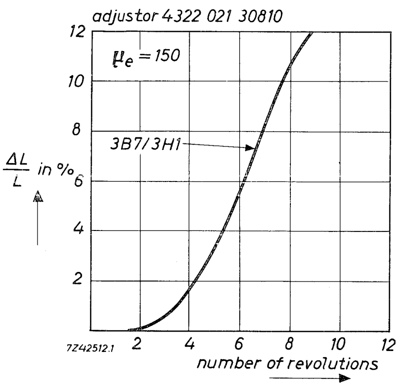


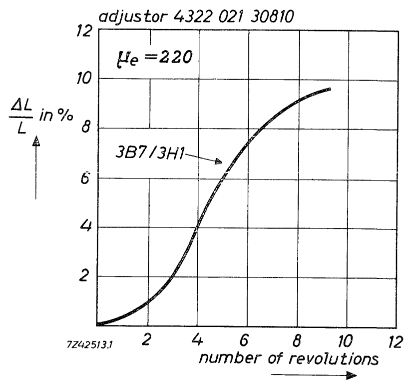


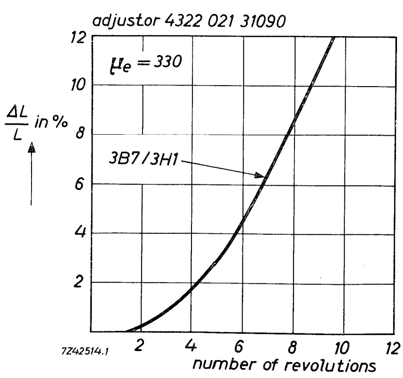



adjustor 4322 021 30980
$\mu_e = 68$
3B7/3H1
3D3
ΔL/L in %
number of revolutions
7Z42064.1


adjustor 4322 021 30980
$\mu_e = 100$
3B7/3H1
ΔL/L in %
number of revolutions
7Z42065.1


adjustor 4322 021 30810
$\mu_e = 150$
3B7/3H1
ΔL/L in %
number of revolutions
7Z42512.1


adjustor 4322 021 30810
$\mu_e = 220$
3B7/3H1
ΔL/L in %
number of revolutions
7Z42513.1


adjustor 4322 021 31090
$\mu_e = 330$
3B7/3H1
ΔL/L in %
number of revolutions
7Z42514.1

STEP-BY-STEP ADJUSTORS

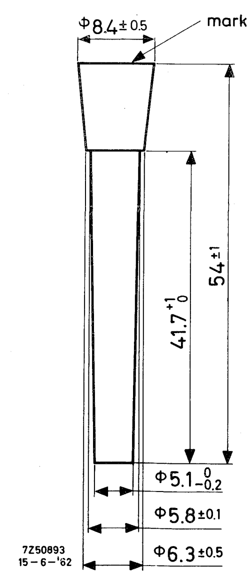
These adjustors are used when a continuous adjustment of the inductance is not necessary. For instance, they are applied in loading coils to bring the inductance within a certain tolerance field. They are not suitable for adjusting the inductance to an exact value, as is usually necessary in filters. The increment of the losses caused by these adjustors is negligible.

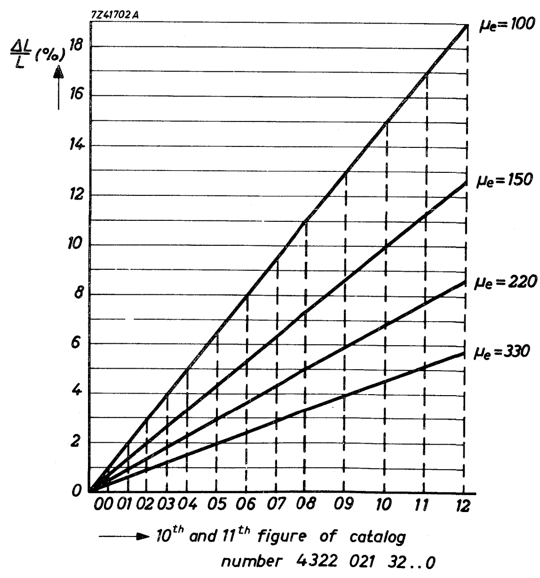
A range of 13 flexible conical adjustors is available under the catalog numbers 4322 021 32000 up to ..32120. Each adjustor causes an increase in the inductance; the higher the catalog number, the greater the effect. The influence of each adjustor on the inductance at different μ_e values of the potcore can be found from the graph.

The 10th and 11th figure of the catalog number are indicated on the head of the adjustor. It should be borne in mind that, when using these adjustors, the inductance of the coil should initially be lower than the wanted value.

When the correct adjustor has been found, it is inserted in the centre hole of the pot. An adhesive (for instance Pliobond of Good Year) is used as sliding and fixing material. After fixing the protruding ends are cut off.

The maximum impregnation temperature is 150 °C.
The maximum working temperature is 90 °C.
Material: rubber with powder iron.

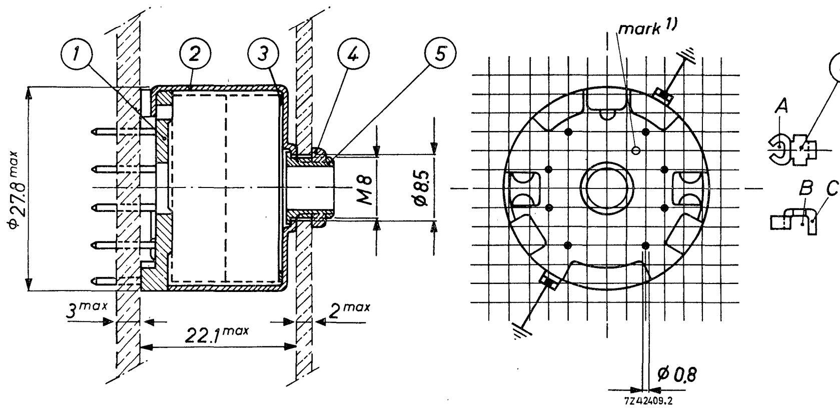




Dimensions in mm

MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30470	(4) nut	4322 021 30710
(2) brass container	4322 021 30550	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30660	(6) soldering spring	4322 021 30700 (8x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The eight soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1.3 + 0.1 mm diameter.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

1) There is another mark hole in a similar position on the top of the container.

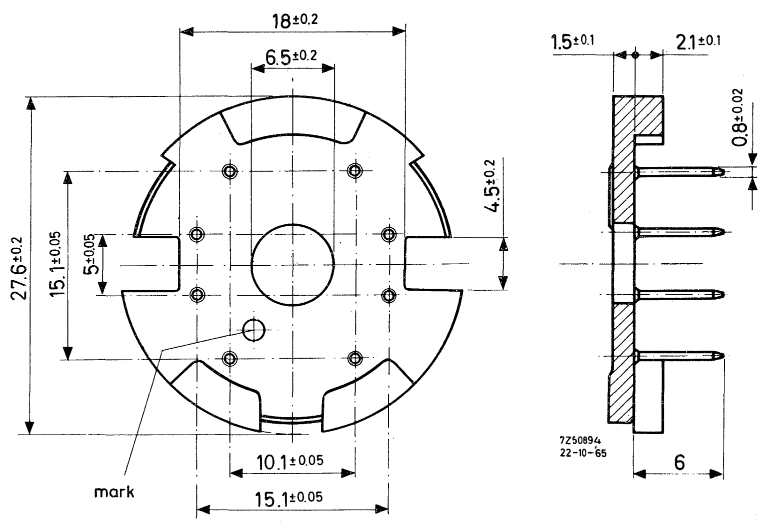
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.
Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 200 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

(1) Tag plate 4322 021 30470

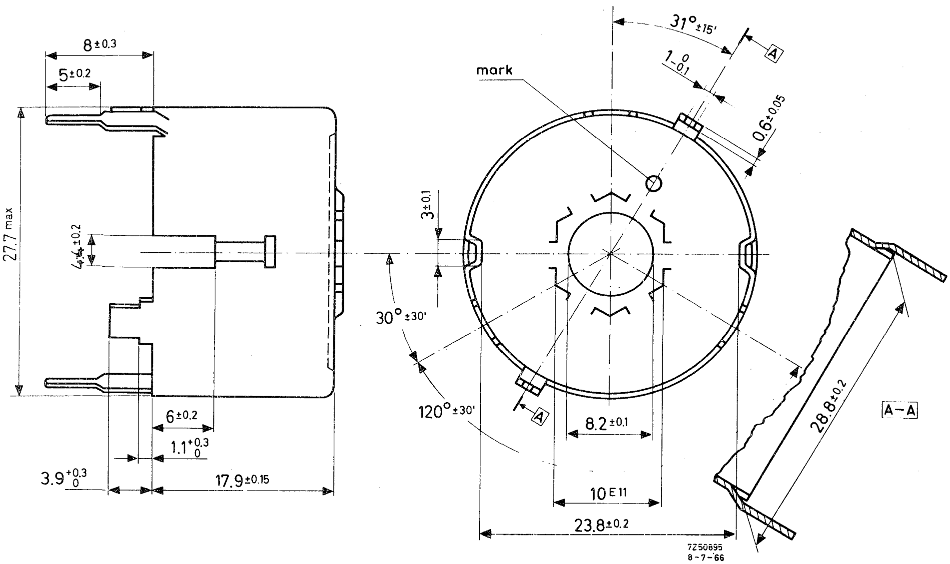
Plate: reinforced polyester

Pins : phosphorbronze, dipsoldered



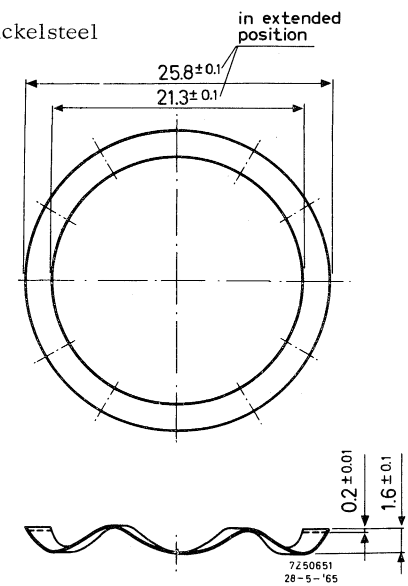
(2) Container 4322 021 30550

Material: brass, nickel plated



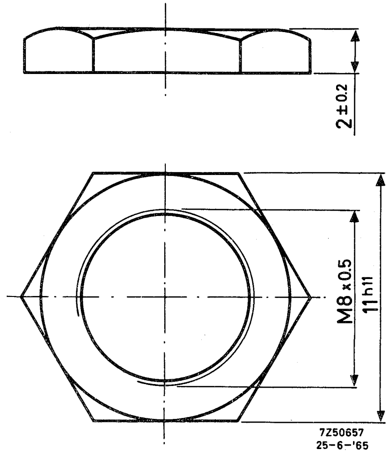
(3) Spring 4322 021 30660

Material: chrome-nickelsteel



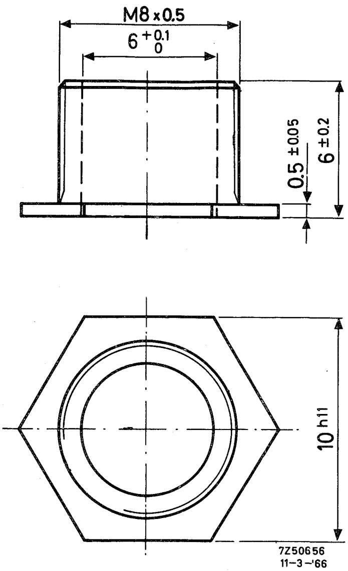
(4) Nut 4322 021 30710

Material: brass, nickel plated



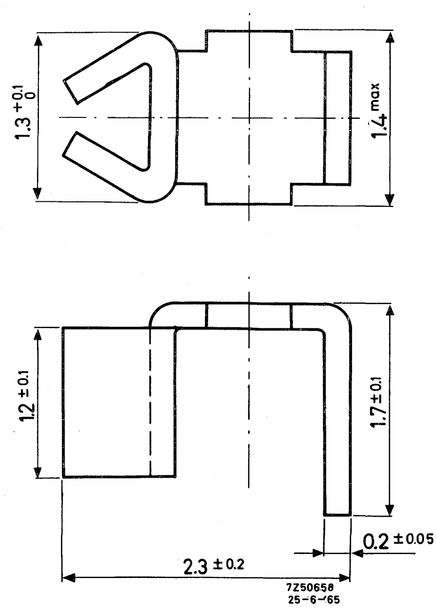
(5) Fixing bush 4322 021 30720

Material: aluminium



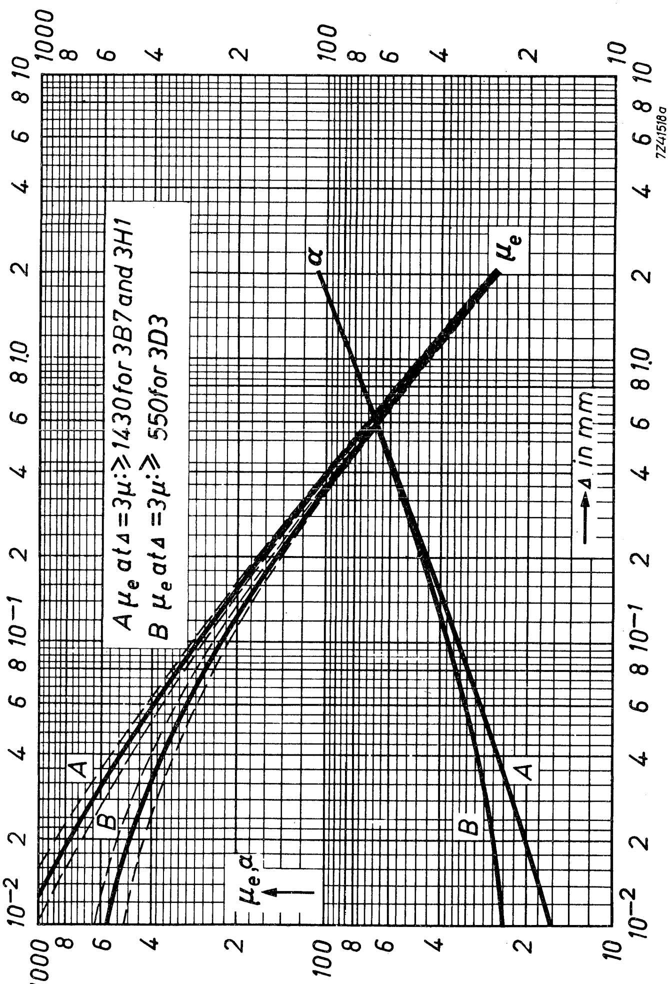
(6) Soldering spring 4322 021 30700

Material : brass, dipsoldered

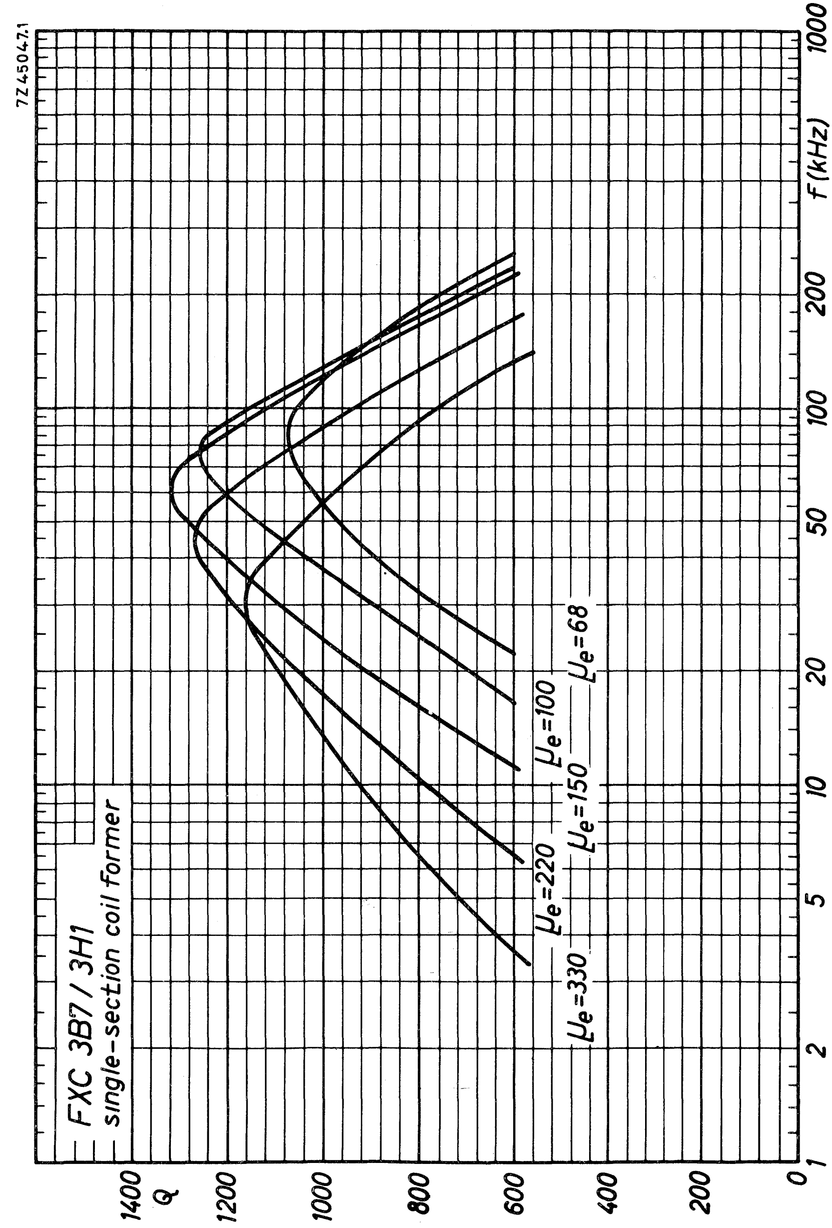


CHARACTERISTIC CURVES

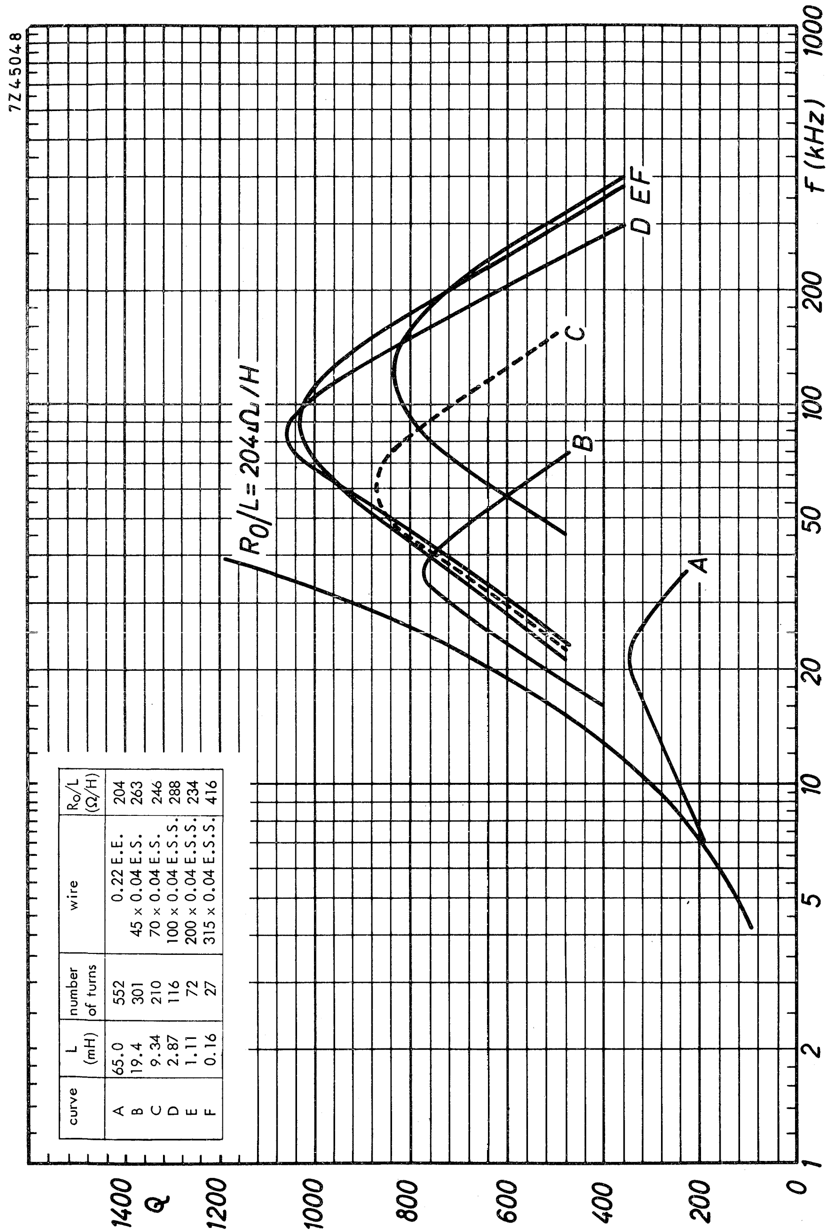
μ_e - α CURVES



TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1



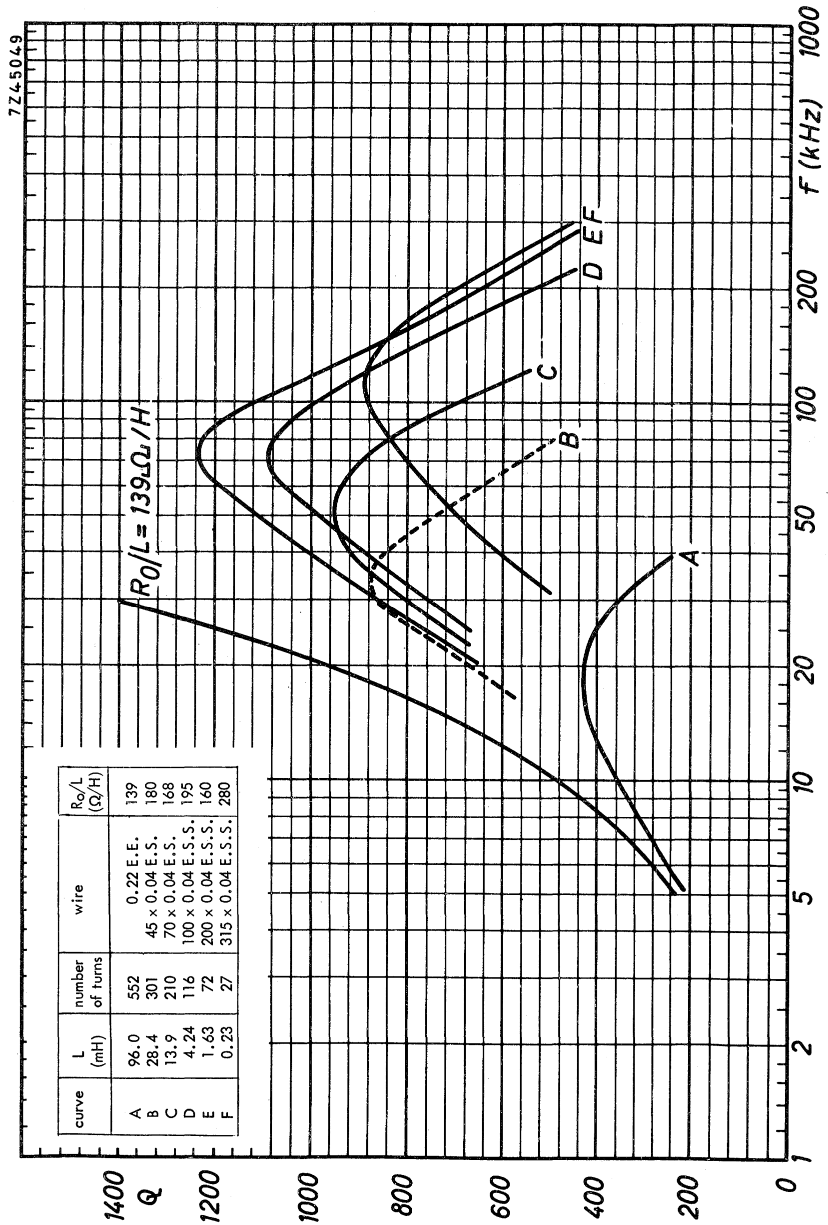
Enveloping curves



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	65.0	552	0.22 E.E.	204
B	19.4	301	45 × 0.04 E.S.	263
C	9.34	210	70 × 0.04 E.S.	246
D	2.87	116	100 × 0.04 E.S.S.	288
E	1.11	72	200 × 0.04 E.S.S.	234
F	0.16	27	315 × 0.04 E.S.S.	416

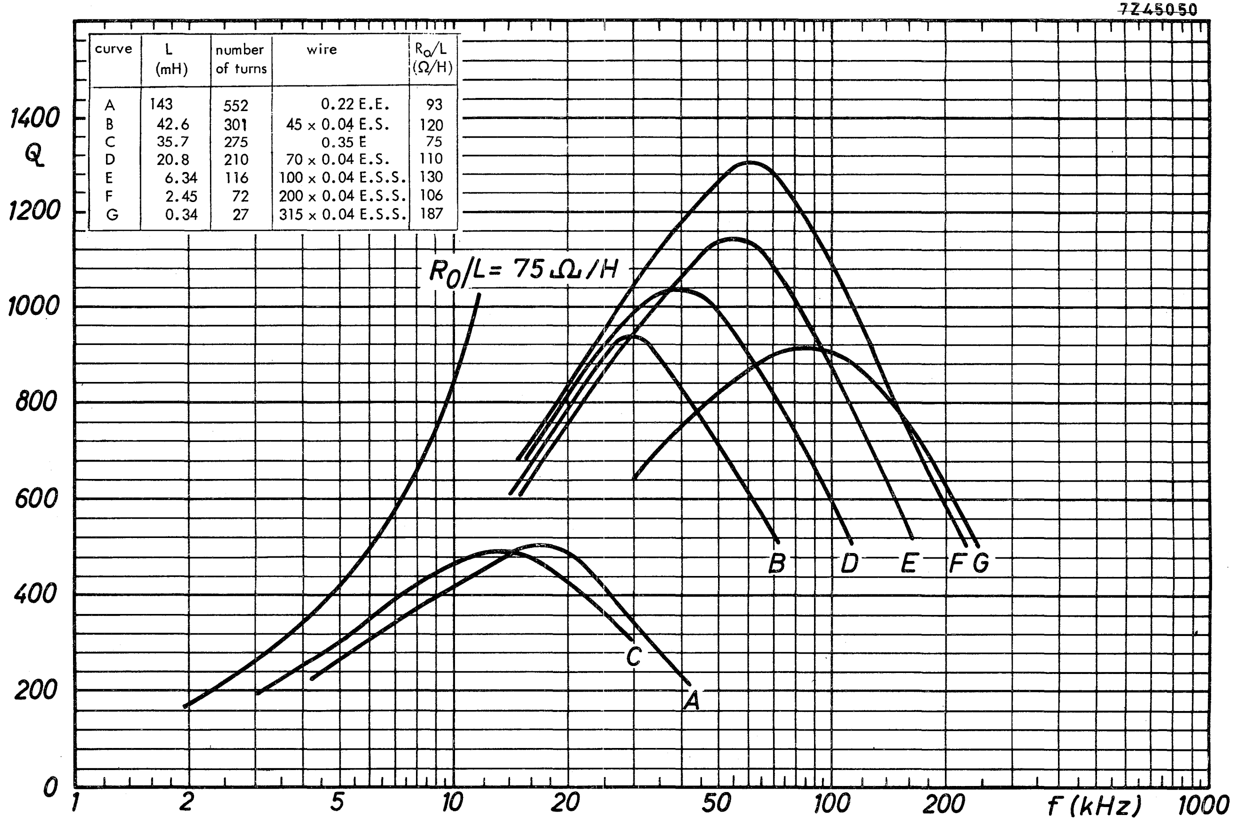
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

$\mu_e = 68$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	96.0	552	0.22 E.E.	139
B	28.4	301	45 × 0.04 E.S.	180
C	13.9	210	70 × 0.04 E.S.	168
D	4.24	116	100 × 0.04 E.S.S.	195
E	1.63	72	200 × 0.04 E.S.S.	160
F	0.23	27	315 × 0.04 E.S.S.	280

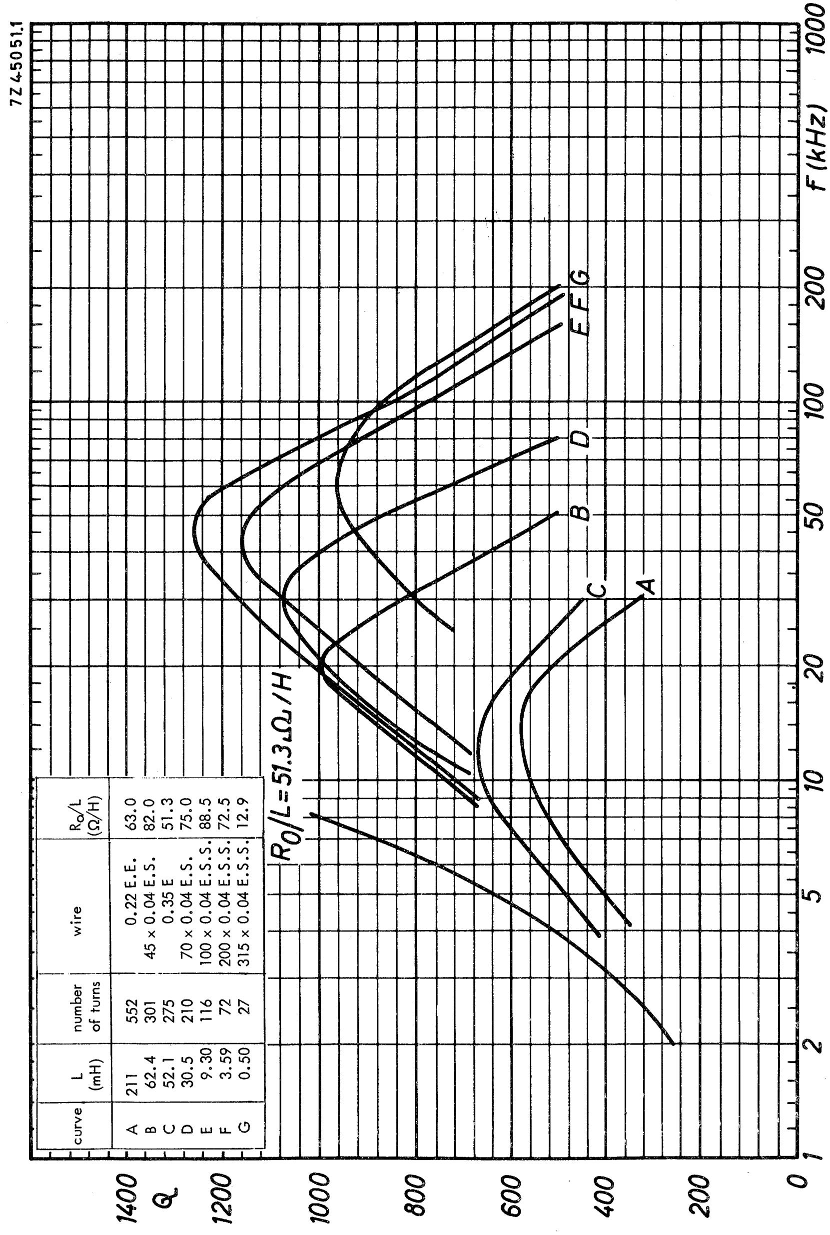
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 100$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	143	552	0.22 E.E.	93
B	42.6	301	45 × 0.04 E.S.	120
C	35.7	275	0.35 E	75
D	20.8	210	70 × 0.04 E.S.	110
E	6.34	116	100 × 0.04 E.S.S.	130
F	2.45	72	200 × 0.04 E.S.S.	106
G	0.34	27	315 × 0.04 E.S.S.	187

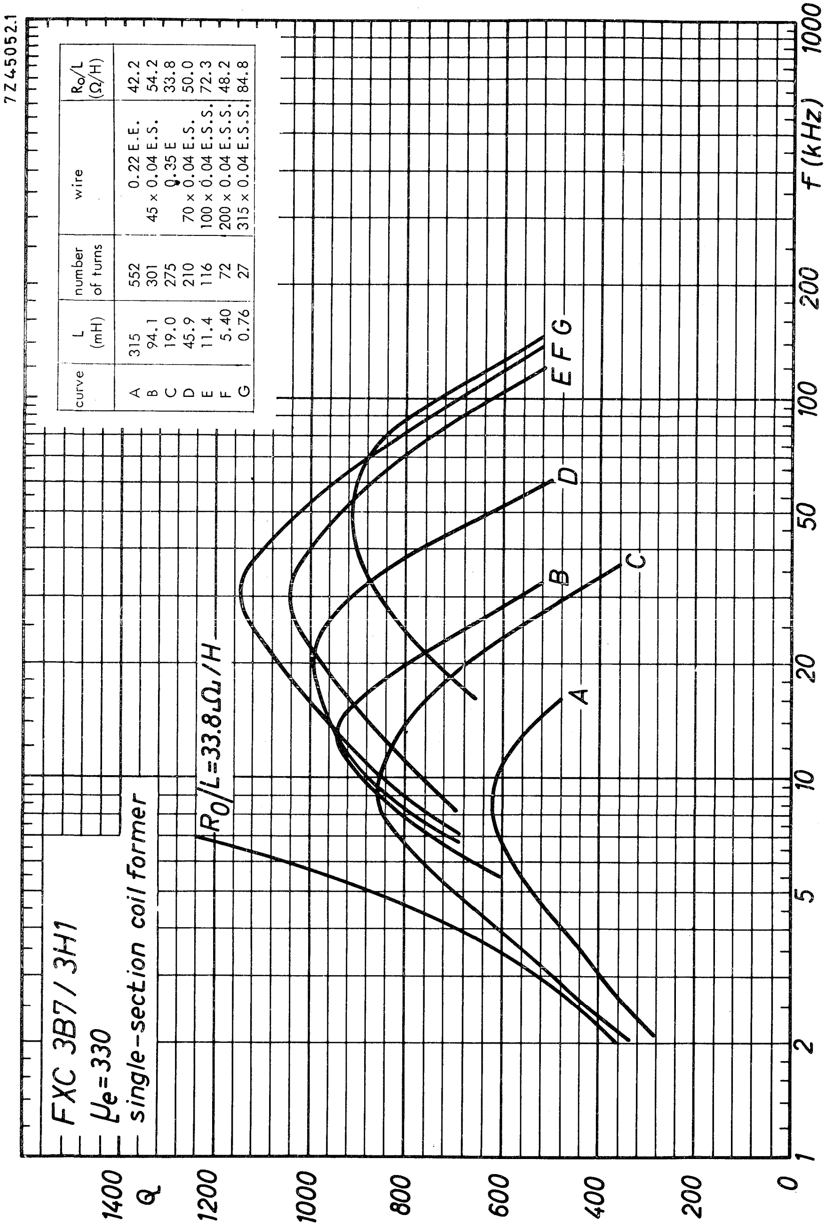
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

$\mu_e = 150$



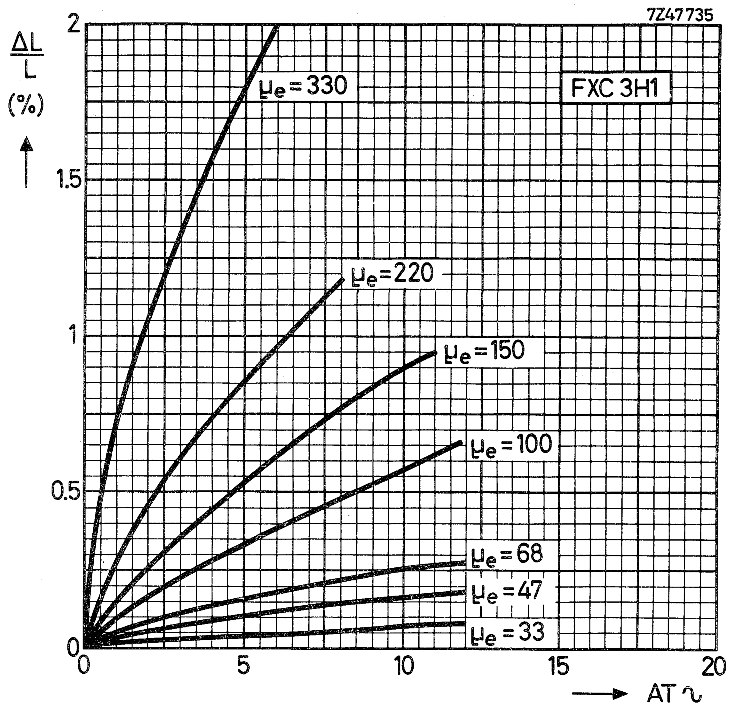
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	211	552	0.22 E.E.	63.0
B	62.4	301	45 × 0.04 E.S.	82.0
C	52.1	275	0.35 E	51.3
D	30.5	210	70 × 0.04 E.S.	75.0
E	9.30	116	100 × 0.04 E.S.S.	88.5
F	3.59	72	200 × 0.04 E.S.S.	72.5
G	0.50	27	315 × 0.04 E.S.S.	12.9

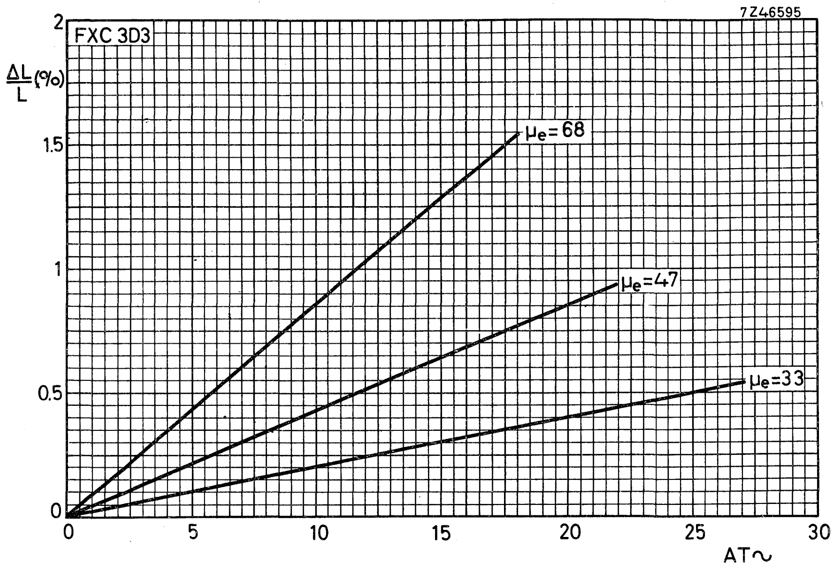
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 220$

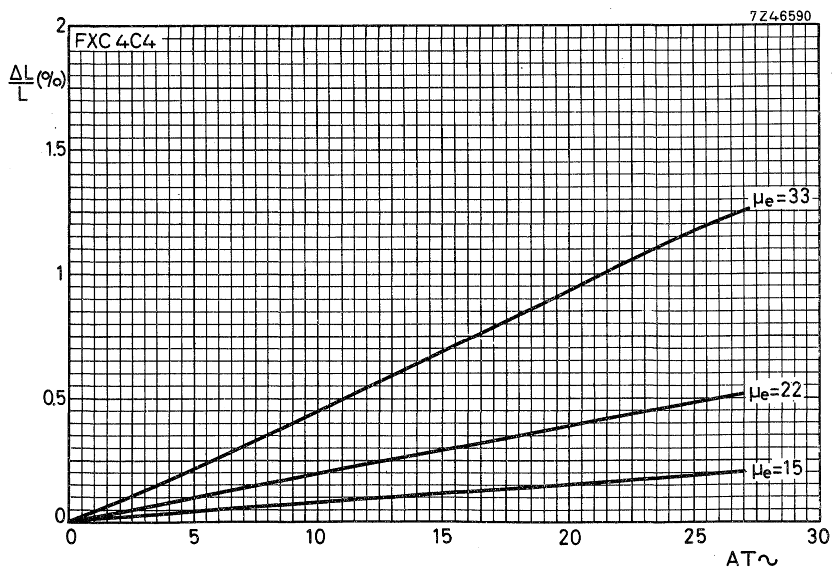


FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
μ_e = 330

INDUCTANCE VARIATION AS A FUNCTION OF AT~

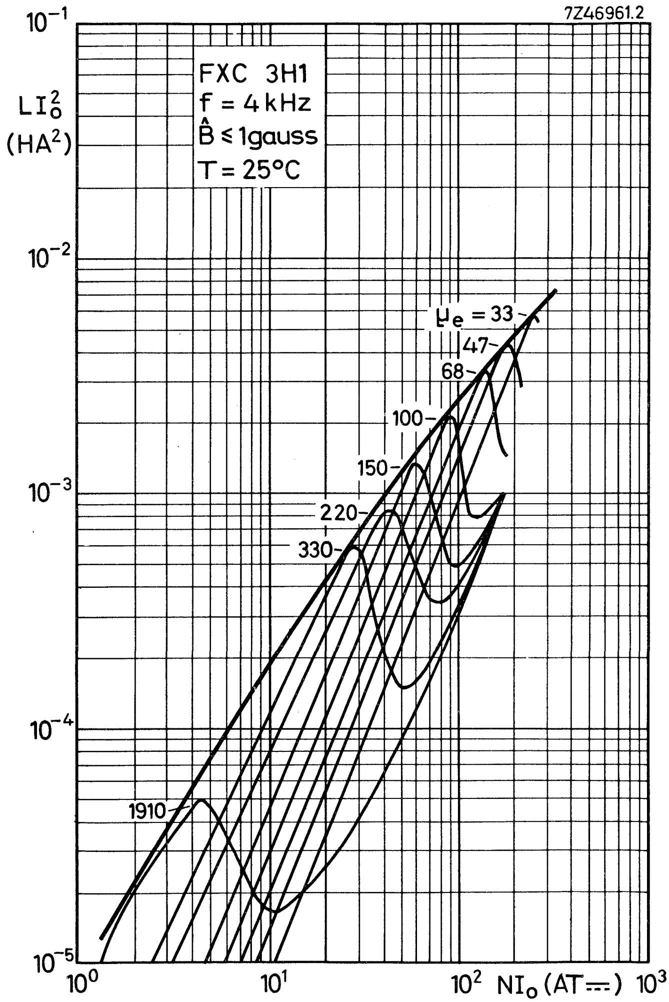



7Z46595
FXC 3D3
ΔL/L (%)
2
1.5
1
0.5
0
μe=68
μe=47
μe=33
0
5
10
15
20
25
30
AT~

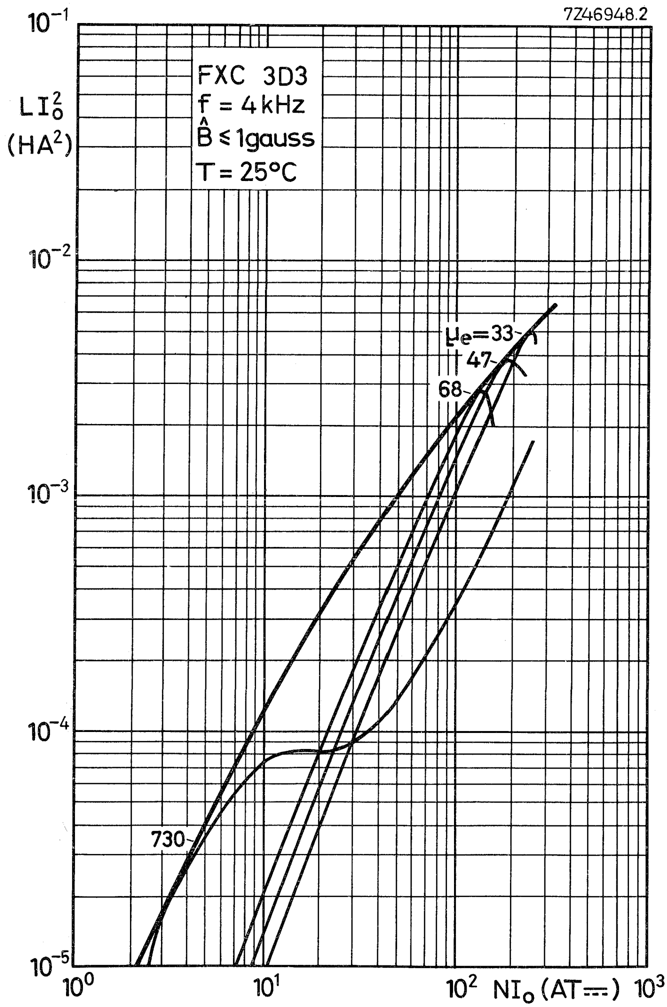

7Z46590
FXC 4C4
ΔL/L (%)
2
1.5
1
0.5
0
μe=33
μe=22
μe=15
0
5
10
15
20
25
30
AT~

HANNA CURVES

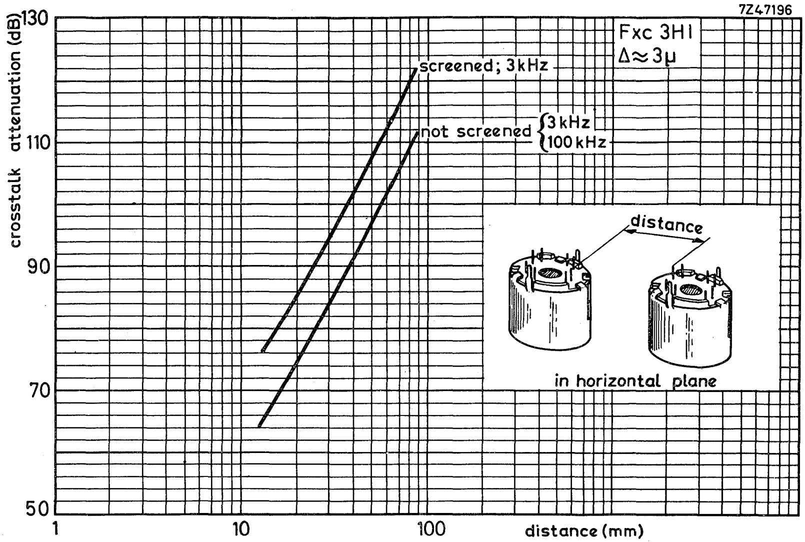
Indicating the optimum inductance for a certain μ_e-value and direct current.
Typical values

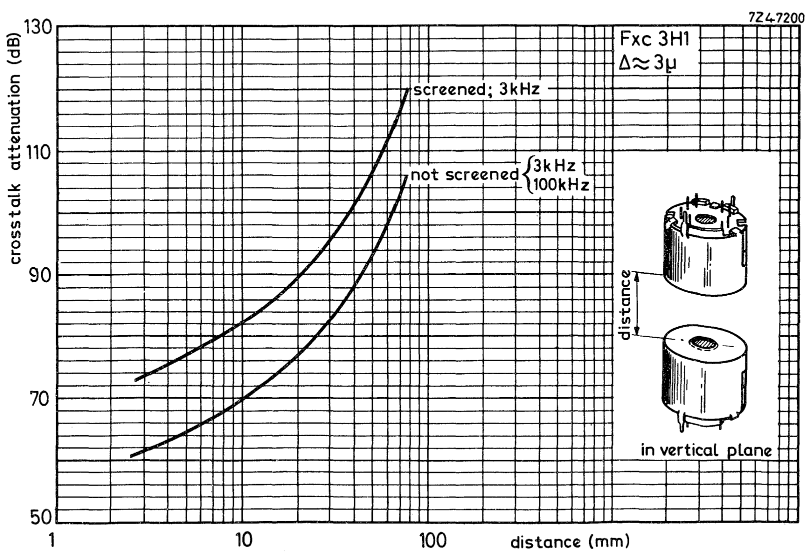


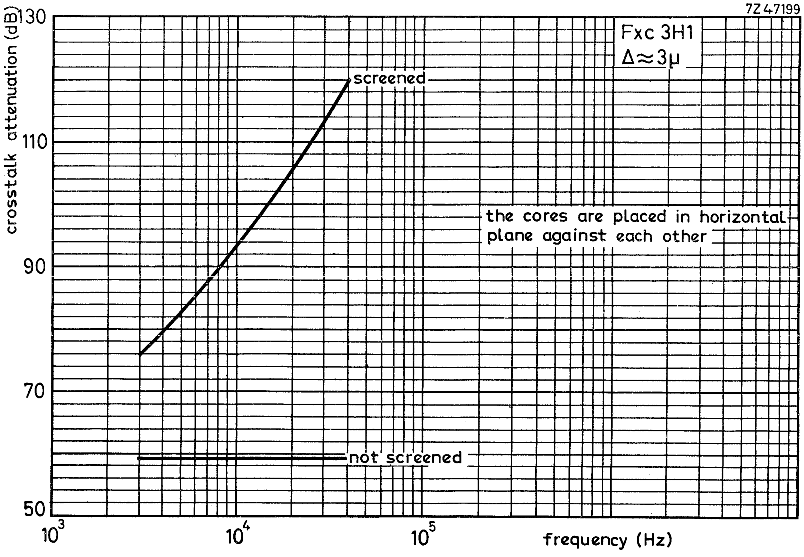
Typical values



CROSSTALK ATTENUATION






7Z47199
Fxc 3H1
Δ≈3μ
screened
not screened
the cores are placed in horizontal plane against each other
crosstalk attenuation (dB)
130
110
90
70
50
10^3
10^4
10^5
frequency (Hz)

POTCORES

INTRODUCTION

Three types of core can be supplied:

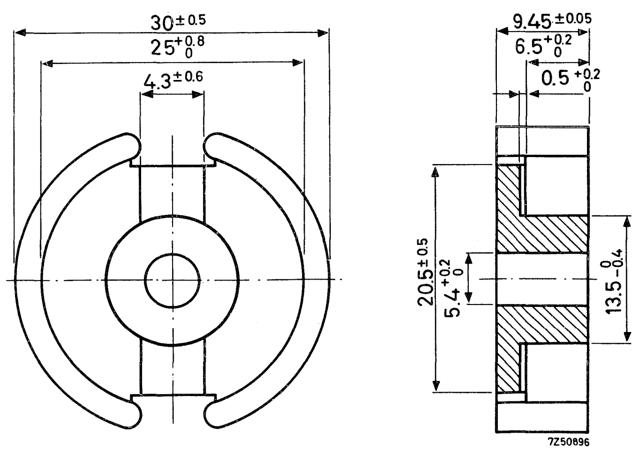
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 22250
3H1	4322 020 22260
3D3	4322 020 22270

Properties

For toroidally wound core halves the values in Table I are quaranteed.

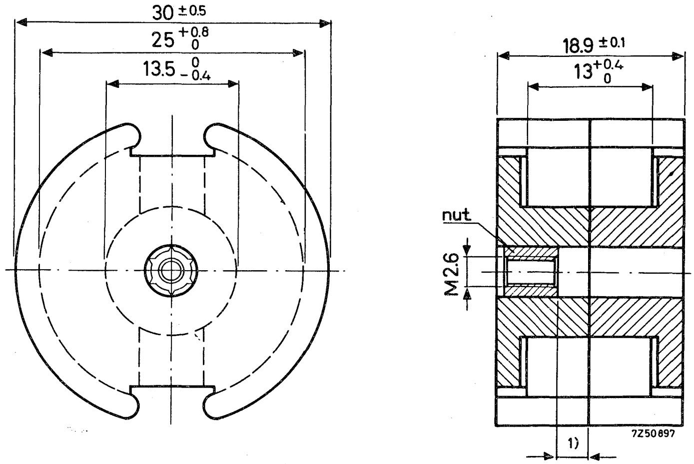
Table I	temp. (°C)	grade 3B7	3H1	3D3
T.F. x 10^6	+5 to +23 +23 to +55 +23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to +2
D.F. x 10^6 (10-100 min)	23 ± 1	≤ 4.3	≤ 4.3	≤ 12

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 250 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (kHz)	grade 3B7	3H1	3D3
μ_e	≤ 1	4	≥ 1490	≥ 1490	
	≤ 1	100	≤ 13.3	≤ 13.3	≥ 555
α	≤ 1	4			
	≤ 1	100			≤ 21.7
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	≤ 1	4	≤ 1.2	≤ 1.2	
	≤ 1	100	≤ 6	≤ 6	≤ 8
	≤ 1	500			≤ 16
	≤ 1	1000			≤ 40
$q_{2-24-100}$	15-30	4	≤ 1.8	≤ 1.8	
	3-12	100			≤ 3.0

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 3....
Without nut, catalog number = 4322 022 1....

Weight = 34 g

Effective length l_e = 4.52 cm

$\Sigma \frac{l_e}{A_e} = 3.30\ \text{cm}^{-1}$

Effective volume V_e = 6.19 cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 3 for potcores with nut, insert 1 for potcores without nut.
   Examples of catalog number:
   μ_e = 33, grade 3D3, potcore with nut, catalog number = 4322 022 30430
   A_L = 400, grade 3B7, potcore without nut, catalog number = 4322 022 11080
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

[1]) For this distance see adjustment curves under Inductance Adjustment.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022		
			3B7	3H1	3D3
33	89.2	± 1	–	.0230	.0430
47	74.7	± 1	–	–	.0440
68	62.1	± 1	.0050	.0250	.0450
100	51.3	± 1.5	.0060	.0260	–
150	41.8	± 2	.0070	.0270	–
220	34.6	± 3	.0080	.0280	–
330	28.2	± 3	.0090	.0290	–
740	18.9	± 25	–	–	10400
1990	11.5	± 25	10000	10200	–

Number of turns $N = \alpha \sqrt{L}$ (L in 10^{-3} H)

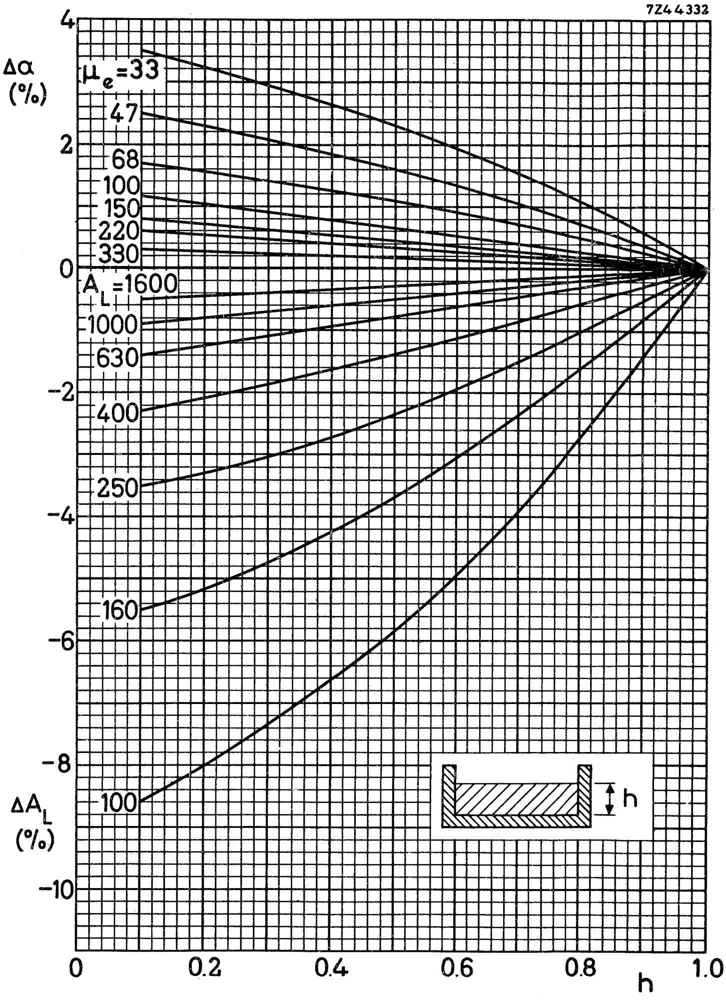
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022		
			3B7	3H1	3D3
100	26.2	± 1	–	–	.1440
160	42	± 1	–	–	.1450
250	65.5	± 1	.1060	.1260	.1460
400	105	± 1.5	.1080	.1280	–
630	165	± 2	.1100	.1300	–
1000	263	± 3	.1110	.1310	–
1600	420	± 3	.1120	.1320	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See notes on the previous page.

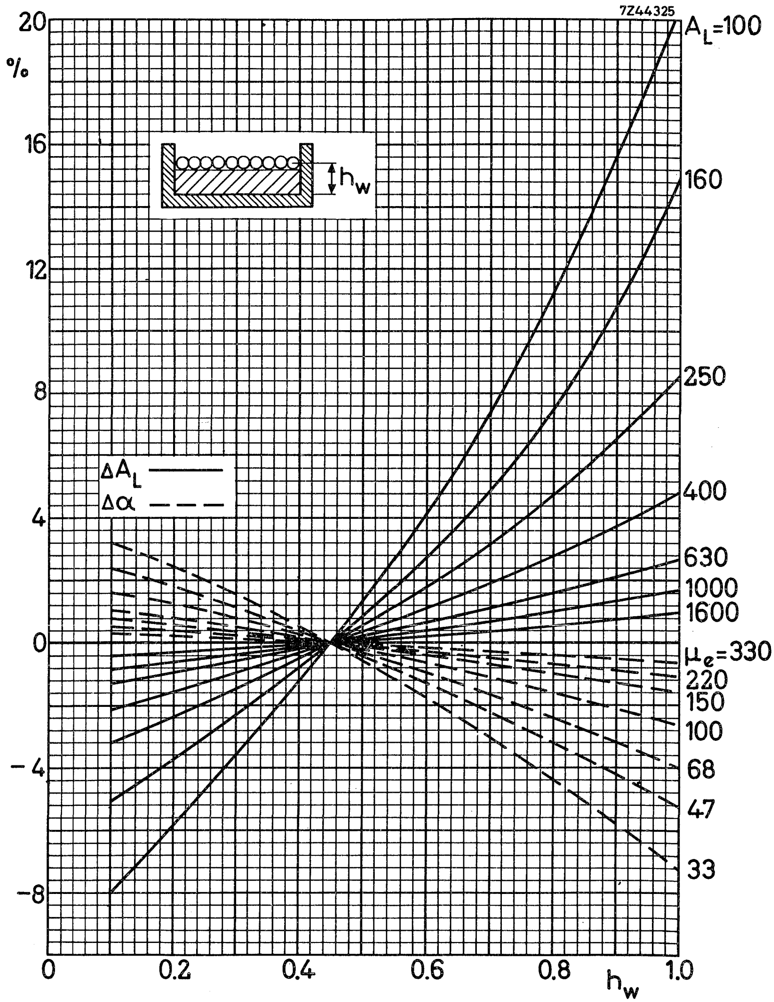
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 62.1 + 1.25%.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_W on a single-section coil former.
Valid for ferroxcube 3B7, 3H1 and 3D3.
Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 62.1 - 1.6%.

COIL FORMERS

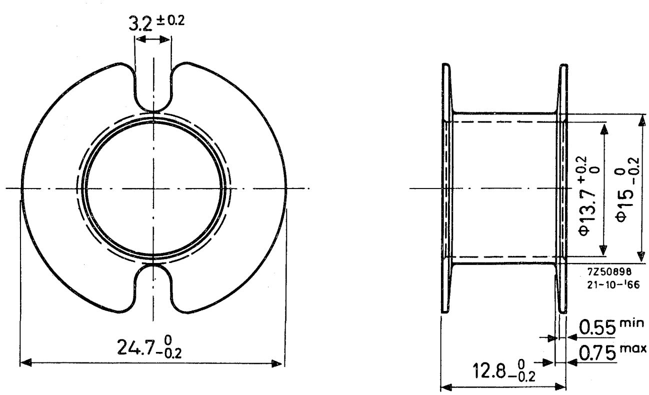
GENERAL

Three types of coil former can be supplied:

- with one section
- with two sections
- with three sections

The dimensions conform with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



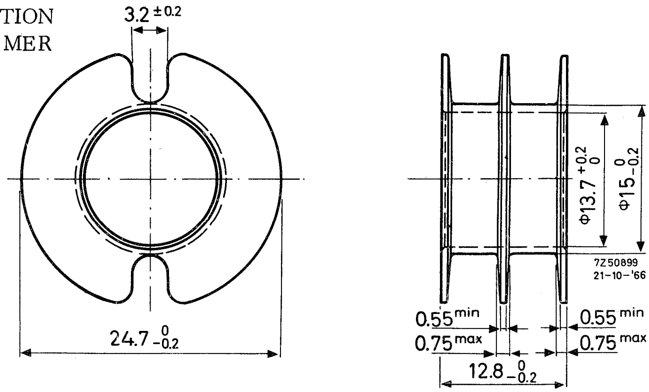
Catalog number	4322 021 30360
Material	polycarbonate K486
Window area	55 mm^2
Mean length of turn	6.2 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 5.07 \times 10^3 \quad \Omega/H$$

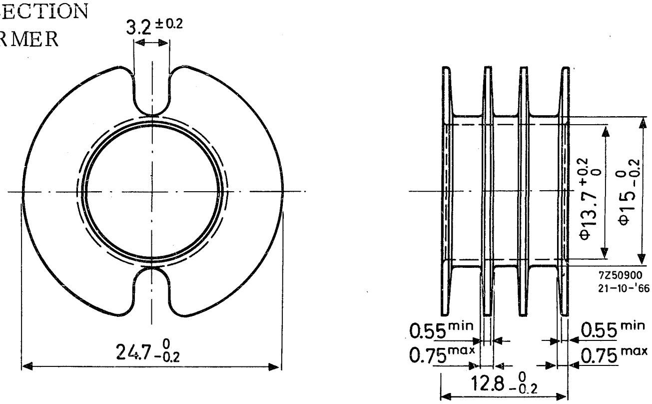
Weight 0.75 g

TWO-SECTION COIL FORMER



Catalog number	4322 021 30370		D.C. losses	
Material	polycarbonate K486		$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 5.38 \times 10^3$ Ω/H	
Window area	2 x 26 mm^2			
Mean length of turn	6.2 cm			
Max. temperature	130 °C		Weight	1.0 g

THREE-SECTION COIL FORMER



Catalog number	4322 021 30380		D.C. losses	
Material	polycarbonate K486		$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 5.74 \times 10^3$ Ω/H	
Window area	3 x 16 mm^2			
Mean length of turn	6.2 cm			
Max. temperature	130 °C		Weight	1.2 g

INDUCTANCE ADJUSTMENT

CONTINUOUS ADJUSTORS

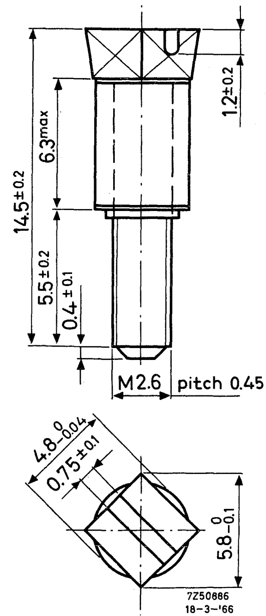


Fig.A

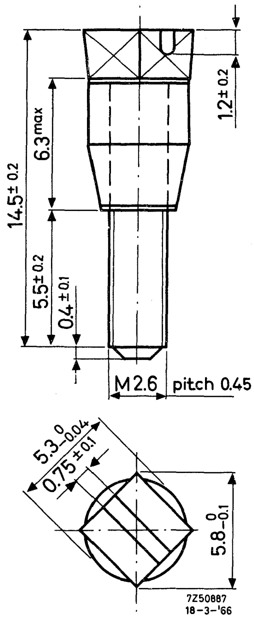


Fig.B

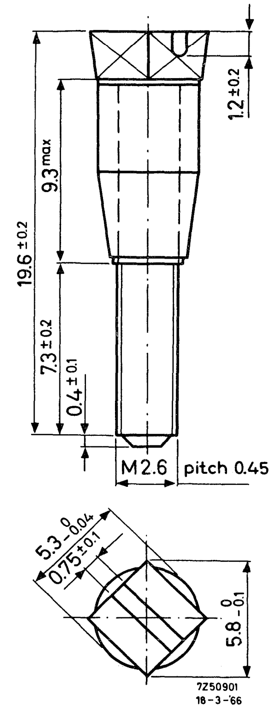


Fig.C

The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.03 % by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.

The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.

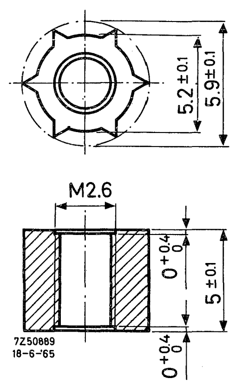
The influence of the adjustors on the variability of the inductance is negligible. The maximum permissible temperature is 110 °C.

Available types and recommended applications.

Fig.	Colour	catalog number 4322 021	potcore	
			μ_e	A_L
A	green	30780	33	100
A	red	30800	47	160
B	white	30980	68	250
B	white	30980	100	400
A	brown	30810	150	630
B	grey	31090	220	1000
C	black	31120	330	1600

NUT FOR ADJUSTOR

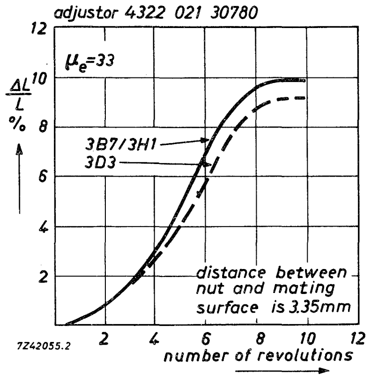
These data are given for those manufacturers who prefer to insert the nut themselves.

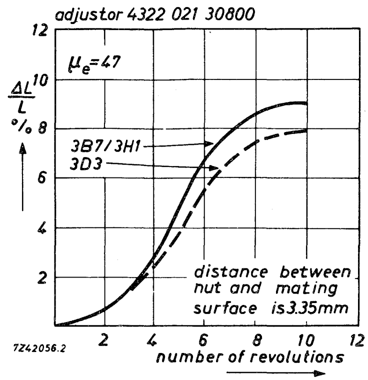


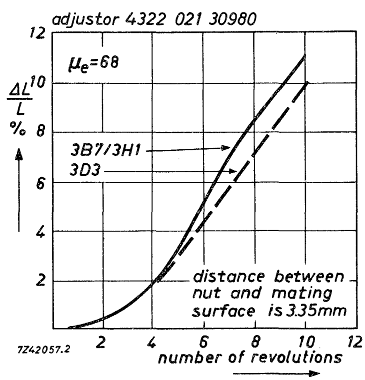
Catalog number	4322 021 30160
Material	polycarbonate
Max. impregnation temperature during 24 hours	120 °C
Recommended distance from mating surface to nut (see Adjustment curves)	3.35 ± 0.15 mm or 4.35 ± 0.15 mm

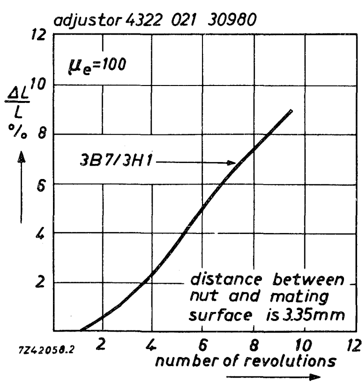
For more information see Potcores General, Mounting data.

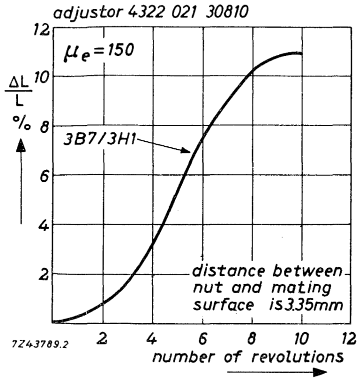
ADJUSTMENT CURVES

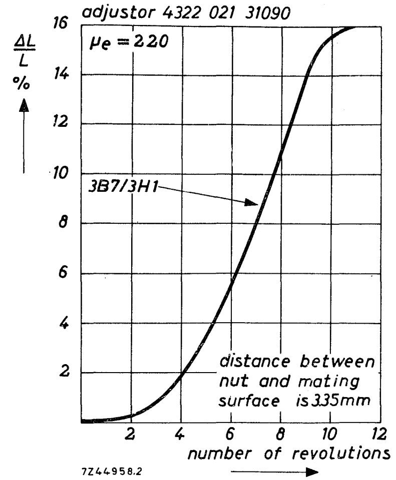


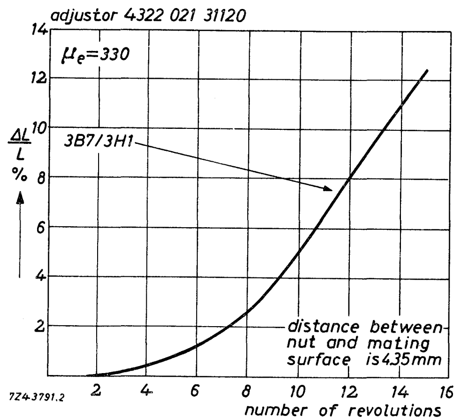







adjustor 4322 021 30810
μ_e=150
ΔL/L %
3B7/3H1
distance between nut and mating surface is 3.35mm
number of revolutions
7Z43789.2

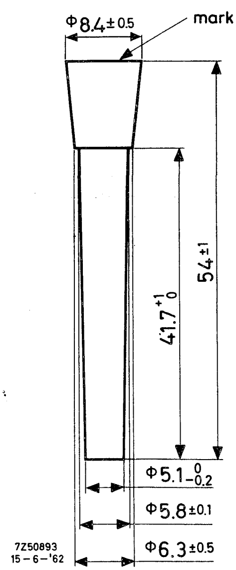

adjustor 4322 021 31090
μ_e=220
ΔL/L %
3B7/3H1
distance between nut and mating surface is 3.35mm
number of revolutions
7Z44958.2

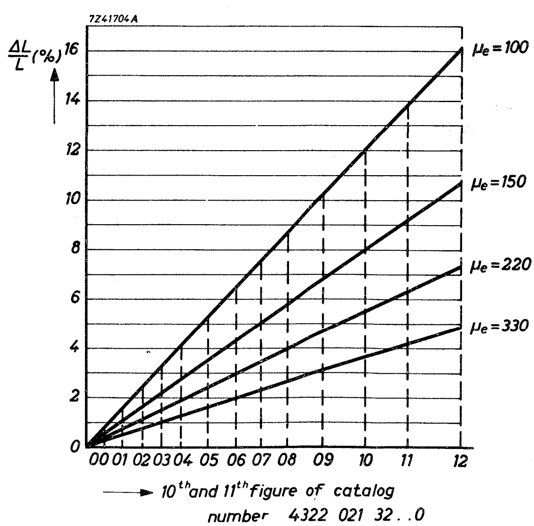

adjustor 4322 021 31120
μ_e=330
ΔL/L %
3B7/3H1
distance between nut and mating surface is 4.35mm
number of revolutions
7Z43791.2

STEP-BY-STEP ADJUSTORS

These adjustors are used when a continuous adjustment of the inductance is not necessary. For instance, they are applied in loading coils to bring the inductance within a certain tolerance field. They are not suitable for adjusting the inductance to an exact value, as is usually necessary in filters. The increment of the losses caused by these adjustors is negligible.
A range of 13 flexible conical adjustors is available under the catalog numbers 4322 021 32000 up to 021 32120. Each adjustor causes an increase in the inductance; the higher the catalog number, the greater the effect. The influence of each adjustor on the inductance at different μ_e values of the potcore can be found from the graph.
The 10th and 11th figure of the catalog number are indicated on the head of the adjustor. It should be borne in mind that, when using these adjustors, the inductance of the coil should initially be lower than the wanted value.
When the correct adjustor has been found, it is inserted in the centre hole of the pot. An adhesive (for instance Pliobond of Good Year) is used as sliding and fixing material. After fixing the protruding ends are cut off.

The maximum impregnation temperature is 150 °C.
The maximum working temperature is 90 °C.
Material: rubber with powder iron.

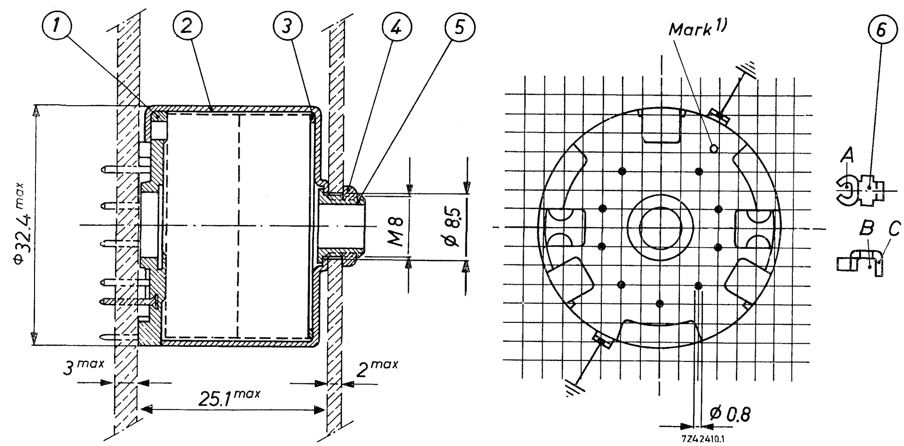




Dimensions in mm

MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30480	(4) nut	4322 021 30710
(2) brass container	4322 021 30560	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30670	(6) soldering spring	4322 021 30700 (9x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin: then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The nine soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1.3 ± 0.1 mm diameter.

---

1) There is another mark in a similar position on the top of the container.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

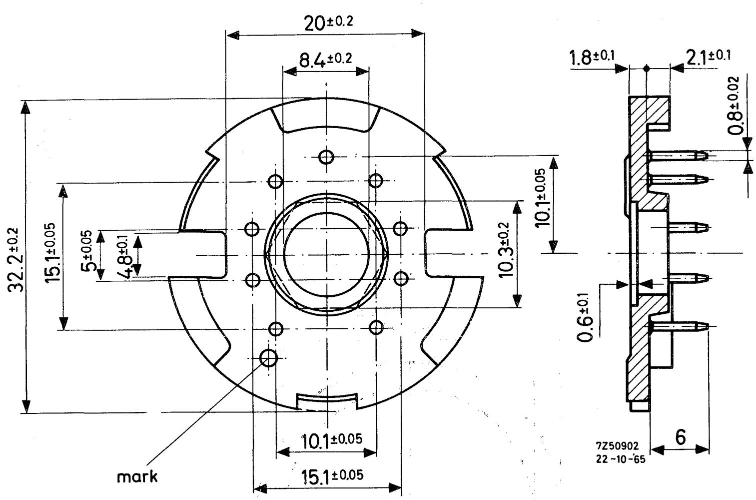
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 250 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

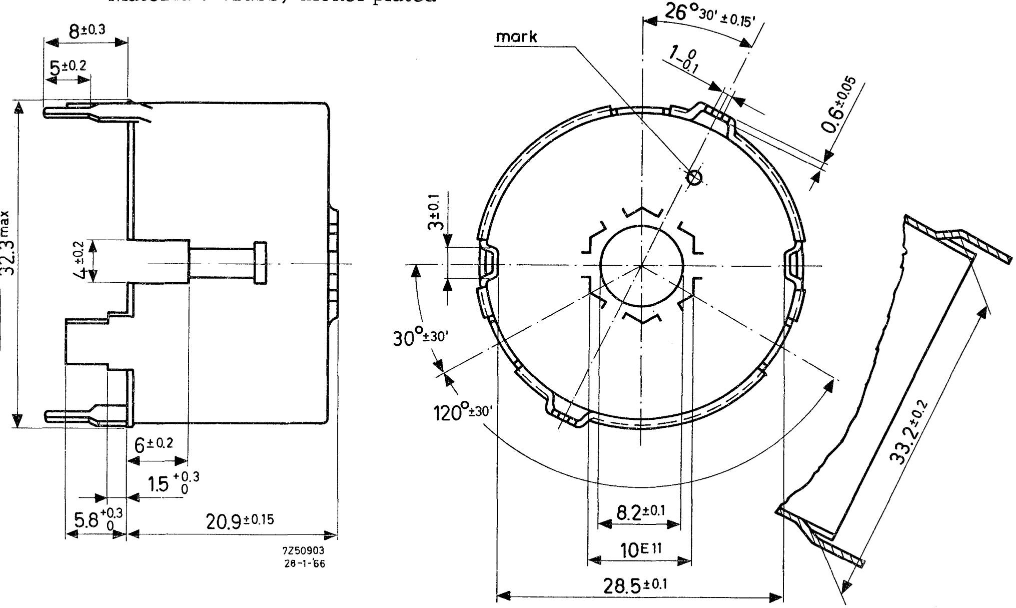
(1) Tag plate 4322 021 30480

Plate: reinforced polyester
Pins : phosphorbronze, dipsoldered



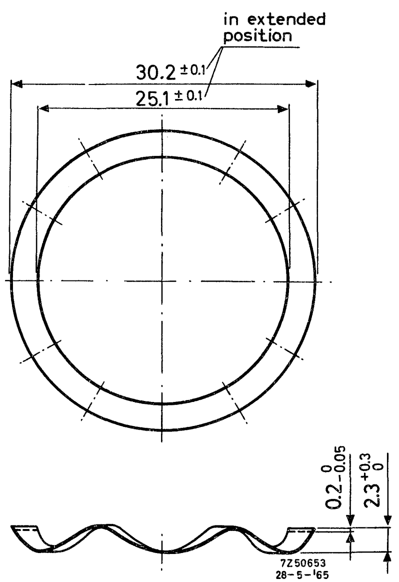
(2) Container 4322 021 30560

Material: brass, nickel plated



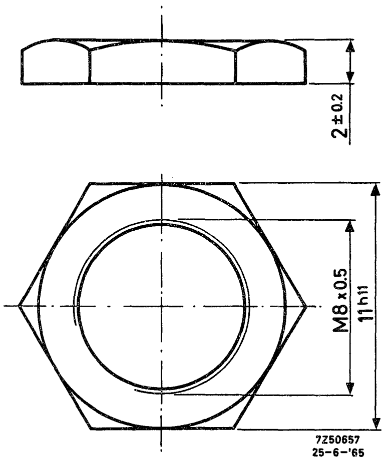
(3) Spring 4322 021 30670

Material: steel



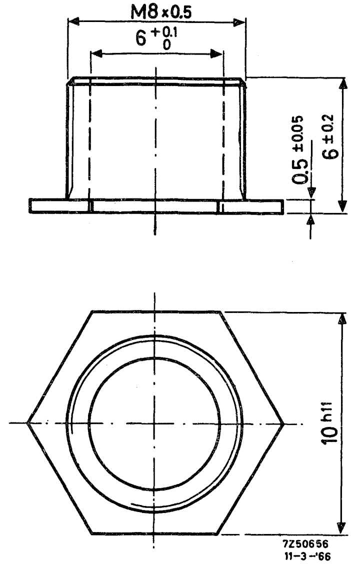
(4) Nut 4322 021 30710

Material: brass, nickel plated



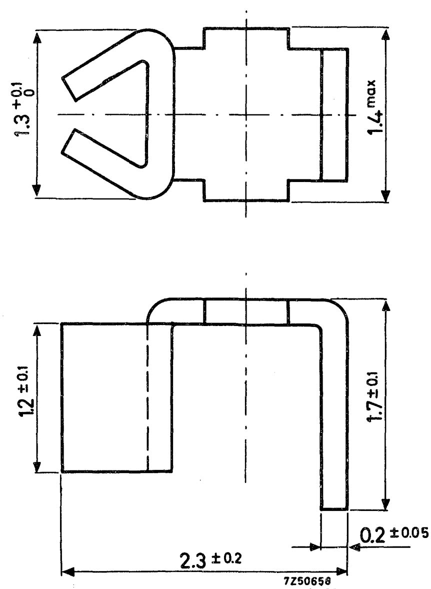
(5) Fixing bush 4322 021 30720

Material: aluminium



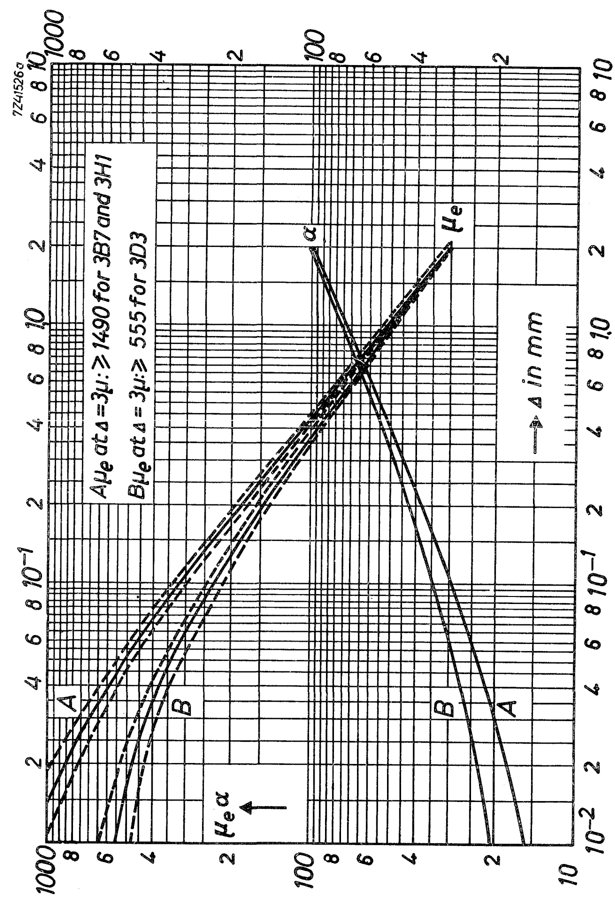
(6) Soldering spring 4322 021 30700

Material: brass, dipsoldered



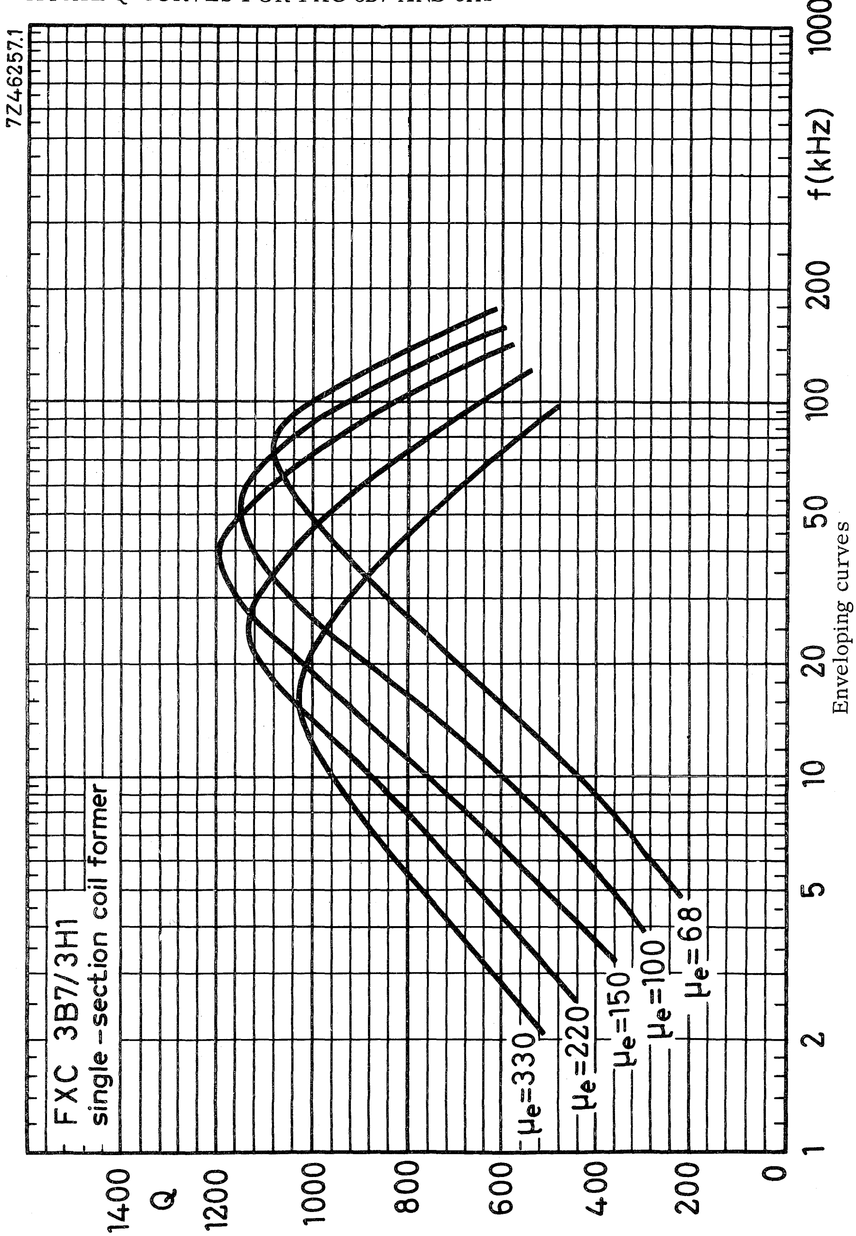
CHARACTERISTIC CURVES

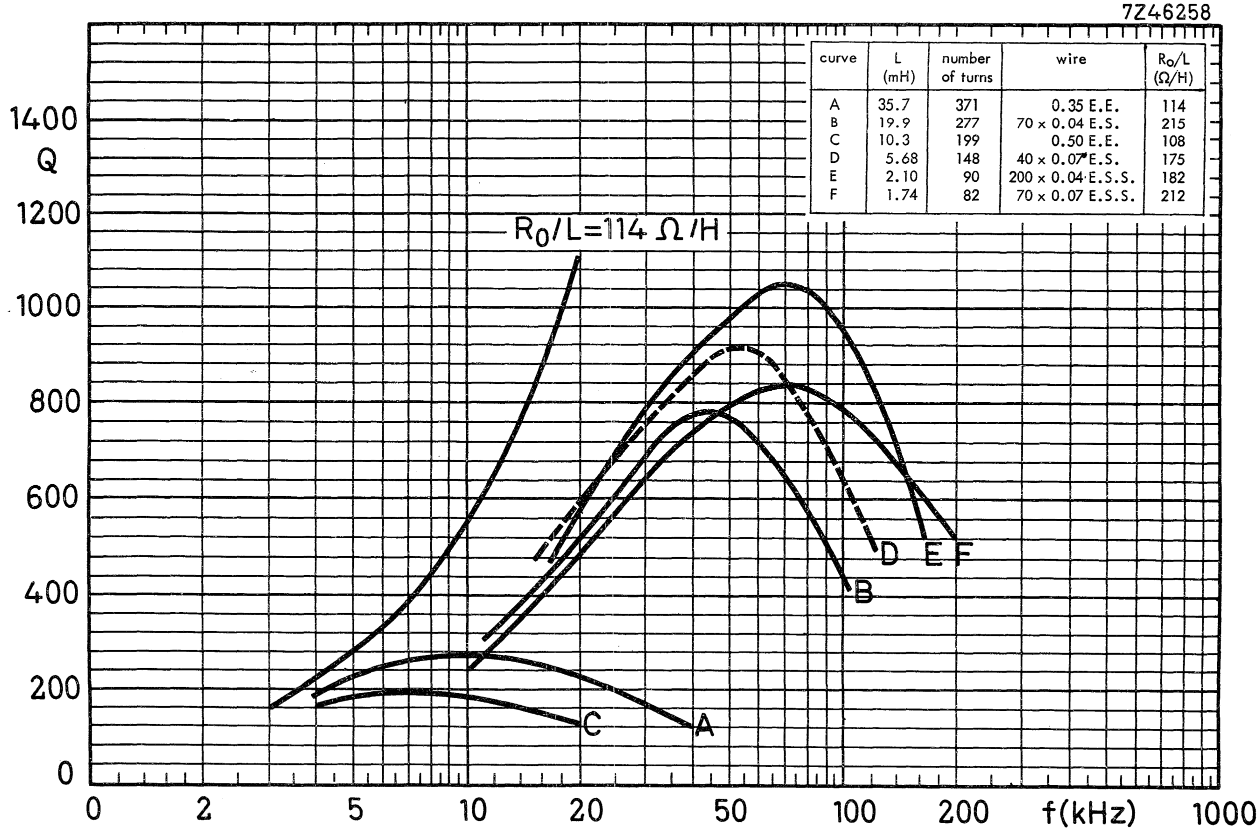
μ_e-α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length.

TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1

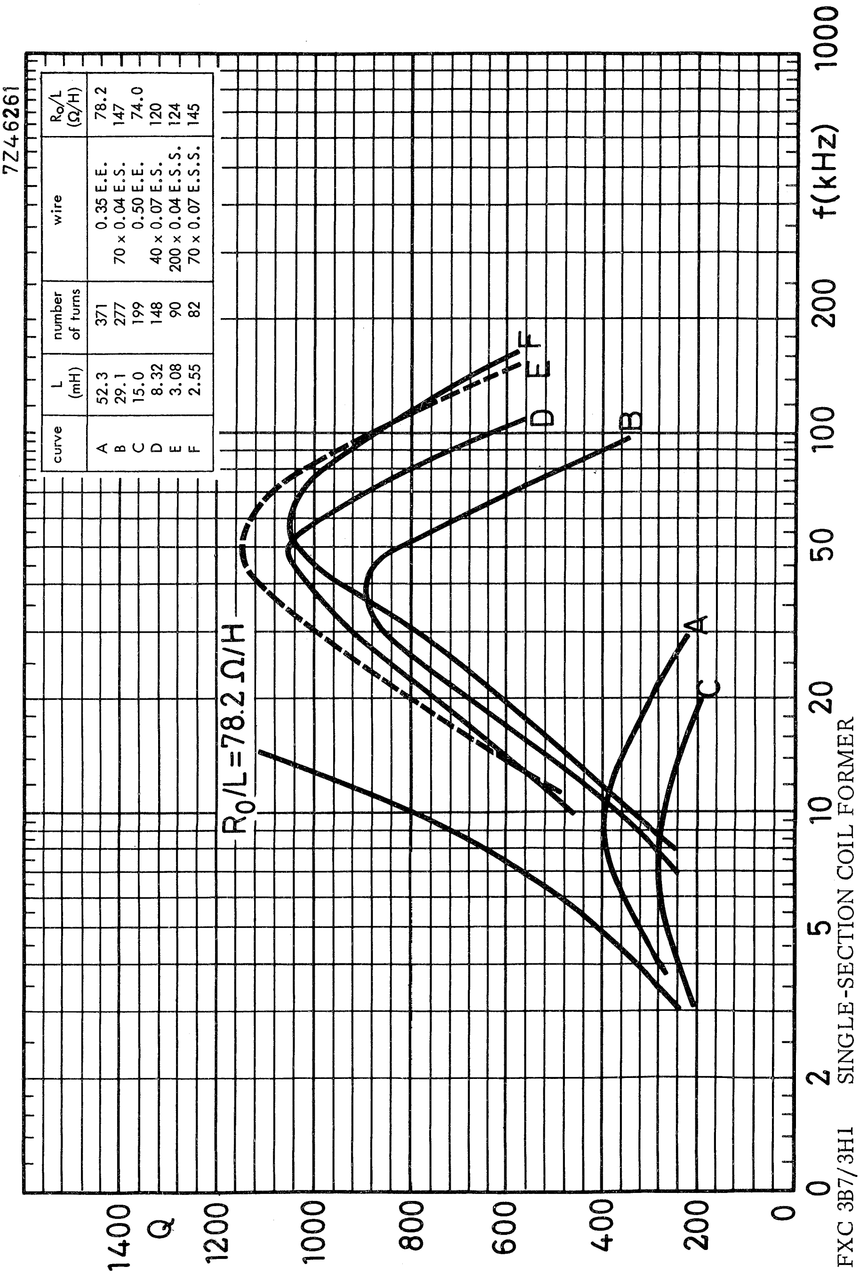




curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	35.7	371	0.35 E.E.	114
B	19.9	277	70 × 0.04 E.S.	215
C	10.3	199	0.50 E.E.	108
D	5.68	148	40 × 0.07 E.S.	175
E	2.10	90	200 × 0.04 E.S.S.	182
F	1.74	82	70 × 0.07 E.S.S.	212

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

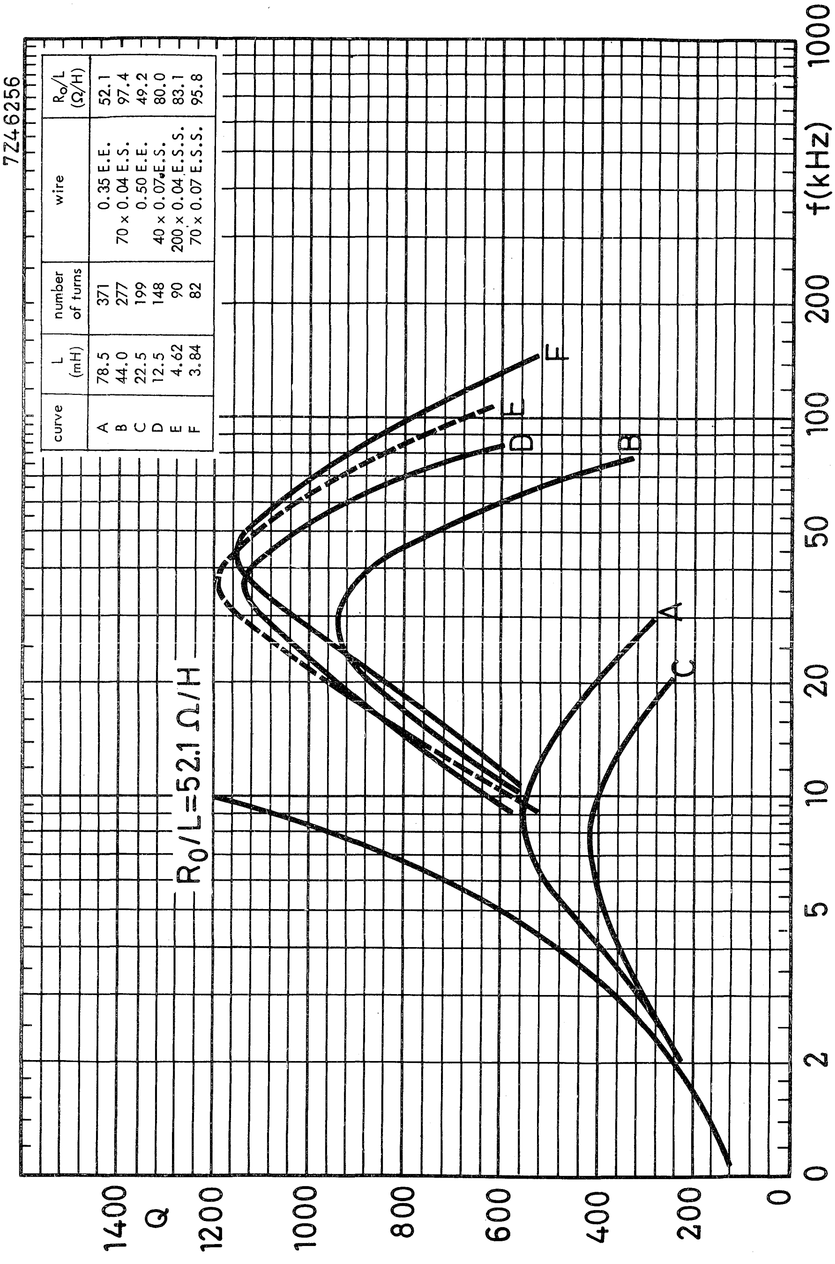
$\mu_e = 68$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	52.3	371	0.35 E.E.	78.2
B	29.1	277	70 × 0.04 E.S.	147
C	15.0	199	0.50 E.E.	74.0
D	8.32	148	40 × 0.07 E.S.	120
E	3.08	90	200 × 0.04 E.S.S.	124
F	2.55	82	70 × 0.07 E.S.S.	145

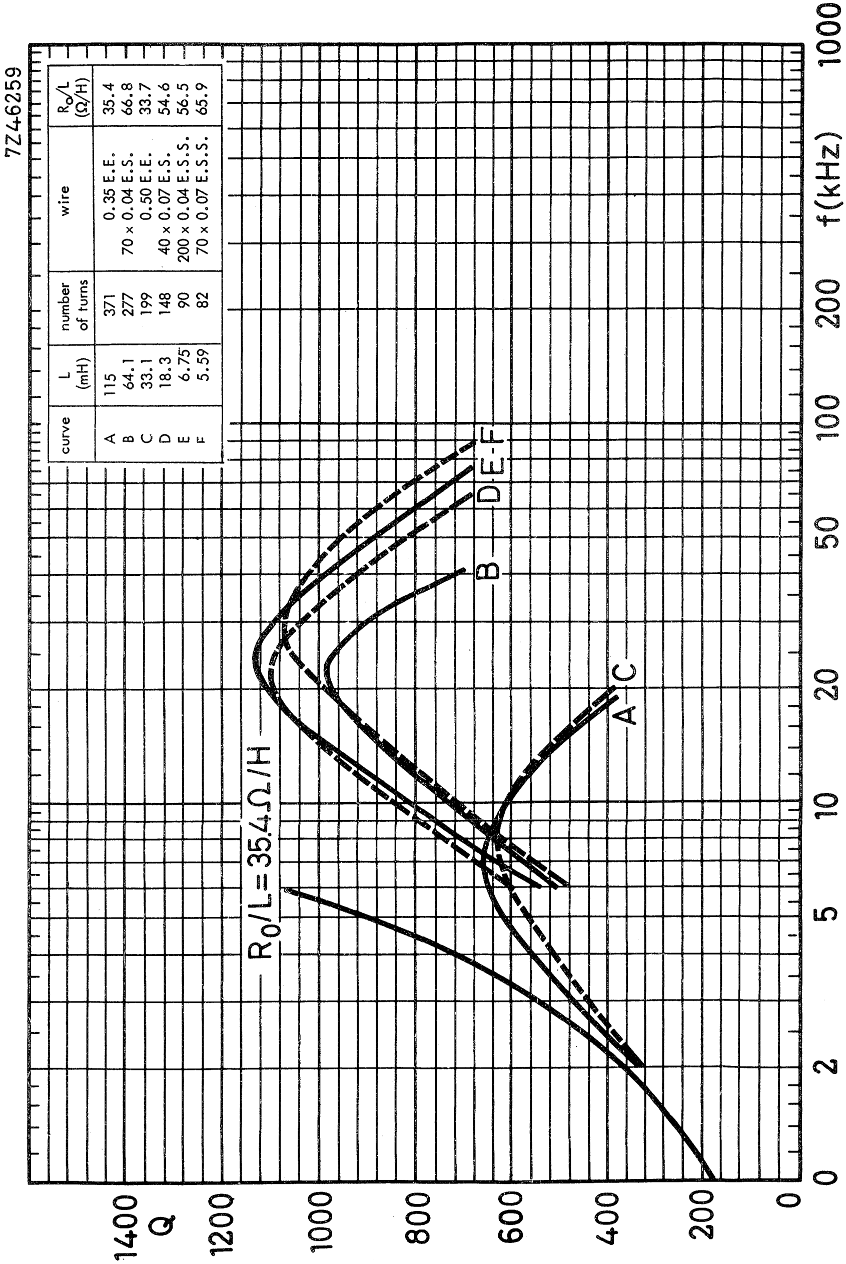
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

$\mu_e = 100$



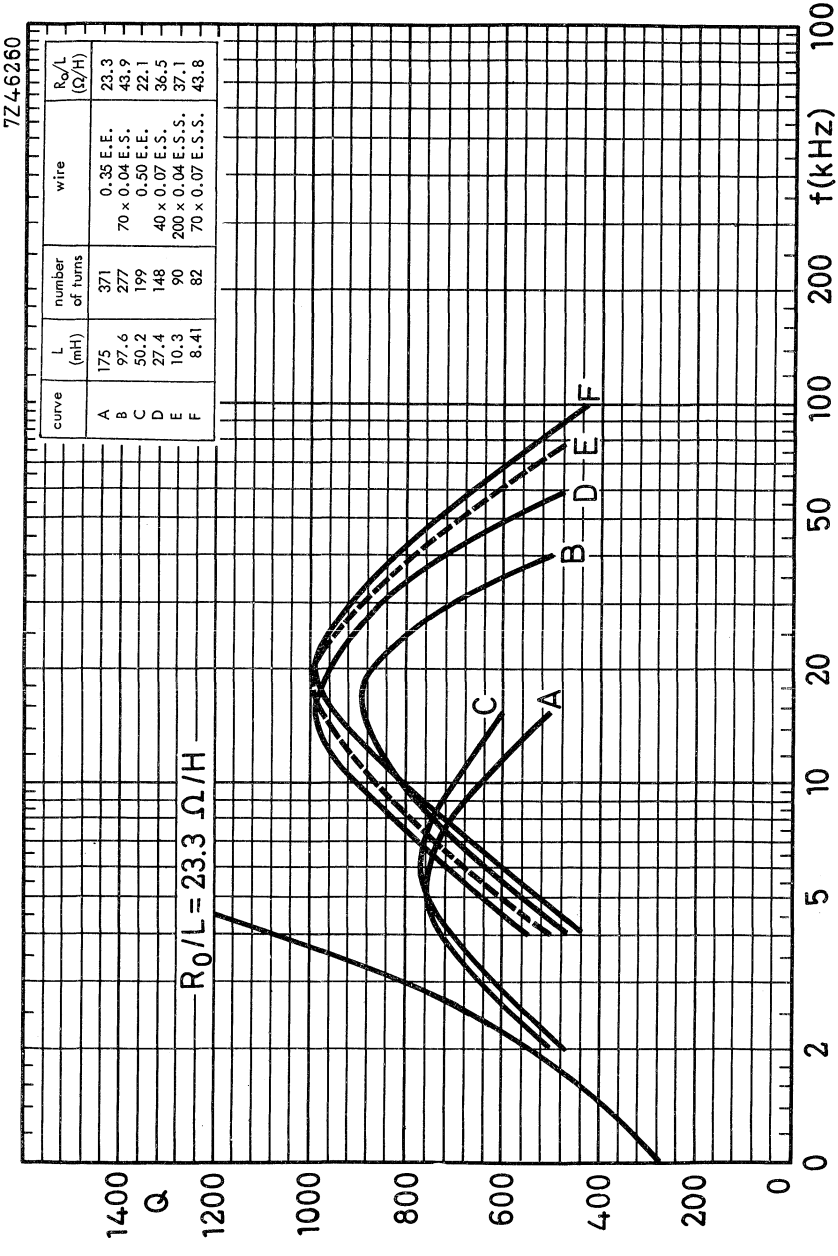
curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	78.5	371	0.35 E.E.	52.1
B	44.0	277	70 × 0.04 E.S.	97.4
C	22.5	199	0.50 E.E.	49.2
D	12.5	148	40 × 0.07 E.S.	80.0
E	4.62	90	200 × 0.04 E.S.S.	83.1
F	3.84	82	70 × 0.07 E.S.S.	95.8

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 150$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	115	371	0.35 E.E.	35.4
B	64.1	277	70 × 0.04 E.S.	66.8
C	33.1	199	0.50 E.E.	33.7
D	18.3	148	40 × 0.07 E.S.	54.6
E	6.75	90	200 × 0.04 E.S.S.	56.5
F	5.59	82	70 × 0.07 E.S.S.	65.9

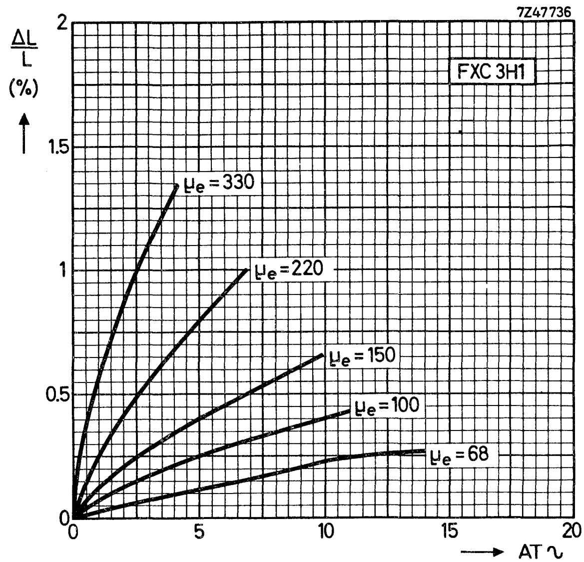
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 220$

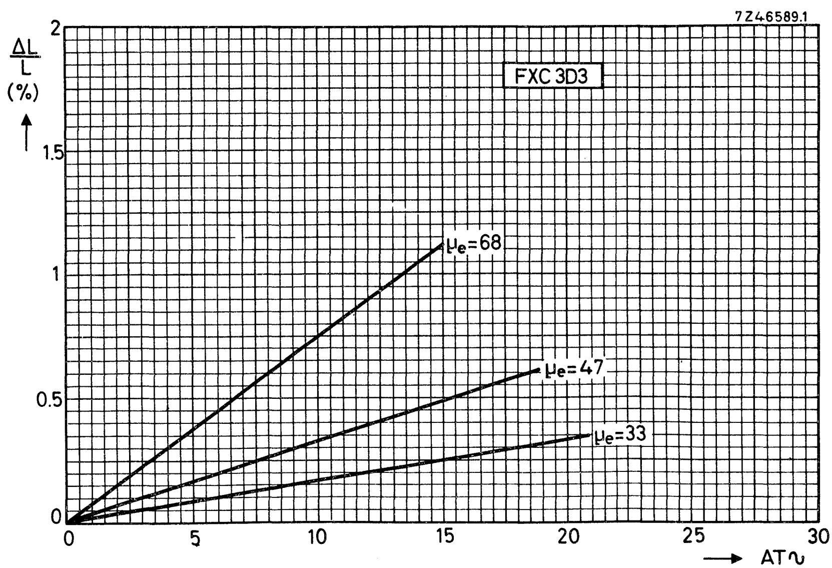


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	175	371	0.35 E.E.	23.3
B	97.6	277	70 × 0.04 E.S.	43.9
C	50.2	199	0.50 E.E.	22.1
D	27.4	148	40 × 0.07 E.S.	36.5
E	10.3	90	200 × 0.04 E.S.S.	37.1
F	8.41	82	70 × 0.07 E.S.S.	43.8

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 330$

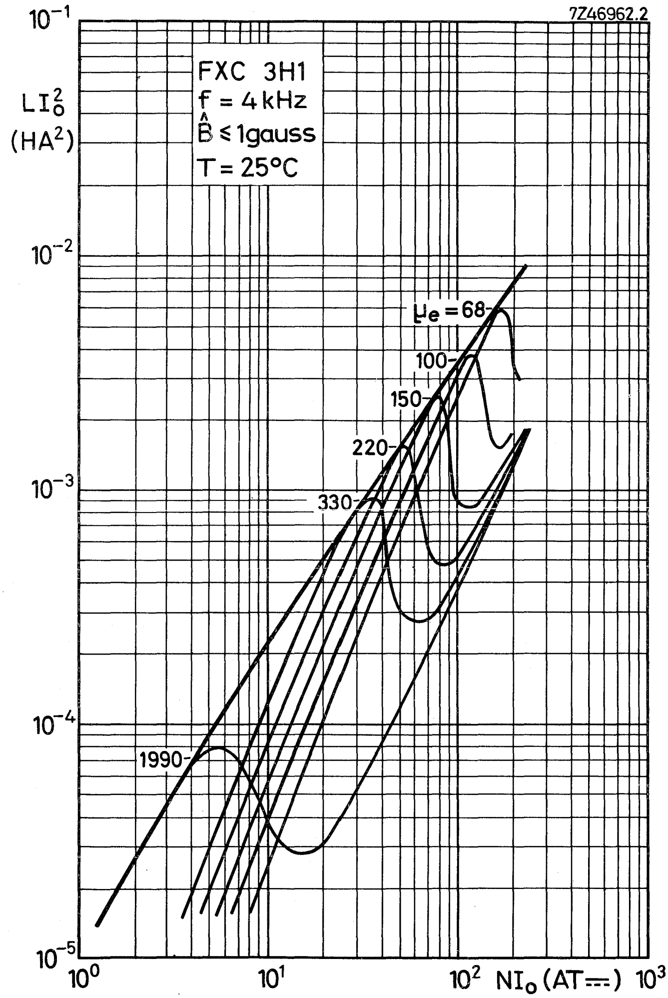
INDUCTANCE VARIATION AS A FUNCTION OF AT~



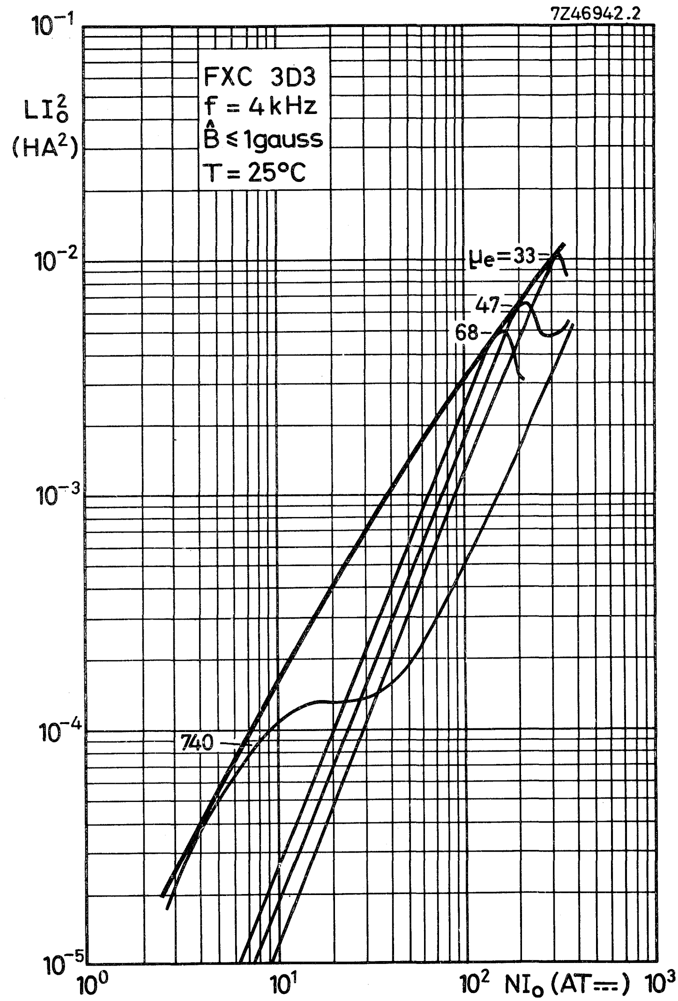


HANNA CURVES

Indicating the optium inductance for a certain μ_e-value and direct current.
Typical values.



Typical values



POTCORES

INTRODUCTION

Three types of core can be supplied:

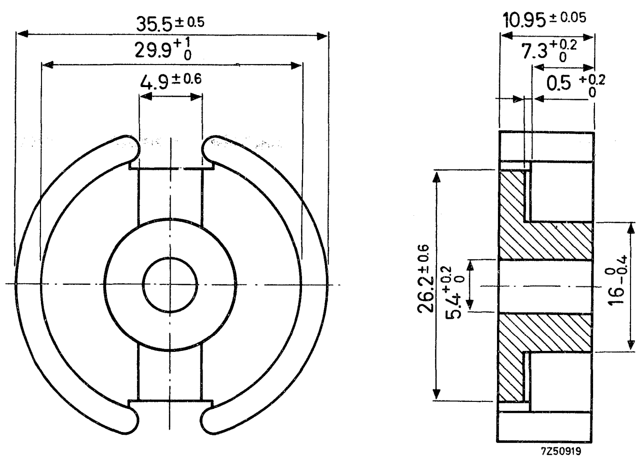
- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E_6 range of values or an A_L factor in the R_5 range.
- Pre-adjusted potcores without nut.

The dimensions of the potcores are in accordance with the following specifications: I.E.C. 133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 293 (Germany).

Potcores and associated parts are ordered by their 12-digit catalog number.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B7	4322 020 22500
3H1	4322 020 22510
3D3	4322 020 22520

Properties

For toroidally wound core halves the values in Table I are guaranteed.

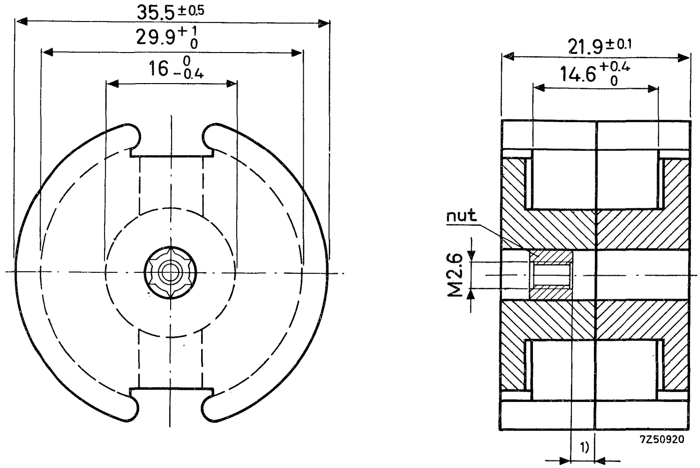
Table I	temp. (°C)	grade		
		3B7	3H1	3D3
T.F. x 10^6	+5 to +23	–	–	–
	+23 to +55	–	–	–
	+23 to +70	−0.6 to +0.6	+0.6 to +1.8	0 to +2
D.F. x 10^6 (10-100 min)	23 ± 1	≤4.3	≤4.3	≤12

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 350 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (kHz)	grade		
			3B7	3H1	3D3
μ_e	≤ 1	4	≥ 1520	≥ 1520	
	≤ 1	100			≥ 560
α	≤ 1	4	≤ 11.7	≤ 11.7	
	≤ 1	100			≤ 19.3
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	≤ 1	4	≤ 1.2	≤ 1.2	
	≤ 1	100	≤ 6	≤ 6	≤ 8
	≤ 1	500			≤ 18
	≤ 1	1000			≤ 45
$q_{2\text{-}24\text{-}100}$	15 - 30	4	≤ 1.8	≤ 1.8	
	3 - 12	100			≤ 3.0

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 3....
Without nut, catalog number = 4322 022 1....

Weight		=	74 g
Effective length	l_e	=	5.32 cm
	$\Sigma \frac{l_e}{A_e}$	=	2.64 cm^{-1}
Effective volume	V_e	=	10.7 cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 3 for potcores with nut, insert 1 for potcores without nut.
   Examples of catalog number:
   μ_e = 33, grade 3D3, potcore with nut, catalog number = 4322 022 32430
   A_L = 1600, grade 3B7, potcore without nut, catalog number = 4322 022 13120
2. The inductance will only be within the given tolerance if the winding space of the coil former is completely filled.

1) See Adjustment curves.

Potcores with standard μ_e values [1]

μ_e	α	tolerance on inductance (%)	catalog number 4322 022		
			3B7	3H1	3D3
33	79.7	± 1	–	–	.2430
47	66.8	± 1	–	–	.2440
68	55.6	± 1	.2050	.2250	.2450
100	45.8	± 1.5	.2060	.2260	–
150	37.4	± 2	.2070	.2270	–
220	30.9	± 3	.2080	.2280	–
330	25.2	± 25	.2090	.2290	–
750	16.7	± 25	–	–	12400
2030	10.2	± 25	12000	12200	–

Number of turns $N = \alpha \sqrt{L}$ (L in 10^{-3} H)

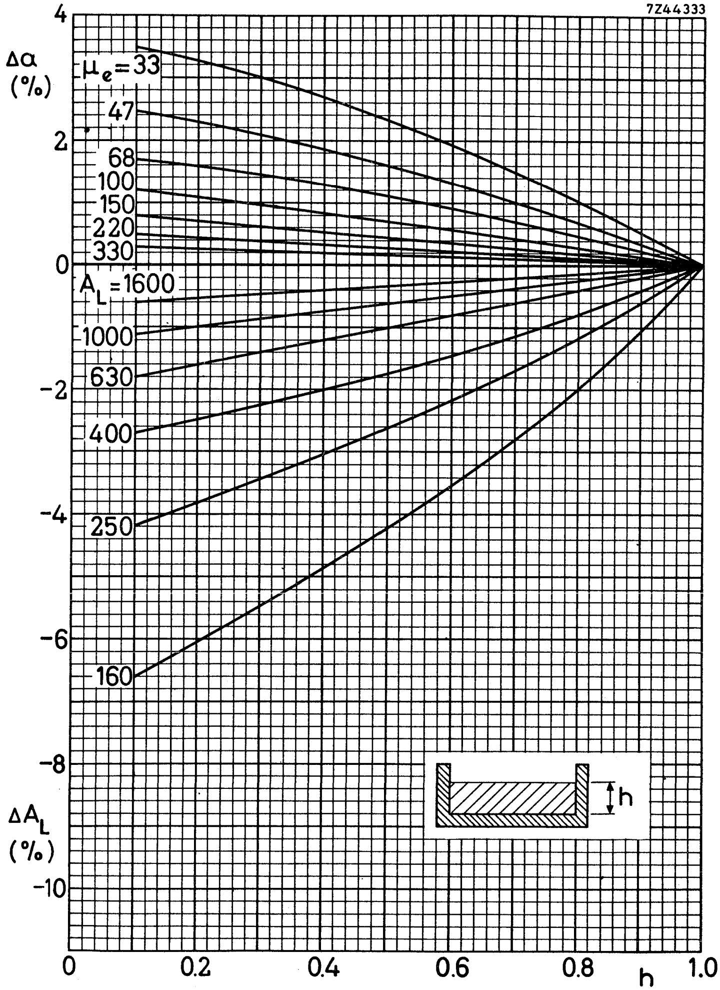
Potcores with standard A_L factors [1]

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 022		
			3B7	3H1	3D3
40	8.39	± 1	.3020	–	–
100	21	± 1	.3040	–	–
160	33.6	± 1	–	–	.3450
250	52.5	± 1	.3060	.3260	.3460
400	84	± 1.5	.3080	.3280	.3480
630	132	± 2	.3100	.3300	–
1000	210	± 3	.3110	.3310	–
1600	336	± 3	.3120	.3320	–

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

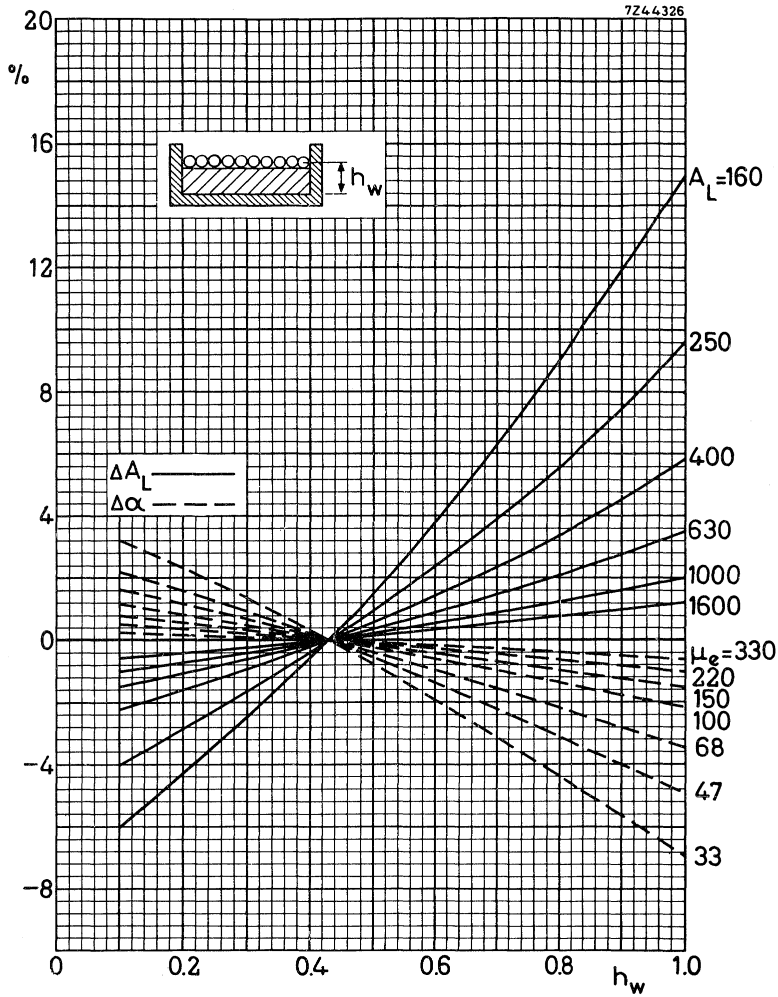
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 68 in that case obtains an α factor of 55.6 + 1.20 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_w on a single-section coil former.

Valid for ferroxcube 3B7, 3H1 and 3D3.

Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 68 obtains for that winding an α factor of 55.6 - 1.6 %.

COIL FORMERS

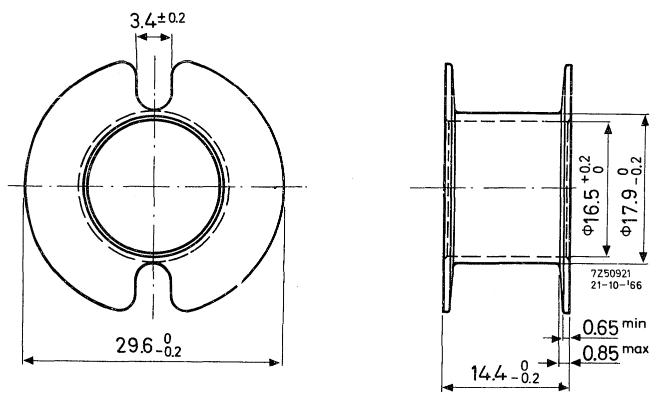
GENERAL

Three types of coil former can be supplied:

- with one section
- with two sections
- with three sections

The dimensions conform with the following specifications: I.E.C.133 (international), C.C.T.U. 06-02 (France) and D.I.N. 41 294 (Germany).
The dimensions in the drawings are in mm.

SINGLE-SECTION COIL FORMER



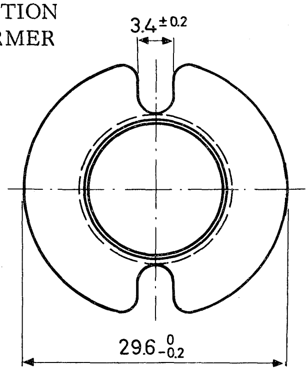
Catalog number	4322 021 30390
Material	polycarbonate K486
Window area	75 mm^2
Mean length of turn	7.4 cm
Max. temperature	130 °C

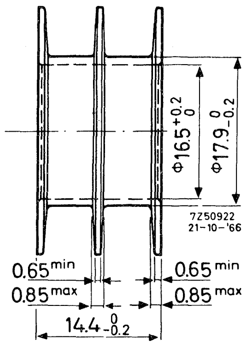
D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 3.59 \times 10^3 \ \Omega/H$$

Weight 1.2 g

TWO-SECTION
COIL FORMER





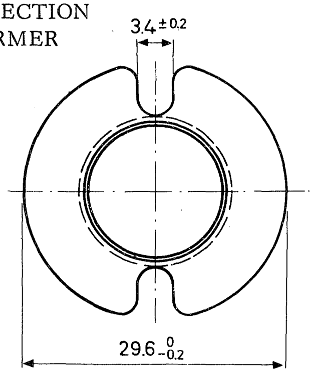
Catalog number	4322 021 30400
Material	polycarbonate K486
Window area	2 x 35 mm^2
Mean length of turn	7.4 cm
Max. temperature	130 °C

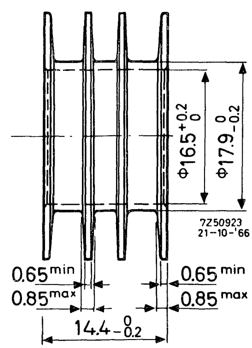
D.C. losses

$$\frac{R_0}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 3.81 \times 10^3 \quad \Omega/H$$

Weight 1.55 g

THREE-SECTION
COIL FORMER





Catalog number	4322 021 30410
Material	polycarbonate K486
Window area	3 x 22 mm^2
Mean length of turn	7.4 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_0}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 4.06 \times 10^3 \quad \Omega/H$$

Weight 1.8 g

INDUCTANCE ADJUSTMENT

CONTINUOUS ADJUSTORS

The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.03 % by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.
The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.
The influence of the adjustors on the variability of the inductance is negligible.
The maximum permissible temperature is 110 °C.

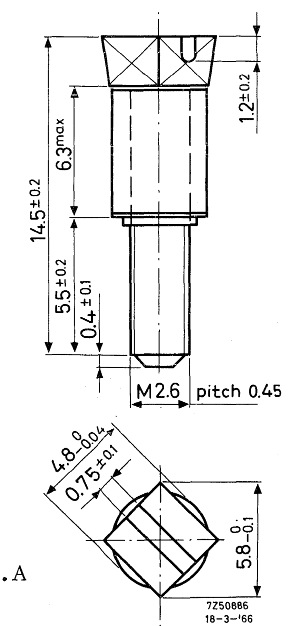


Fig.A

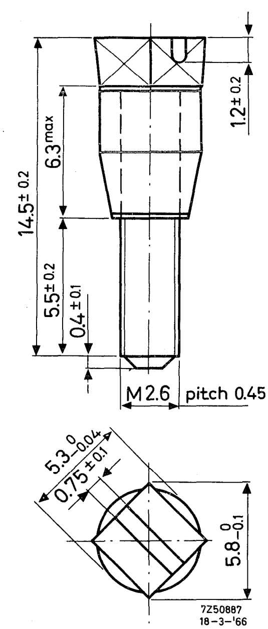


Fig.B

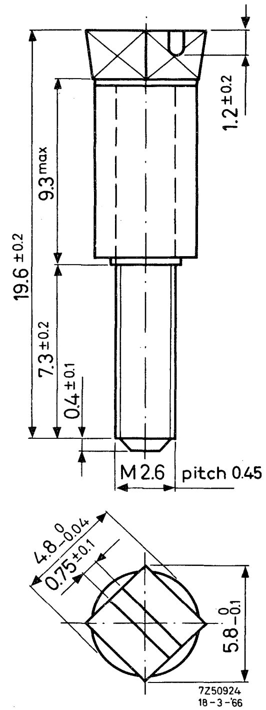


Fig.C

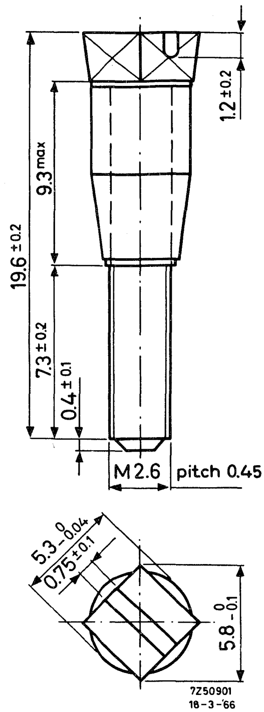


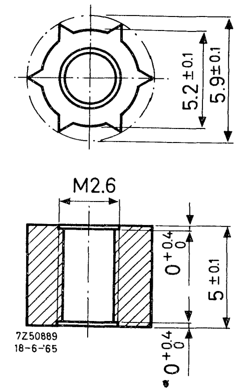
Fig.D

Available types and recommended applications for potcores with grade 3B7, 3H1 and 3D3:

Fig.	colour	catalog number 4322 021	potcore	
			μ_e	A_L
A	yellow	30790	33	160
B	white	30980	47	250
B	white	30980	68	–
A	brown	30810	100	400
A	brown	30810	–	630
C	grey	31110	150	–
B	grey	31090	220	1000
D	black	31120	330	1600

NUT FOR ADJUSTOR

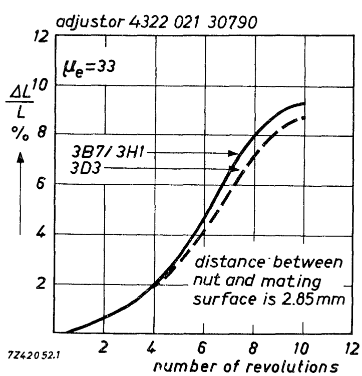
These data are given for those manufacturers who prefer to insert the nut themselves.

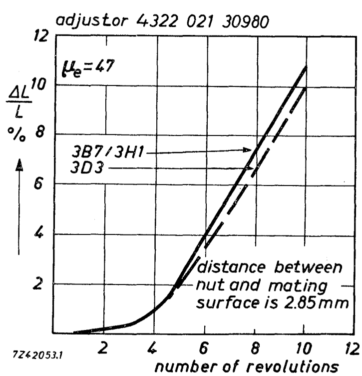


Catalog number	4322 021 30160
Material	polycarbonate
Max. impregnation temperature during 24 hours	120 °C
Recommended distance from mating surface to nut (See Adjustment curves)	2.85 ± 0.15 mm or 4.95 ± 0.15 mm

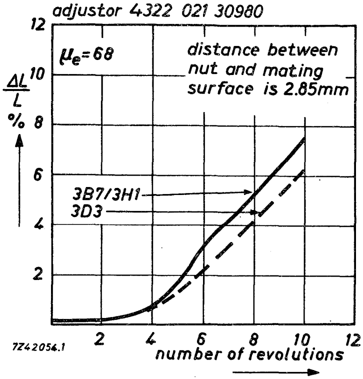
For more information see Potcores General, Mounting data.

ADJUSTMENT CURVES

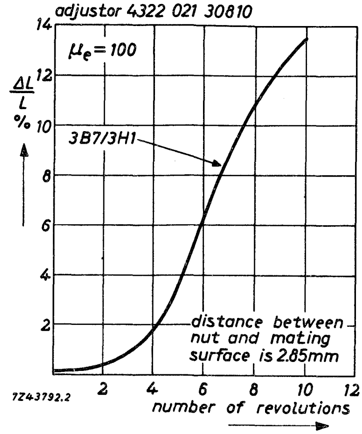




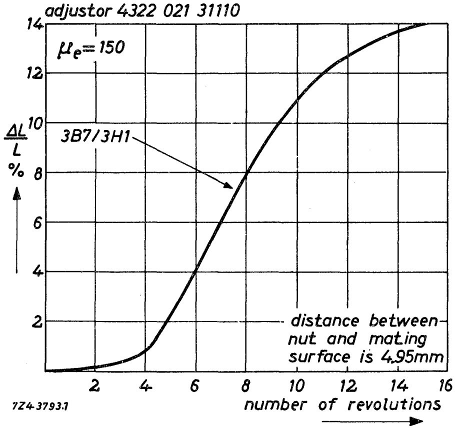
adjustor 4322 021 30980



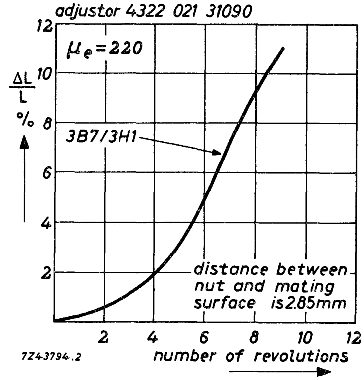
adjustor 4322 021 30810



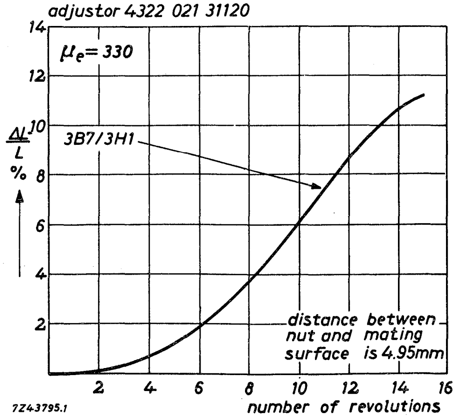
adjustor 4322 021 31110



adjustor 4322 021 31090



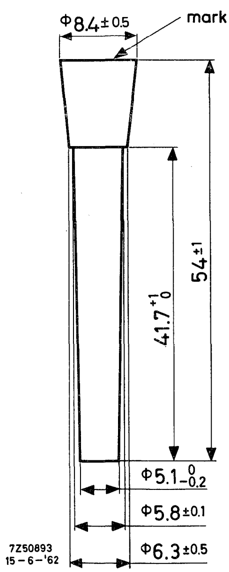
adjustor 4322 021 31120

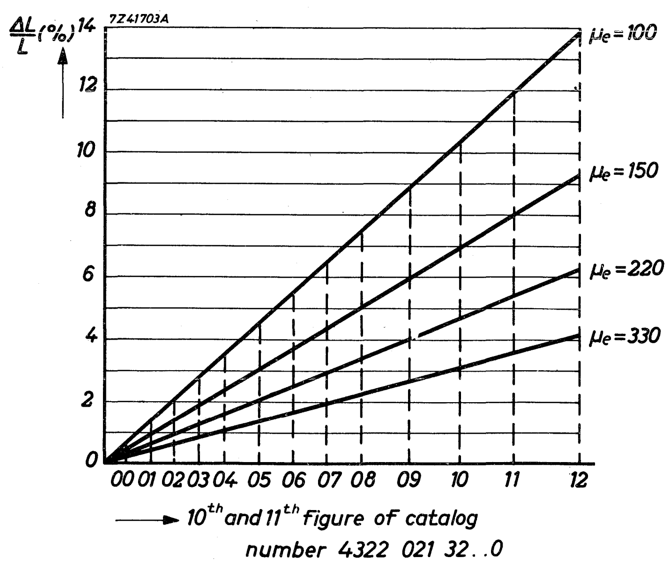


STEP-BY-STEP ADJUSTORS

These adjustors are used when a continuous adjustment of the inductance is not necessary. For instance, they are applied in loading coils to bring the inductance within a certain tolerance field. They are not suitable for adjusting the inductance to an exact value, as is usually necessary in filters. The increment of the losses caused by these adjustors is negligible.
A range of 13 flexible conical adjustors is available under the catalog numbers 4322 021 32000 up to 021 32120. Each adjustor causes an increase in the inductance; the higher the catalog number, the greater the effect. The influence of each adjustor on the inductance at different μ_e values of the potcore can be found from the graph.
The 10th and 11th figure of the catalog number are indicated on the head of the adjustor. It should be borne in mind that, when using these adjustors, the inductance of the coil should initially be lower than the wanted value.
When the correct adjustor has been found, it is inserted in the centre hole of the pot. An adhesive (for instance Pliobond of Good Year) is used as sliding and fixing material. After fixing the protruding ends are cut off.

The maximum impregnation temperature is 150 °C.
The maximum working temperature is 90 °C.
Material: rubber with powder iron.

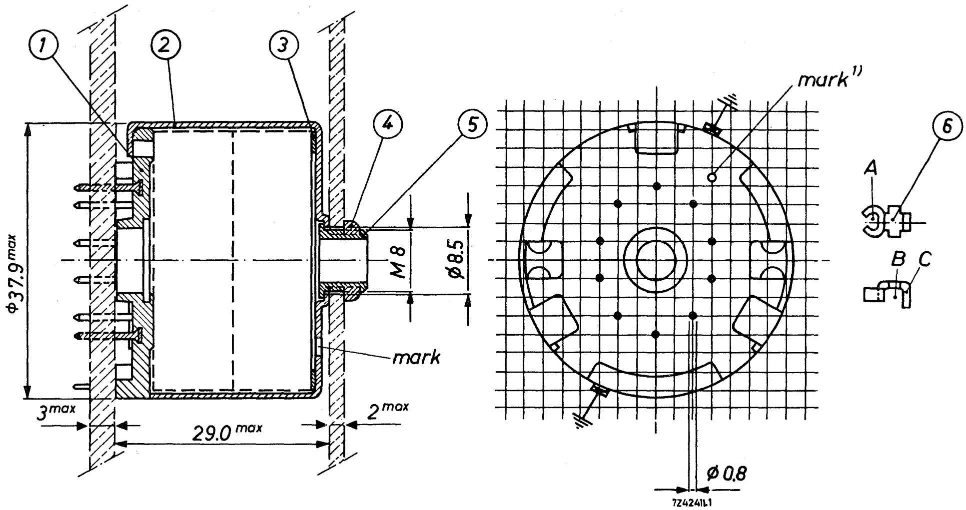




Dimensions in mm

MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30490	(4) nut	4322 021 30710
(2) brass container	4322 021 30570	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30680	(6) soldering spring	4322 021 30700 (10x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The ten soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1.3 ± 0.1 mm diameter.

[1]) There is another mark in a similar position on the top of the container.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

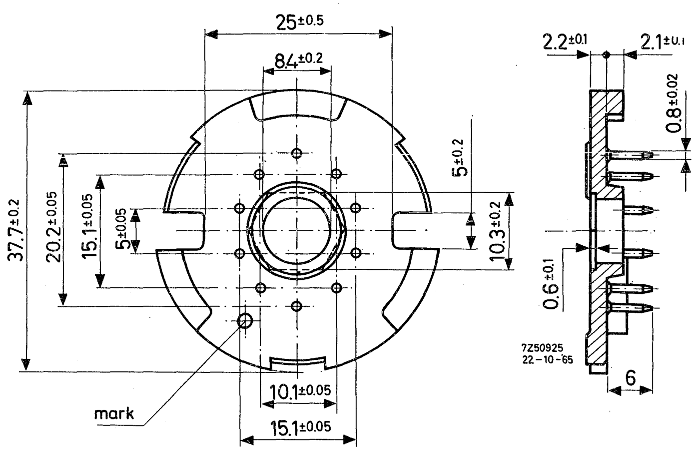
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 350 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

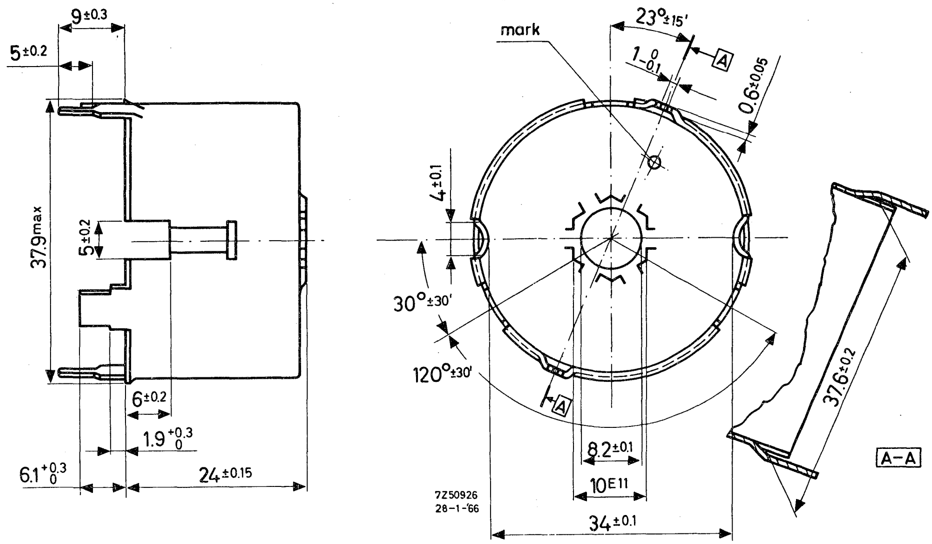
(1) Tag plate 4322 021 30490

Plate : reinforced polyester
Pins : phosphorbronze, dipsoldered



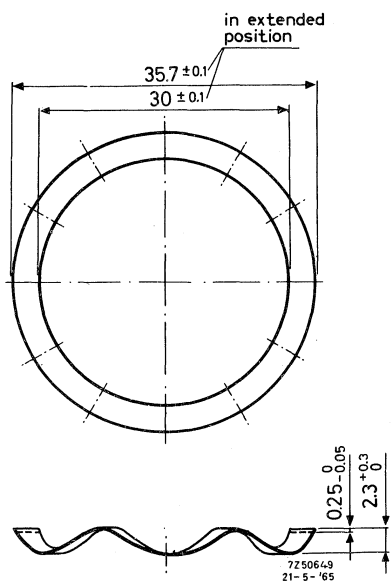
(2) Container 4322 021 30570

Material : brass, nickel plated



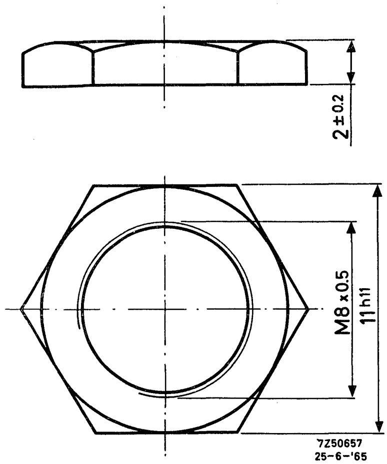
(3) Spring 4322 021 30680

Material : steel



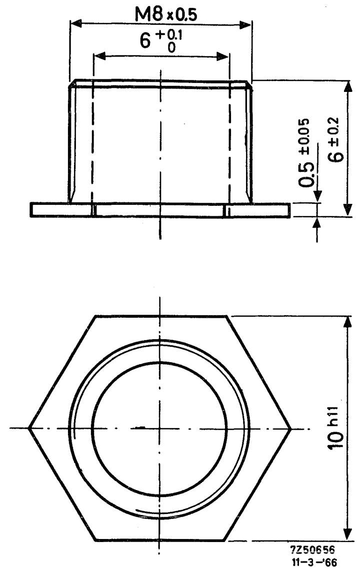
(4) Nut 4322 021 30710

Material : brass, nickel plated



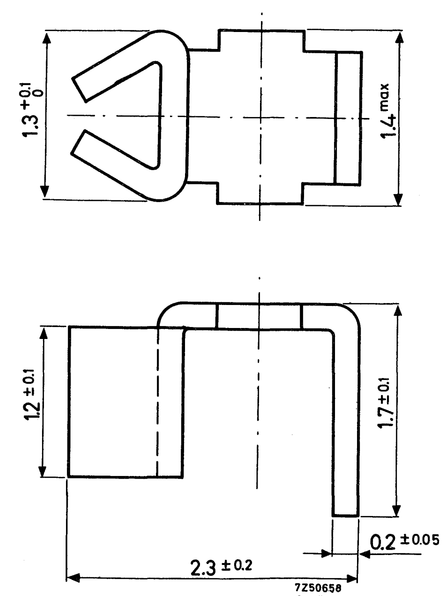
(5) Fixing bush 4322 021 30720

Material : aluminium



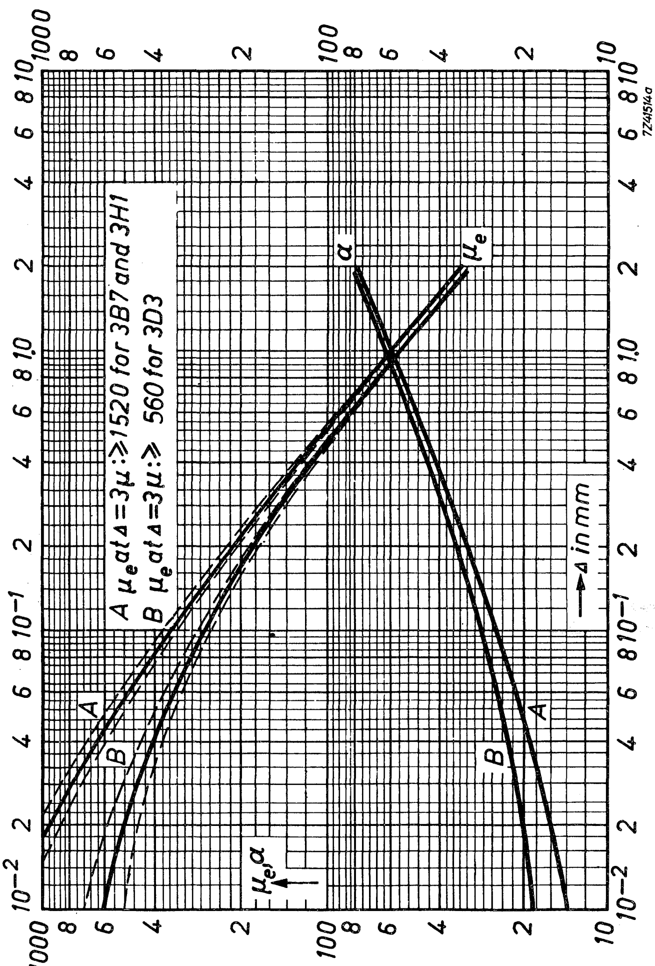
(6) Soldering spring 4322 021 30700

Material : brass, dipsoldered



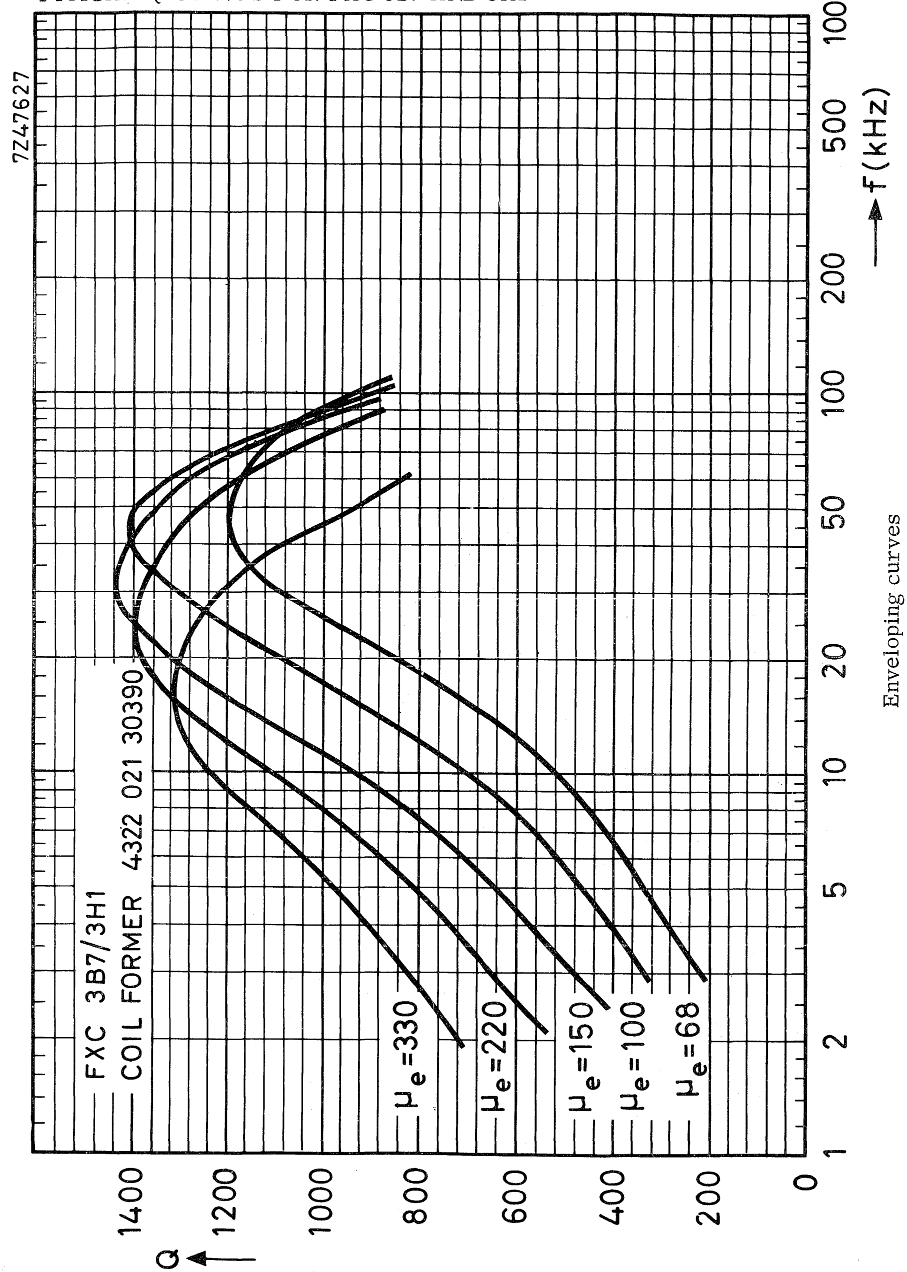
CHARACTERISTIC CURVES

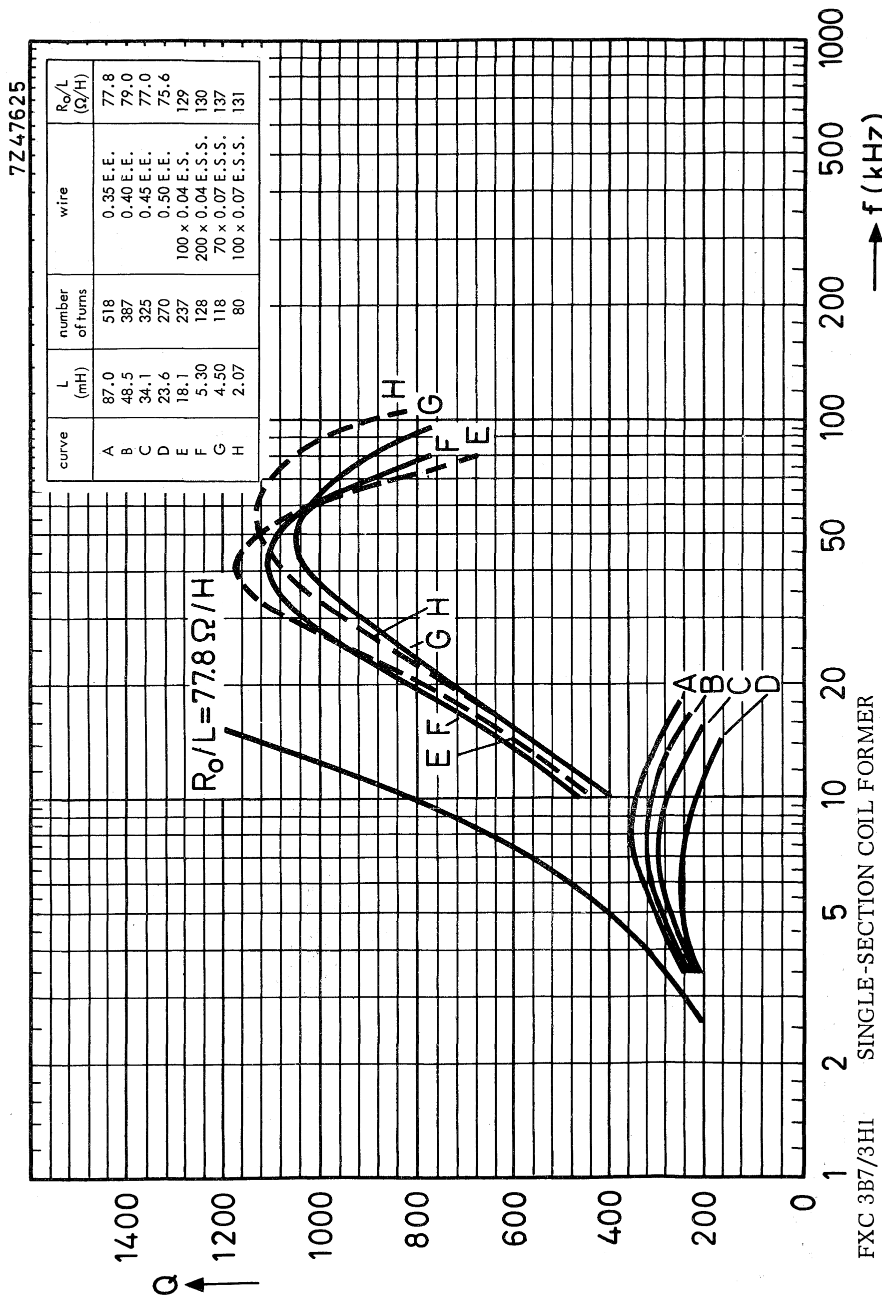
μ_e-α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length

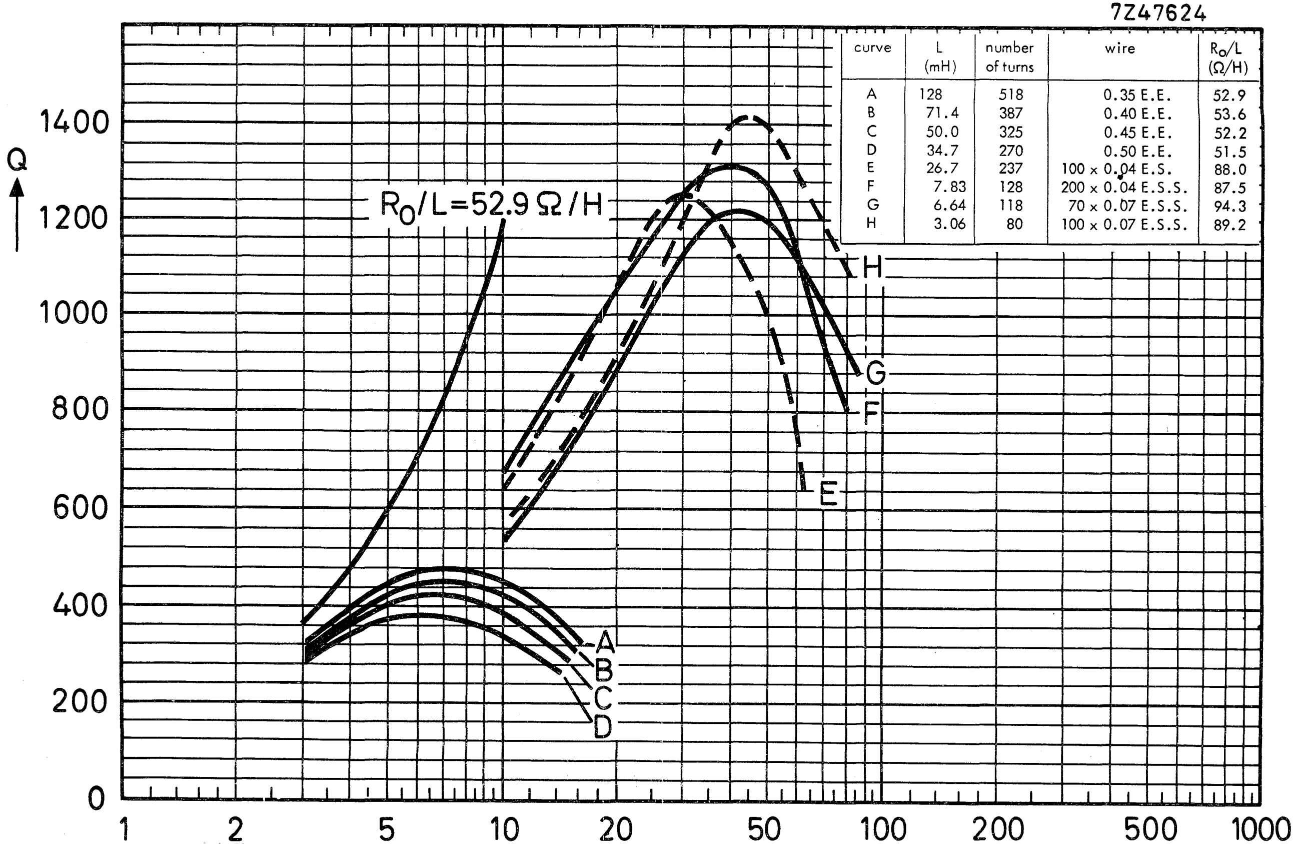
TYPICAL Q-CURVES FOR FXC 3B7 AND 3H1





curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	87.0	518	0.35 E.E.	77.8
B	48.5	387	0.40 E.E.	79.0
C	34.1	325	0.45 E.E.	77.0
D	23.6	270	0.50 E.E.	75.6
E	18.1	237	100 × 0.04 E.S.	129
F	5.30	128	200 × 0.04 E.S.S.	130
G	4.50	118	70 × 0.07 E.S.S.	137
H	2.07	80	100 × 0.07 E.S.S.	131

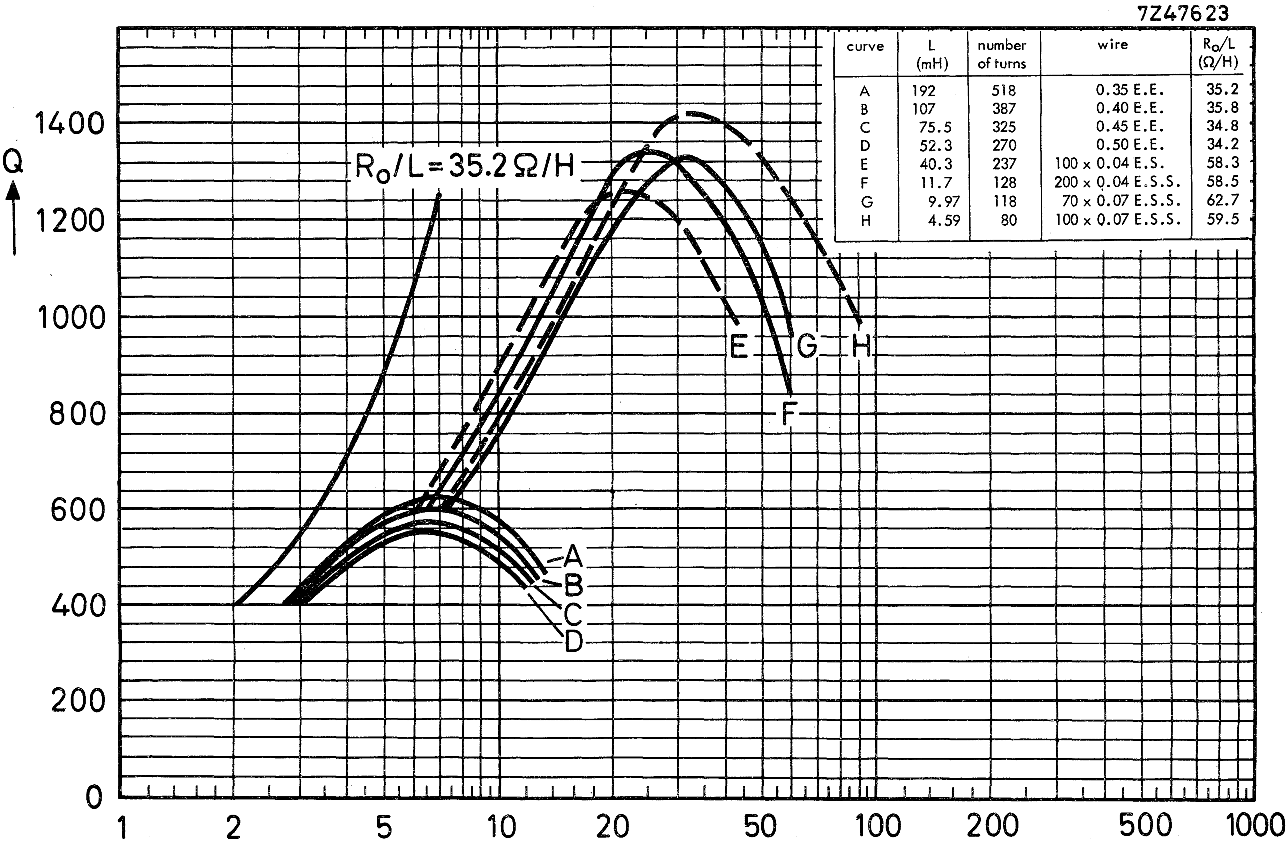
FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 68$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	128	518	0.35 E.E.	52.9
B	71.4	387	0.40 E.E.	53.6
C	50.0	325	0.45 E.E.	52.2
D	34.7	270	0.50 E.E.	51.5
E	26.7	237	100 × 0.04 E.S.	88.0
F	7.83	128	200 × 0.04 E.S.S.	87.5
G	6.64	118	70 × 0.07 E.S.S.	94.3
H	3.06	80	100 × 0.07 E.S.S.	89.2

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

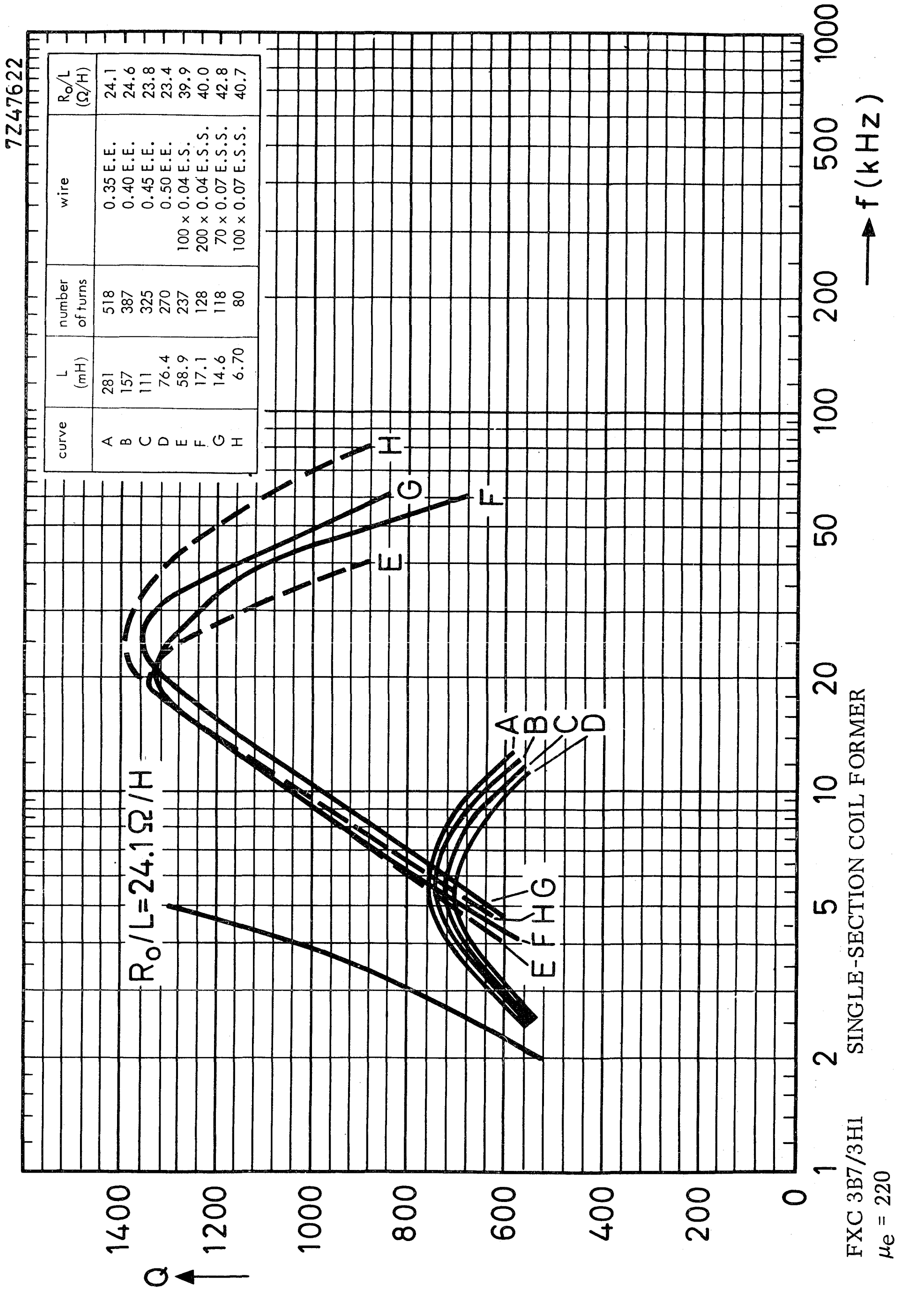
$\mu_e = 100$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	192	518	0.35 E.E.	35.2
B	107	387	0.40 E.E.	35.8
C	75.5	325	0.45 E.E.	34.8
D	52.3	270	0.50 E.E.	34.2
E	40.3	237	100 x 0.04 E.S.	58.3
F	11.7	128	200 x 0.04 E.S.S.	58.5
G	9.97	118	70 x 0.07 E.S.S.	62.7
H	4.59	80	100 x 0.07 E.S.S.	59.5

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER

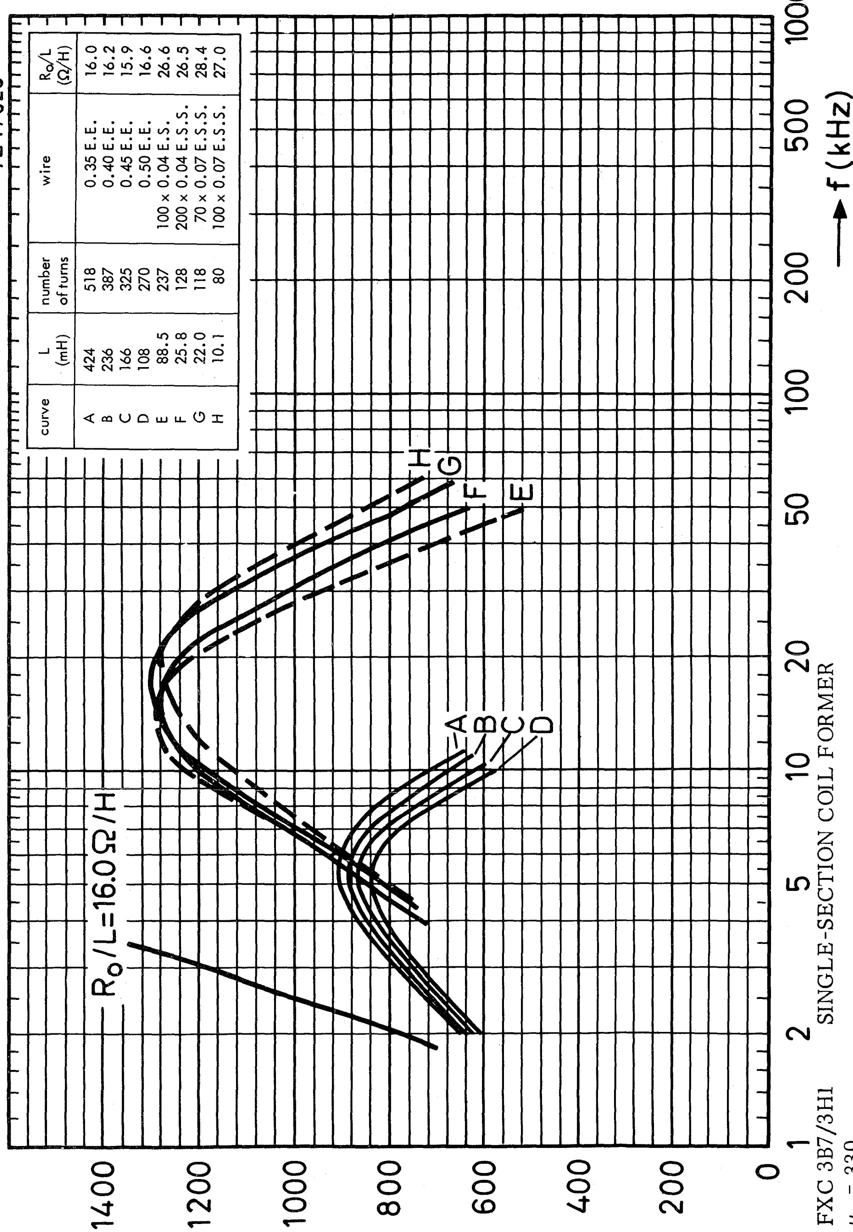
$\mu_e = 150$



curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	281	518	0.35 E.E.	24.1
B	157	387	0.40 E.E.	24.6
C	111	325	0.45 E.E.	23.8
D	76.4	270	0.50 E.E.	23.4
E	58.9	237	100 × 0.04 E.S.	39.9
F	17.1	128	200 × 0.04 E.S.S.	40.0
G	14.6	118	70 × 0.07 E.S.S.	42.8
H	6.70	80	100 × 0.07 E.S.S.	40.7

SINGLE-SECTION COIL FORMER

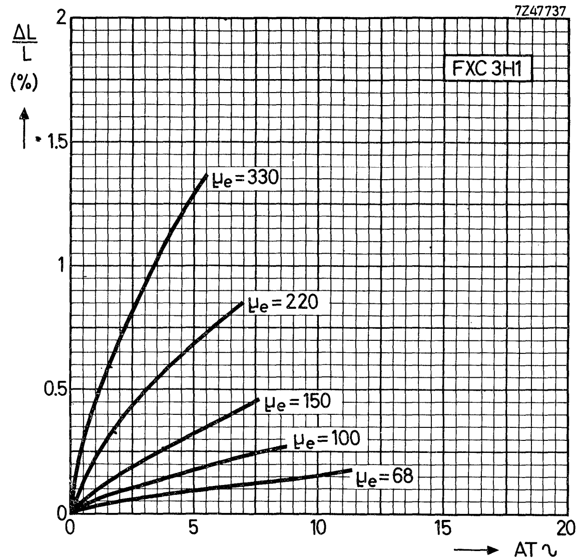
FXC 3B7/3H1
$\mu_e = 220$

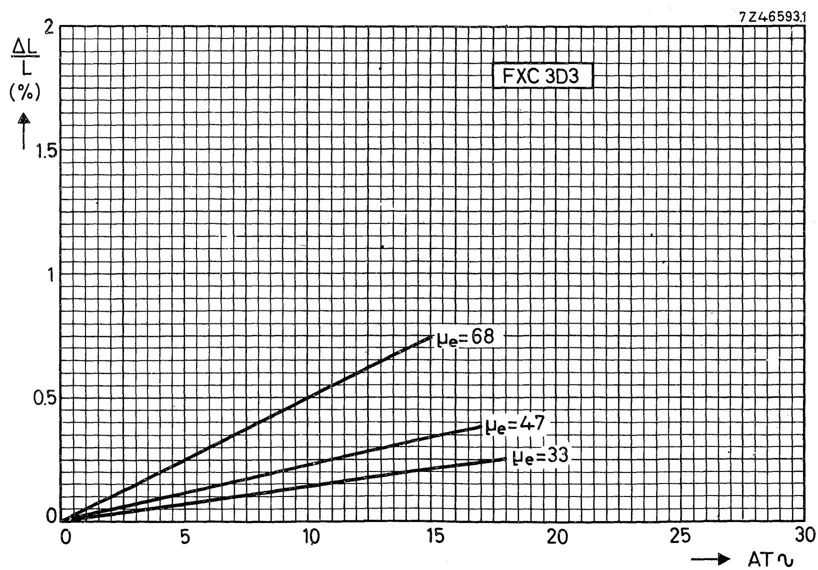


curve	L (mH)	number of turns	wire	R_o/L (Ω/H)
A	424	518	0.35 E.E.	16.0
B	236	387	0.40 E.E.	16.2
C	166	325	0.45 E.E.	15.9
D	108	270	0.50 E.E.	16.6
E	88.5	237	100 × 0.04 E.S.	26.6
F	25.8	128	200 × 0.04 E.S.S.	26.5
G	22.0	118	70 × 0.07 E.S.S.	28.4
H	10.1	80	100 × 0.07 E.S.S.	27.0

FXC 3B7/3H1 SINGLE-SECTION COIL FORMER
$\mu_e = 330$

INDUCTANCE VARIATION AS A FUNCTION OF AT∼

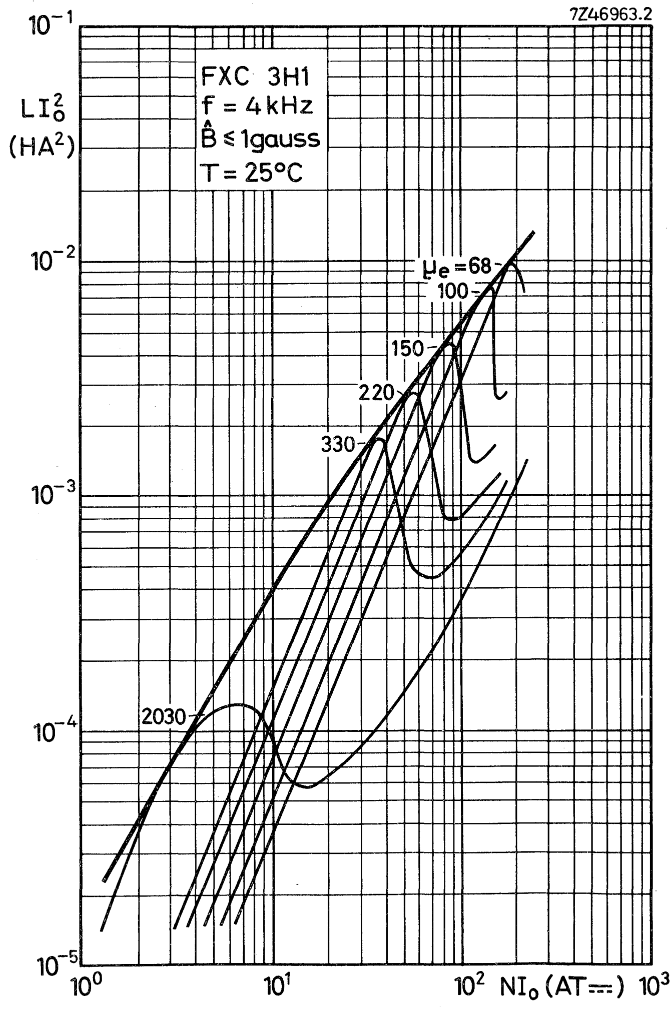




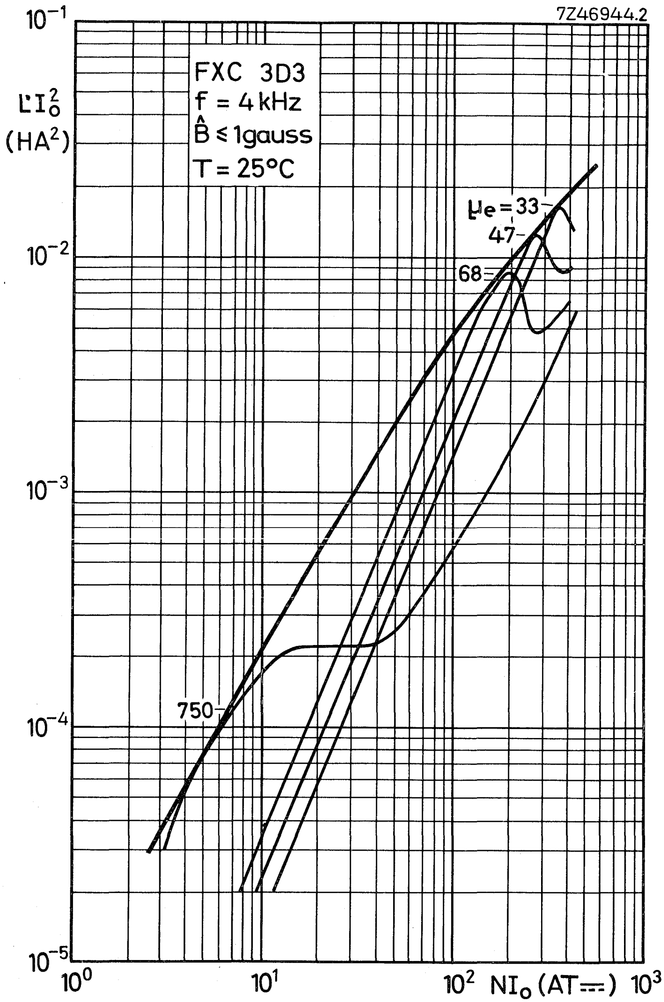
HANNA CURVES

Indicating the optimum inductance for a certain μ_e-value and direct current.

Typical values.



Typical values



POTCORES

INTRODUCTION

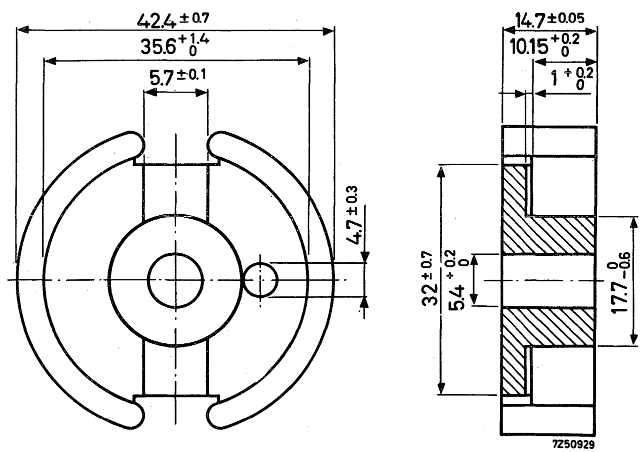
Three types of core can be supplied:

- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores (potcores with an air gap) which are provided with a nut for an adjustor. These have an effective permeability (μ_e) in accordance with the E6 range of values or an A_L factor in the R5 range.
- Pre-adjusted potcores without nut.

Potcores and associated parts are ordered by their 12-digit catalog number.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number (without hole A)	catalog number (with hole A)
3B5	4322 020 22770	4322 020 22800
3B7	4322 020 22750	4322 020 22780
3H1	4322 020 22760	4322 020 22790

The versions without hole A are used for filter coils, the versions with hole A for L-asymmetry adjustment of loading coils.

Properties

For toroidally wound core halves the values in Table I are guaranteed.

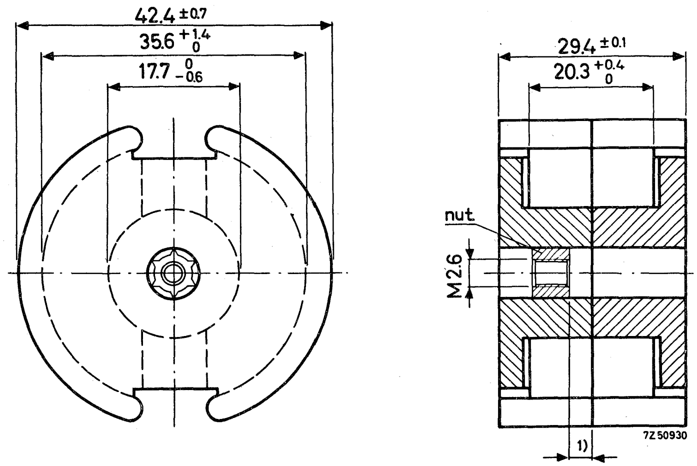
Table I	temp. (^oC)	grade		
		3B5	3B7	3H1
T.F. x 10^6	+23 to +70	–	–0.6 to +0.6	+0.6 to +1.8
D.F. x 10^6 (10-100 min)	23 ± 1	–	≤ 4.3	≤ 4.3

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 550 Newton, the values in Table II are guaranteed at 25 ± 10 ^oC.

Table II	$\hat{B}$ (Gs)	freq. (kHz)	grade		
			3B5	3B7	3H1
μ_e	≤ 1	4	≥ 960	≥ 1585	≥ 1585
α	≤ 1	4	≤ 14.6	≤ 11.4	≤ 11.4
$\frac{\tan \delta}{\mu_i}$ x 10^{-6}	≤ 1	4	≤ 2.5	≤ 1.2	≤ 1.2
	≤ 1	100	≤ 15	≤ 8	≤ 8
$q_{2-24-100}$	15-30	4	≤ 2.5	≤ 1.8	≤ 1.8

PRE-ADJUSTED POTCORES

Dimensions in mm



With nut, catalog number = 4322 022 3....
Without nut, catalog number = 4322 022 1....

Weight = 104 g

Effective length l_e = 6.86 cm

$\Sigma \frac{l_e}{A_e} = 2.59\ cm^{-1}$

Effective volume V_e = 18.2 cm^3

Notes to the tables on the next page

1. A point in the place of the 8th digit of the catalog number indicates a choice of the two versions: insert 3 for potcores with nut, insert 1 for potcores without nut.
   Examples of catalog number:
   μ_e = 100, grade 3B7, potcore with nut, catalog number = 4322 022 34060
   A_L = 250, grade 3H1, potcore without nut, catalog number = 4322 022 15260
2. The inductance will only be within the given tolerance if the winding space of the coil is completely filled.

[1]) See Adjustment curves.

Potcores with standard μ_e values [1])

μ_e	α	tolerance on inductance (%)	catalog number 4322 022	
			3B7	3H1
33	78.4	± 1	–	–
47	65.7	± 1	–	–
68	55.0	± 1	–	.4250
100	45.0	± 1.5	.4060	.4260
150	36.8	± 2	.4070	.4270
220	30.4	± 3	.4080	.4280
330	24,8	± 3	.4090	.4290
2120	9.85	± 25	14000	14200

Number of turns $N = \alpha\sqrt{L}$ (L in 10^{-3} H)

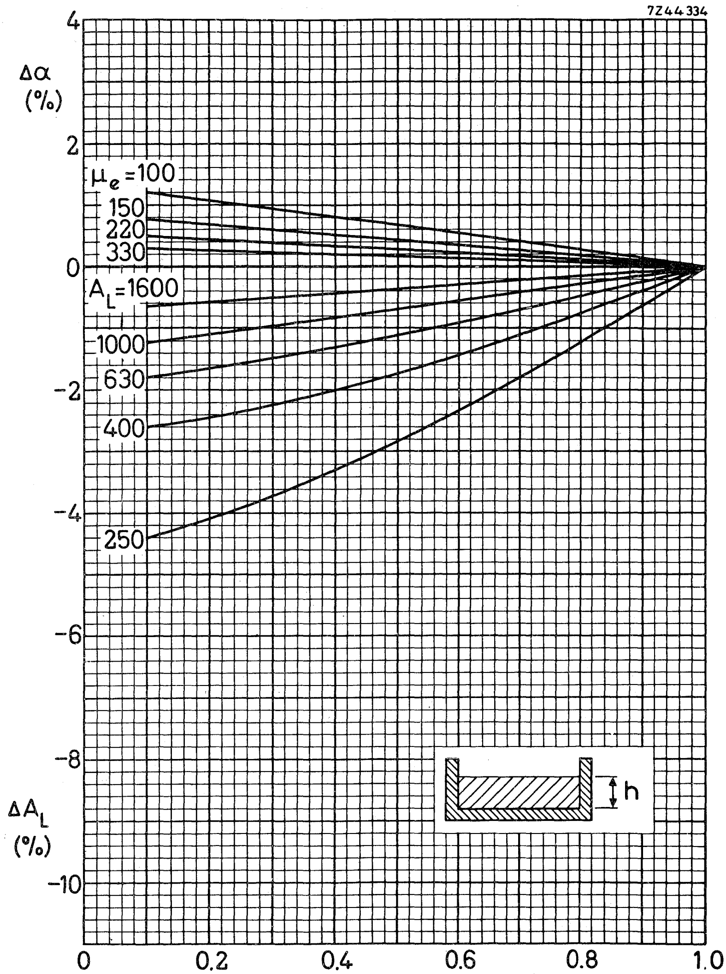
Potcores with standard A_L factors [1])

A_L (nH)	corresponding μ_e-value	tolerance on inductance (%)	catalog number 4322 020		
			3B5	3B7	3H1
250	51	± 1	.5460	.5060	.5260
400	81	± 1	.5480	.5080	.5280
630	130	± 2	.5500	.5100	.5300
1000	205	± 3	.5510	.5110	.5310
1600	325	± 3	.5520	.5120	.5320

Inductance $L = N^2 A_L$ (in 10^{-9} H)

[1]) See Notes on the previous page.

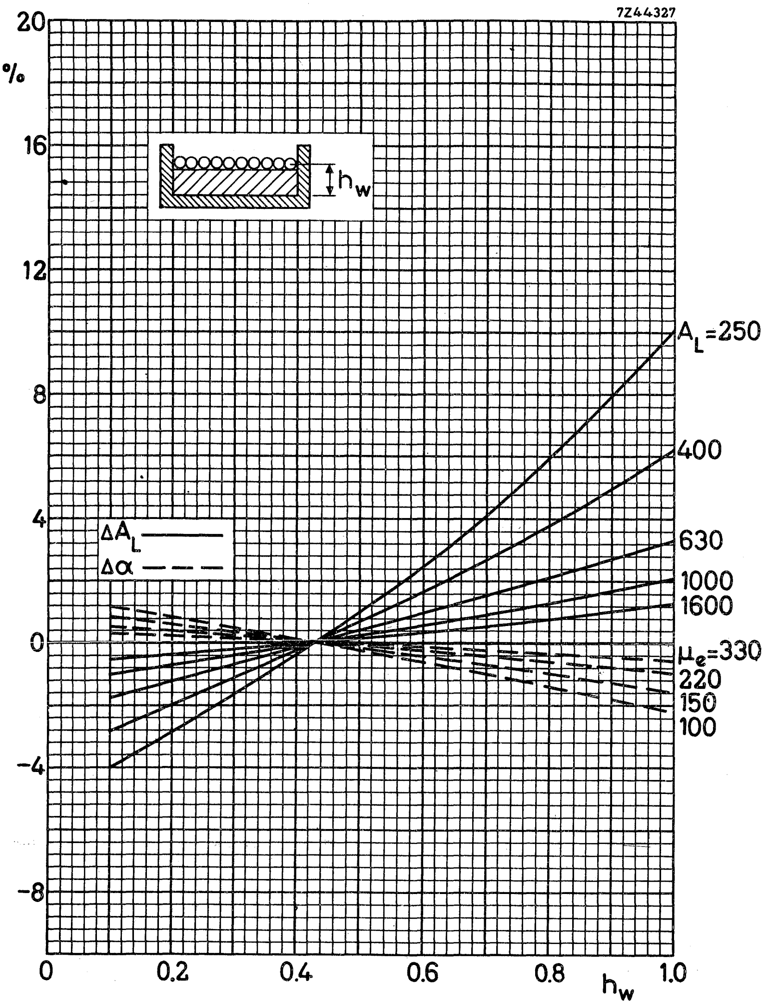
DATA FOR WHEN THE COIL FORMER IS PARTLY FILLED



Increase of the α and decrease of the A_L factor for different μ_e values and A_L factors as a function of the relative winding height on a single-section coil former.

Valid for ferroxcube 3B5, 3B7 and 3H1.

Example: On a single-section coil former only 0.4 part of the available height is used. A potcore with μ_e = 100 in that case obtains an α factor of 45.0 + 0.75 %.



Variation of the α and A_L factors for a coupling winding of one layer as a function of its winding height h_W on a single-section coil former.
Valid for ferroxcube 3B5, 3B7 and 3H1.
Example: On a single-section coil former a coupling winding is laid on 0.7 of the available height. A potcore with μ_e = 100 obtains for that winding an α factor of 45.0 - 1.0 %.

COIL FORMERS

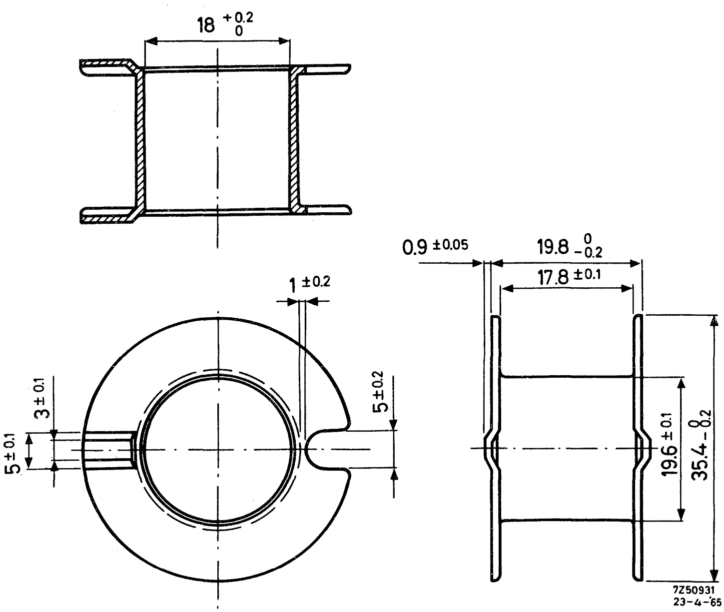
GENERAL

Two types of coil former can be supplied:

- with one section
- with two sections

The dimensions in the drawings are in mm

SINGLE-SECTION COIL FORMER



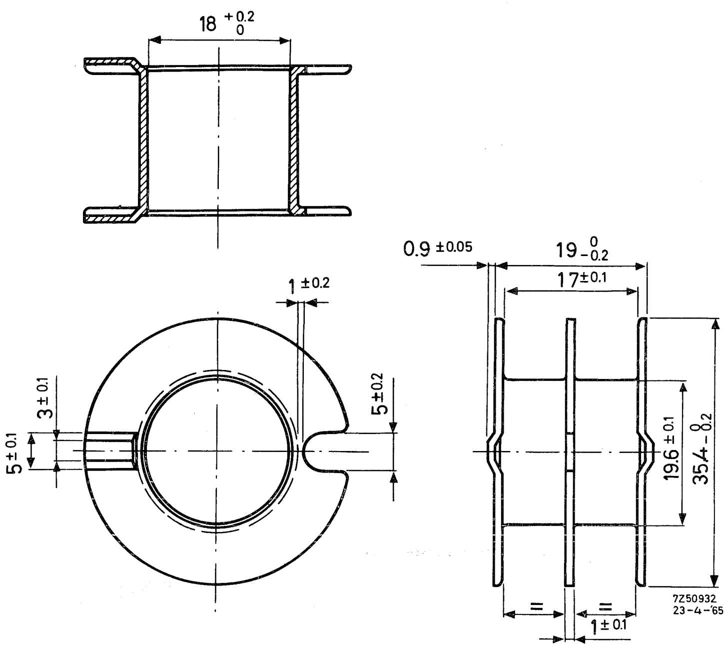
Catalog number	4322 021 30420
Material	polycarbonate K486
Window area	140 mm^2
Mean length of turn	8.6 cm
Max. temperature	130 ^{o}C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 2.16 \times 10^3 \quad \Omega/H$$

Weight 2.4 g

TWO-SECTION COIL FORMER



Catalog number	4322 021 30430
Material	polycarbonate K486
Window area	2 x 63 mm^2
Mean length of turn	8.6 cm
Max. temperature	130 °C

D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 2.40 \times 10^3 \quad \Omega/H$$

Weight 3.0 g

INDUCTANCE ADJUSTMENT

CONTINUOUS ADJUSTORS

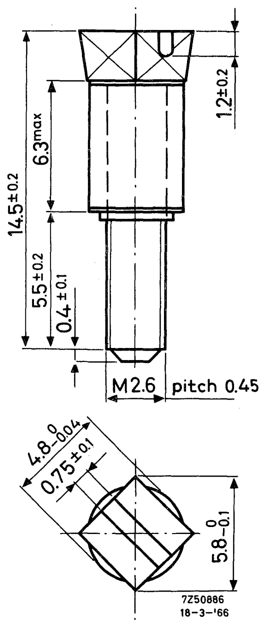


Fig.A

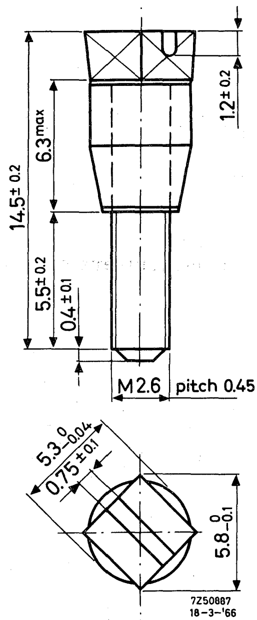


Fig.B

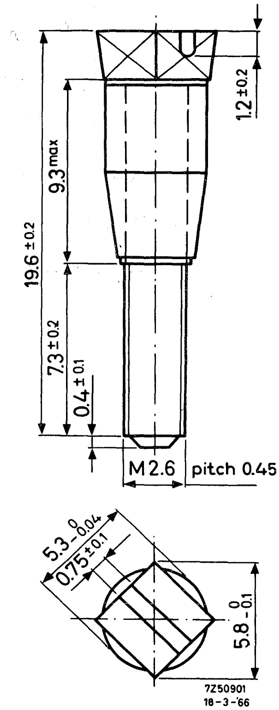


Fig.C

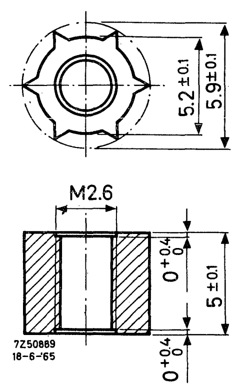
The tolerances on inductance of the pre-adjusted potcores (with adjustor) are given on the pages "Potcores". After inserting a coil (impregnated or not) in an electrical circuit, its inductance can be adjusted to the required value with an accuracy < 0.03 % by means of a continuous inductance adjustor. Such an adjustor increases the inductance of the coil, see following pages.
The adjustor is screwed through the potcore into the nut and is held in position by the corner edges on the top of the adjustor. For special requirements a bigger or smaller adjustment range may be obtained by using an adjustor belonging to the next higher or lower effective permeability.
The influence of the adjustors on the variability of the inductance is negligible.
The maximum permissible temperature is 110 °C.

Available types and recommended applications

Fig.	colour	catalog number 4322 021	potcore	
			μ_e	A_L
B	white	30980	68	250
A	brown	30810	100	400
A	brown	30810	–	630
B	grey	31090	150	1000
B	grey	31090	220	–
C	black	31120	330	1600

NUT FOR ADJUSTOR

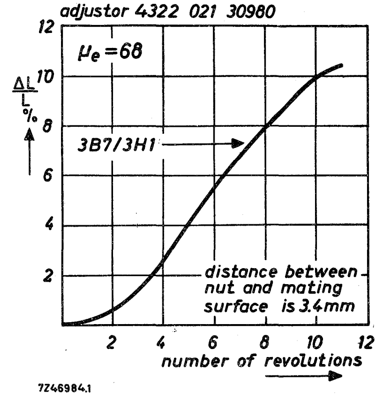
These data are given for those manufacturers who prefer to insert the nut themselves.

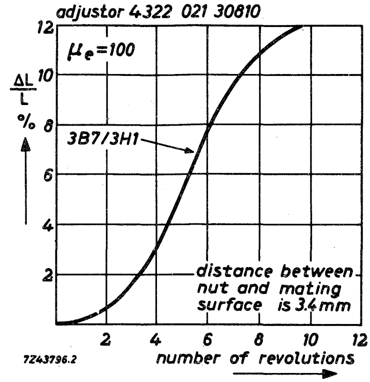


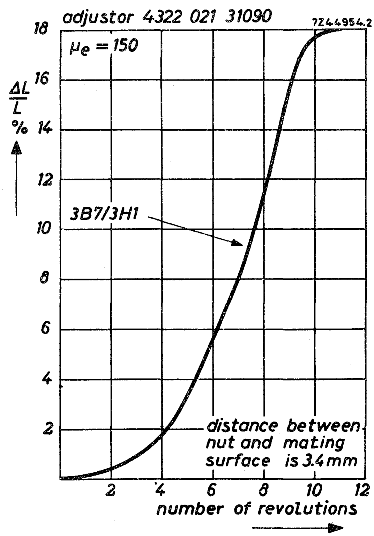
Catalog number	4322 021 30160
Material	polycarbonate
Max. impregnation temperature during 24 hours	120 °C
Recommended distance from mating surface to nut (see Adjustment curves)	3.4 ± 0.15 mm or 5.0 ± 0.15 mm

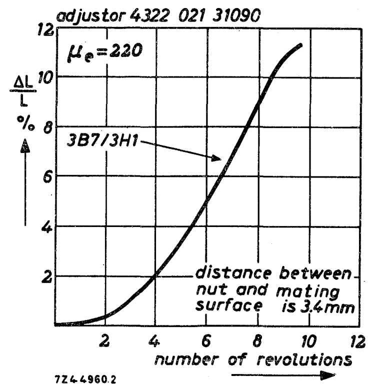
For more information see Potcores General, Mounting Data

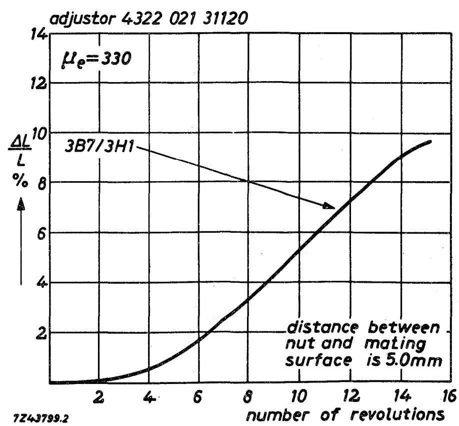
ADJUSTMENT CURVES







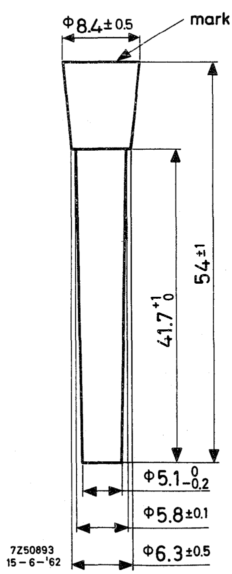


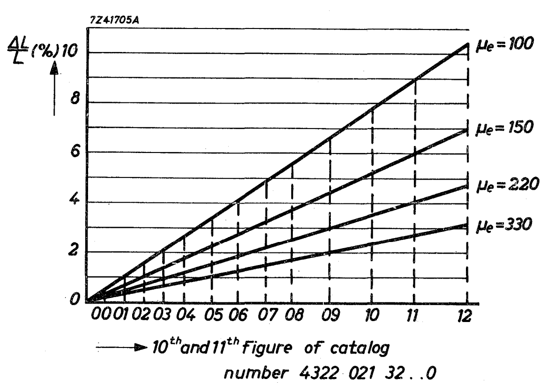


STEP-BY-STEP ADJUSTORS

These adjustors are used when a continuous adjustment of the inductance is not necessary. For instance, they are applied in loading coils to bring the inductance within a certain tolerance field. They are not suitable for adjusting the inductance to an exact value, as is usually necessary in filters. The increment of the losses caused by these adjustors is negligible.
A range of 13 flexible conical adjustors is available under the catalog numbers 4322 021 32000 up to 021 32120. Each adjustor causes an increase in the inductance; the higher the catalog number, the greater the effect. The influence of each adjustor on the inductance at different μ_e values of the potcore can be found from the graph.
The 10th and 11th figure of the catalog number are indicated on the head of the adjustor. It should be borne in mind that, when using these adjustors, the inductance of the coil should initially be lower than the wanted value.
When the correct adjustor has been found, it is inserted in the centre hole of the pot. An adhesive (for instance Pliobond of Good Year) is used as sliding and fixing material. After fixing the protruding ends are cut off.

The maximum impregnation temperature is 150 °C.
The maximum working temperature is 90 °C.
Material: rubber with powder iron.

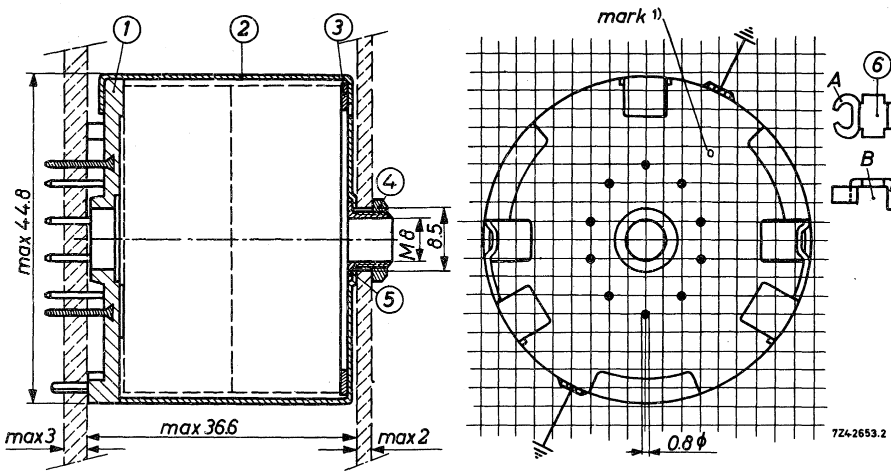




Dimensions in mm

MOUNTING PARTS

MOUNTING



(1) tag plate	4322 021 30500	(4) nut	4322 021 30710
(2) brass container	4322 021 30580	(5) fixing bush	4322 021 30720
(3) spring	4322 021 30690	(6) soldering spring	4322 021 30700 (10x)

The core is suitable for mounting on printed-wiring boards and on conventional panels.

The parts 1, 2, 3 (and 6) are sufficient to construct an assembly for use in combination with printed wiring.

If stranded wire is applied the use of a soldering spring (6) is recommended. Part A of this spring is put over the pin; then the wire is put in B and lip C is bent over.

For solid wire the soldering spring is not strictly necessary.

The ten soldering pins are arranged so as to fit a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1.3±0.1 mm diameter.

---

[1]) There is another mark in a similar position on the top of the container.

If one-hole mounting is preferred, the parts 4 and 5 should be added. The coil assembly may then be mounted on panels having a thickness of up to 2 mm. The panel should be provided with a hole of 8.5 mm diameter.

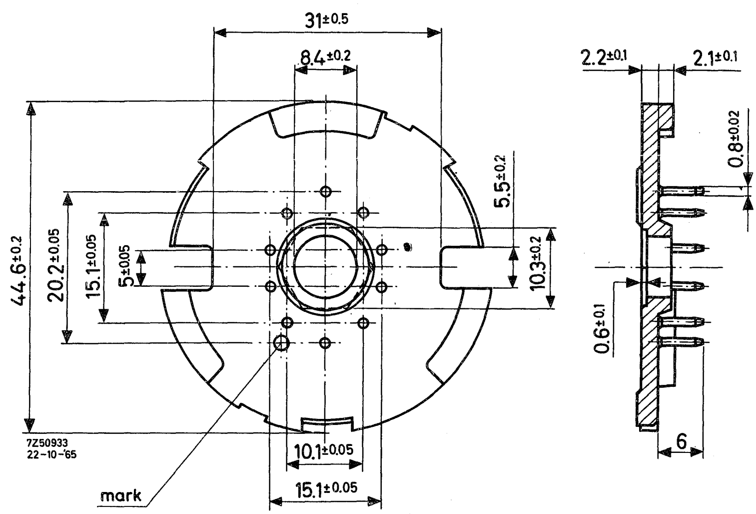
It is recommended to place the spring (3) in the position indicated in order to obtain the best stability against shock and vibration.

Before bending the lips of the container, pressure should be exercised evenly on the rim of the tag plate until the latter meets the container. The force which is required is approximately 550 Newton. After bending the lips the spring will have the correct tension.

PART DRAWINGS (dimensions in mm)

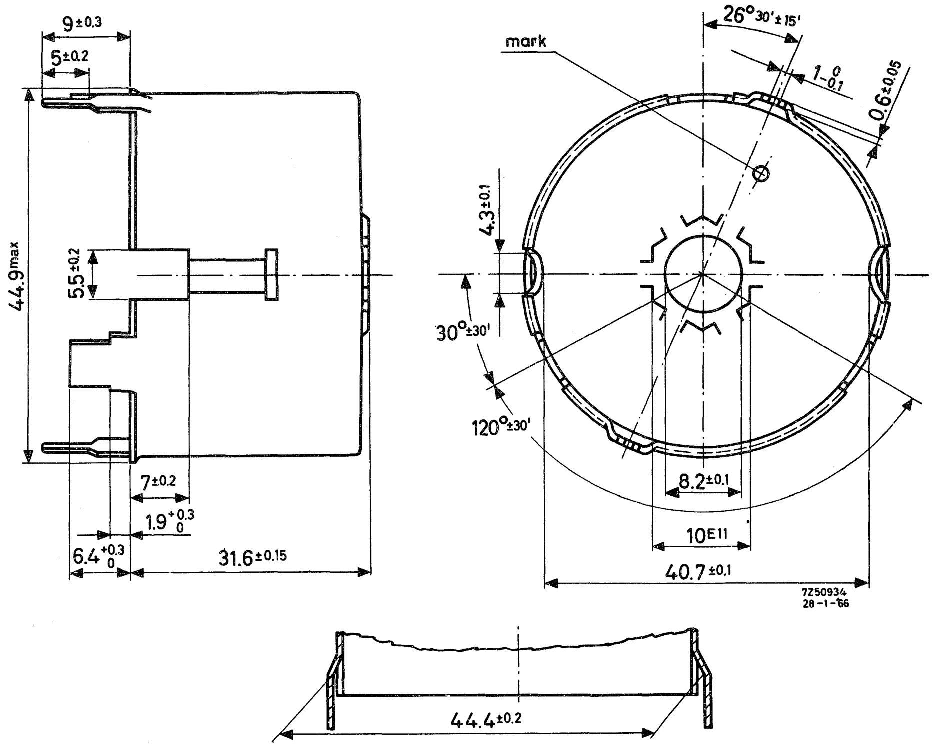
(1) Tag plate 4322 021 30500

Plate: reinforced polyester
Pins : phosphorbronze, dip soldered



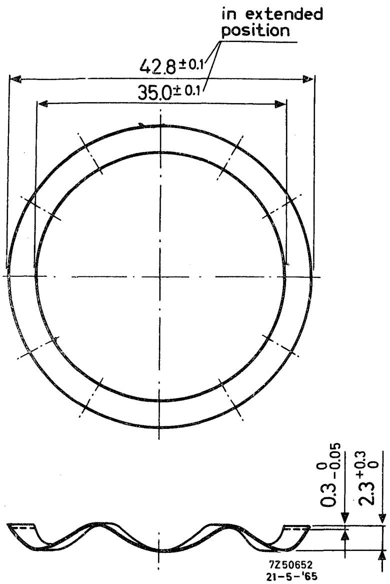
(2) Container 4322 021 30580

Material: brass, nickel plated



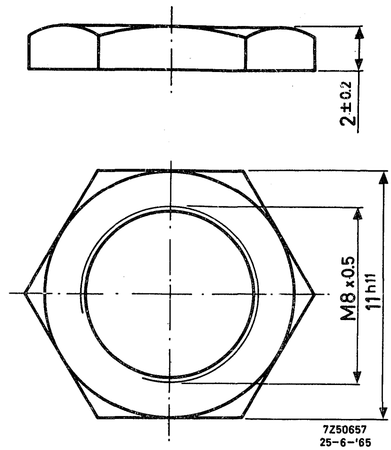
(3) Spring 4322 021 30690

Material: chrome-nickelsteel



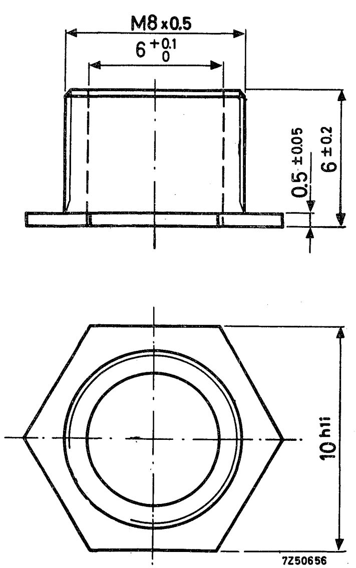
(4) Nut 4322 021 30710

Material: brass, nickel plated



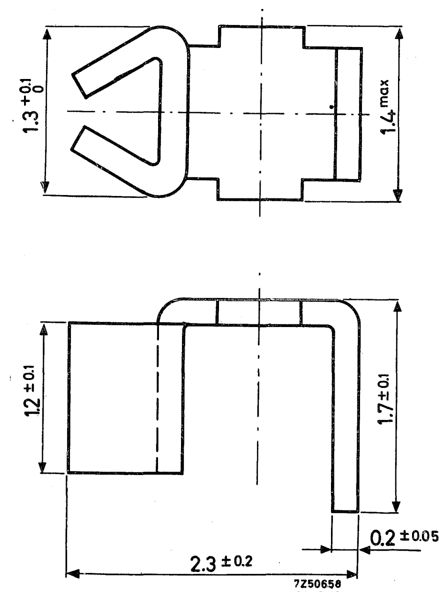
(5) Fixing bush 4322 021 30720

Material: aluminium



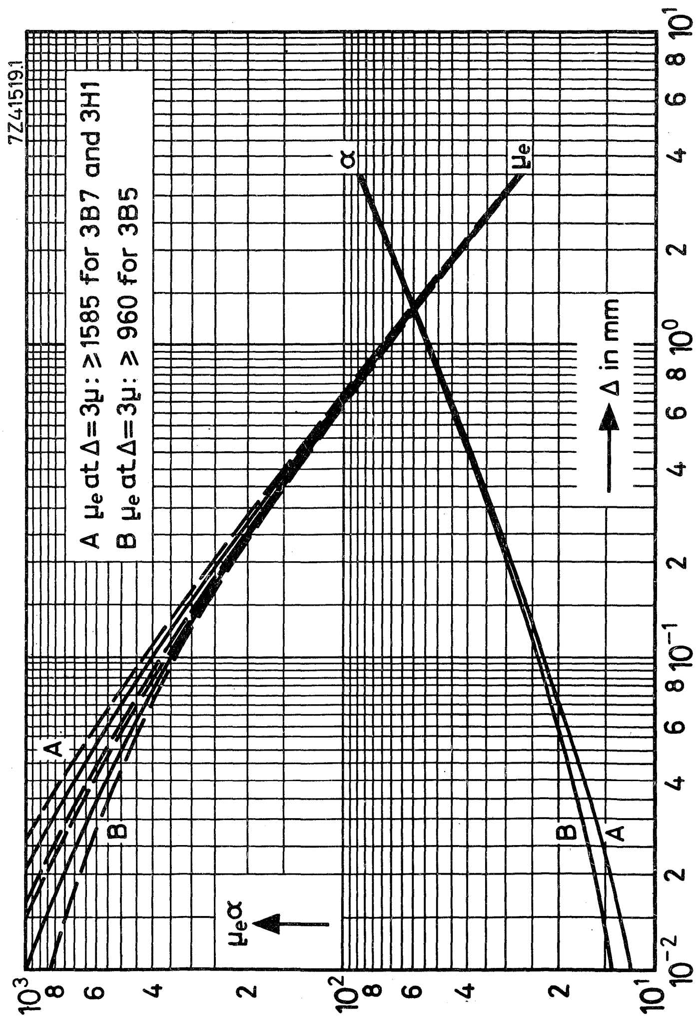
(6) Soldering spring 4322 021 30700

Material: brass, dipsoldered



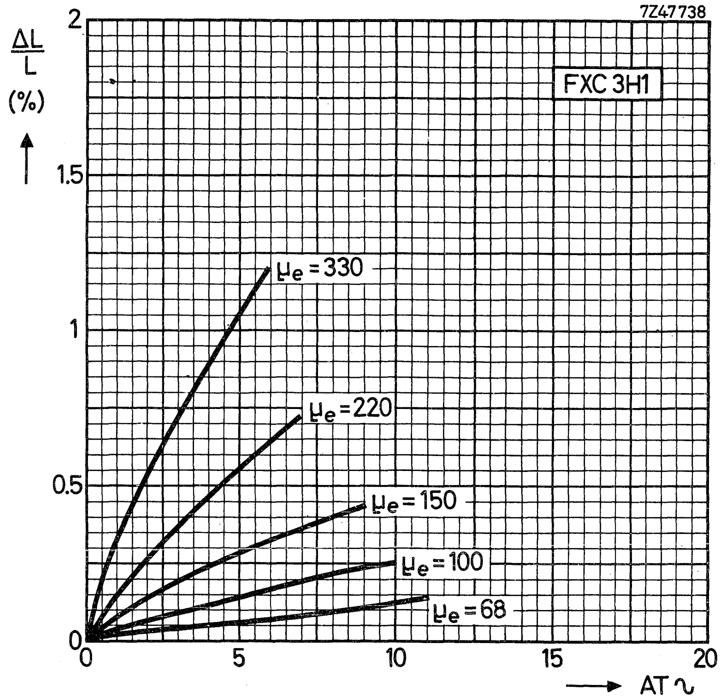
CHARACTERISTIC CURVES

μ_e-α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length

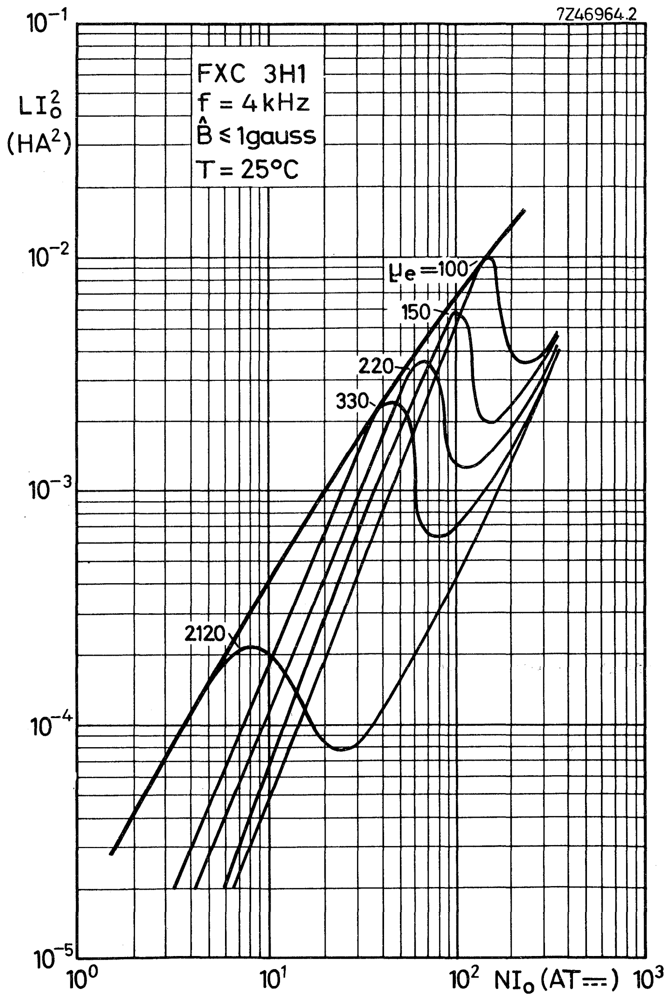
INDUCTANCE VARIATION AS A FUNCTION OF AT~



HANNA CURVE

Indicating the optimum inductance for a certain μ_e-value and direct current.

Typical values



POTCORES

INTRODUCTION

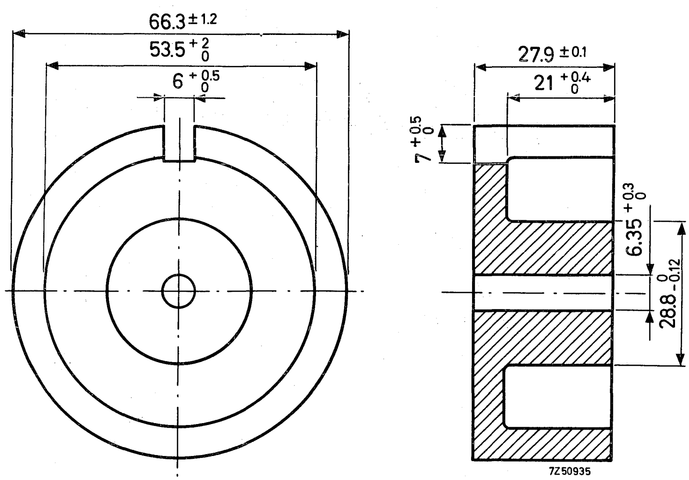
Two types of core can be supplied:

- Separate core halves, air gap to be ground by the user himself.
- Pre-adjusted potcores, available to special order. The μ_e values can be chosen from the E_6 standard series of values, the A_L values from the R_5 series.

Potcores and associated parts are ordered by their 12-digit catalog number.

SEPARATE POTCORE HALVES

Dimensions in mm



Available versions

ferroxcube grade	catalog number
3B5	4322 020 23010
3E1	4322 020 23000
3H1	4322 020 23020

Properties

For toroidally wound core halves the values in Table I are guaranteed.

Table I	temp. (°C)	grade		
		3B5	3E1	3H1
T.F. x 10^6	+23 to +70	0 to +2	-	+0.6 to +1.8
D.F. x 10^6 (10-100 min)	+23 ± 1	≤ 7.5	-	≤ 4.3

For the combination of two potcore halves randomly chosen from a batch and pressed together with a force of 1700 Newton, the values in Table II are guaranteed at 25 ± 10 °C.

Table II	$\hat{B}$ (Gs)	freq. (kHz)	grade		
			3B5	3E1	3H1
μ_e	≤ 1	4	≥ 1000	≥ 1970	≥ 1695
α	≤ 1	4	≤ 11.7	≤ 8.25	≤ 8.96
$\frac{\tan\delta}{\mu_i} \times 10^{-6}$	≤ 1	4	≤ 2.5	-	≤ 1.4
	≤ 1	10	≤ 5	-	≤ 3.5
	≤ 1	100	≤ 25	-	≤ 13
$q_{2-24-100}$	15-30		≤ 2.5	-	≤ 1.0

Weight (two halves) = 550 g

Core factor and effective dimensions:

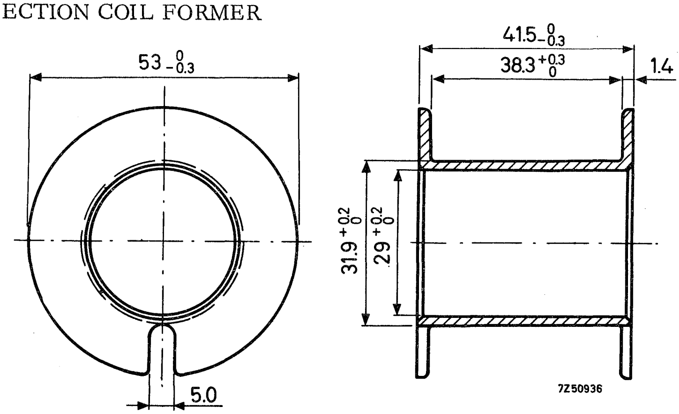
Effective length l_e = 12.3 cm

$$\Sigma \frac{l_e}{A_e} = 1.72\ \text{cm}^{-1}$$

Effective volume V_e = 88.3 cm^3

COIL FORMERS

SINGLE-SECTION COIL FORMER



Catalog number	4322 021 31320
Material	polycarbonate K486
Window area	400 mm^2
Mean length of turn	13 cm
Max. temperature	130 ^{o}C

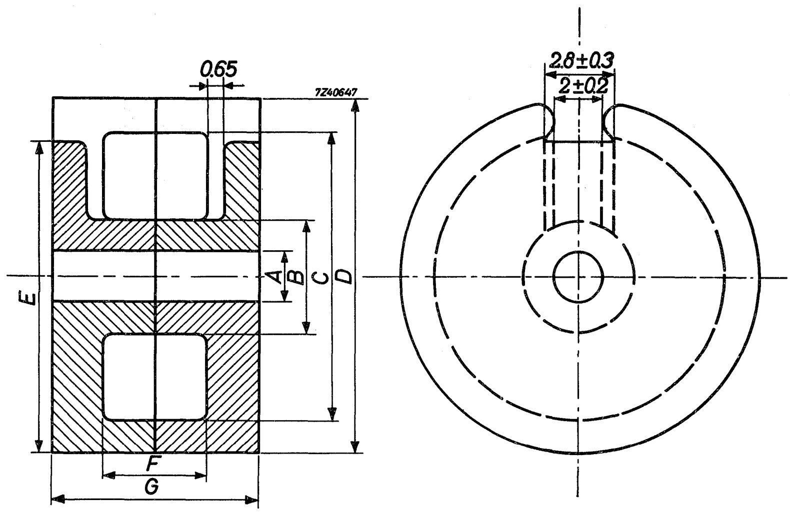
D.C. losses

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 0.80 \times 10^3 \ \Omega/H$$

Weight 11.8 g

S-POTCORES

POTCORES



Two versions of cores can be supplied:

1. Complete potcores with adjusted effective permeability.

2. Separate core halves to be adjusted by the user himself.

The effective permeability of the cores without air gap is determined by the initial permeability of the material, the size of the core and the smoothness of the ground surfaces at the joint between the core halves.

When ordering, the desired core should be indicated by its cat. number. These numbers are for separate core halves.

core half without airgap	FXC	dimensions in mm						
		A	B	C	D	E	F	G
3522 200 03890	3B	$1.9^{+0.2}_{0}$	$4.7^{0}_{-0.4}$	$11.1^{+0.6}_{0}$	14.2 ± 0.4	12.2±0.4	$3.8^{+0.4}_{0}$	8.0 ±0.1
4322 020 20150	3E1	$1.9^{+0.2}_{0}$	$4.7^{0}_{-0.4}$	$11.1^{+0.6}_{0}$	14.2 ± 0.4	12.2±0.4	$3.8^{+0.4}_{0}$	8.0 ±0.1
4322 020 20030	4B1	$1.9^{+0.2}_{0}$	$4.8^{0}_{-0.4}$	$11.2^{+0.8}_{0}$	14.4 ± 0.5	12.3±0.5	$3.6^{+0.4}_{0}$	7.8±0.1
4322 020 20070	4C1	$2.0^{+0.2}_{0}$	$4.8^{0}_{-0.4}$	$11.3^{+0.8}_{0}$	14.6 ± 0.5	12.5±0.5	$3.6^{+0.4}_{0}$	7.8±0.1

core half with air gap	FXC	air gap mm	tolerance on air gap	see for dimensions
4322 020 20000	3B	0.10	± 0.02	3522 200 03890
4322 020 20010	3B	0.20	± 0.02	3522 200 03890
4322 020 20020	3B	0.30	± 0.02	3522 200 03890
4322 020 20040	4B1	0.10	± 0.02	4322 020 20030
4322 020 20050	4B1	0.20	± 0.02	4322 020 20030
4322 020 20060	4B1	0.30	± 0.02	4322 020 20030
4322 020 20080	4C1	0.10	± 0.02	4322 020 20070
4322 020 20090	4C1	0.20	± 0.02	4322 020 20070
4322 020 20100	4C1	0.30	± 0.02	4322 020 20070

[1] For the combination of two potcore halves chosen at random from a lot the following μ_e values are guaranteed at T = 25 ± 10 °C.

	$\hat{B}$ gauss	frequency kHz	catalog number			
			3522 200 03890 FXC 3B	4322 020 20150 FXC 3E1	4322 020 20030 FXC 4B1	4322 020 20070 FXC 4C1
μ_e	≤ 1	100	≥ 450	≥ 920	≥ 170	≥ 96
α	≤ 1	100	≤ 35.4	≤ 24.7	≤ 55.8	≤ 74.5

[1] The mechanical force at which above mentioned values are determined is 80 Newton.

Package: The primary pack contains 30 potcore halves or 15 pre-adjusted potcores S 14/8. Please order in multiples of these quantities.

PRE-ADJUSTED POTCORES

μ_e	α	tolerance on inductance	potcore assembly number			
			FXC 3B dimensions see 3522 200 03890	FXC 3E1 dimensions see 4322 020 20150	FXC 4B1 dimensions see 4322 020 20030	FXC 4C1 dimensions see 4322 020 20070
23.1	144	± 2%				4322 022 99470
23.9	141.4	± 2%			4322 022 99420	
27.1	133	± 2%				4322 022 99460
29	128.5	± 2%			4322 022 99410	
29.5	135	± 2%	4322 022 99520			
34.4	118	± 2%				4322 022 99450
35.9	115.2	± 2%			4322 022 99400	
36	122.5	± 2%	4322 022 99510			
49	106	± 2%	4322 022 99500			
51.5	102	± 3%				4322 022 99440
55.6	94.4	± 3%			4322 022 99390	
74	85	± 3%	4322 022 99490			
128	64.5	± 25%				4322 022 99430
225	48.5	± 25%			4322 022 99380	
600	30.6	± 25%	3422 022 99480			
1230	21.4	± 25%		4322 022 99370		

Number of turns for L_{mH} is $N = \alpha\sqrt{L}$.

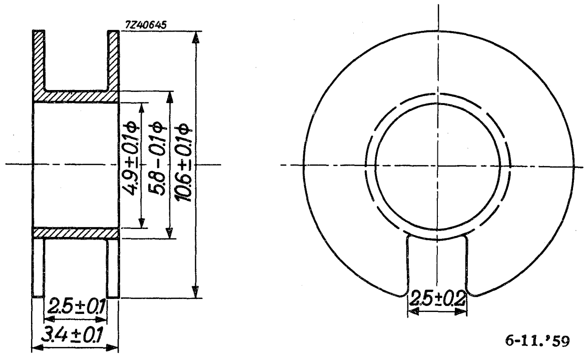
The inductance will be only within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force					
	l_e	for 3B, 3E1 and 4B1	=	1.38	cm
		for 4C1	=	1.36	cm
	$\Sigma \frac{l_e}{A_e}$	for 3B and 3E1	=	7.06	cm^{-1}
		for 4B1	=	6.65	cm^{-1}
		for 4C1	=	6.69	cm^{-1}
Effective volume	V_e	for 3B and 3E1	=	0.268	cm^3
		for 4B1	=	0.287	cm^3
		for 4C1	=	0.276	cm^3

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 43.5 \times 10^3$ Ω/H

Approximate weight of pre-adjusted potcore 3 g

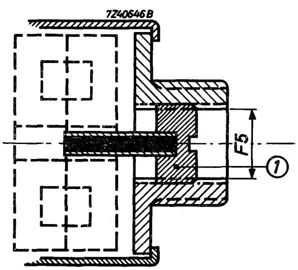
COIL FORMER

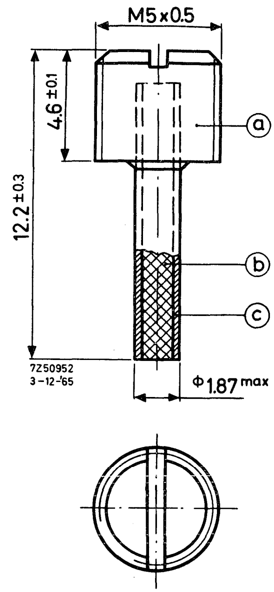


6-11.'59

catalog number	4312 021 28170
material	Polycarbonate
window area in mm^2	6.0
mean length of turns in cm	2.57
approximate weight in grams	0.1
maximum temperature in °C	130

CONTINUOUS INDUCTANCE ADJUSTMENT





(a) Screw : aluminium
(b) Pin : FXC
(c) Tube : kersina

(1) adjustor 4322 021 31390

The adjustor consists of a ferroxcube rod embedded in a ceramic tube. At the end of the ceramic tube is an F5 screw.

Depending on the place of the adjusting pin with respect to the air gap a certain inductance adjustment can be reached (see next page).

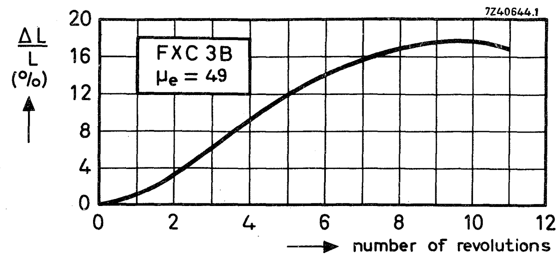


Fig. 1 Inductance variation for an effective permeability $\mu_e = 49$.

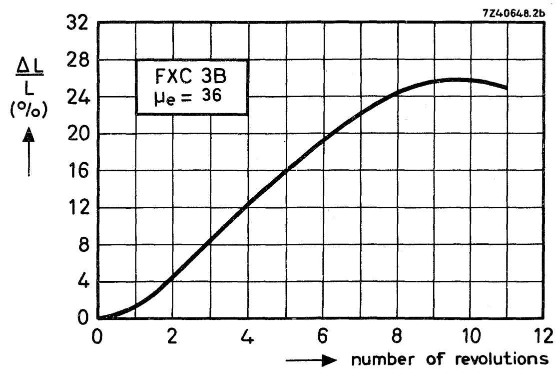


Fig. 2 Inductance variation for an effective permeability $\mu_e = 36$.

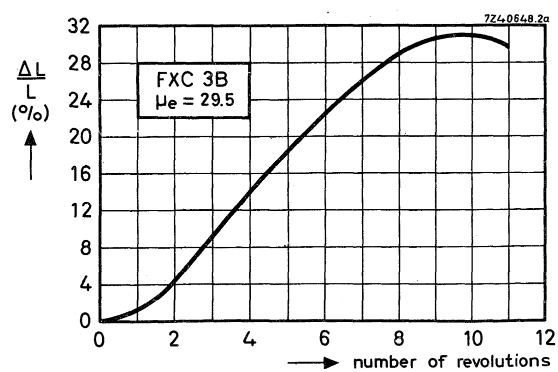
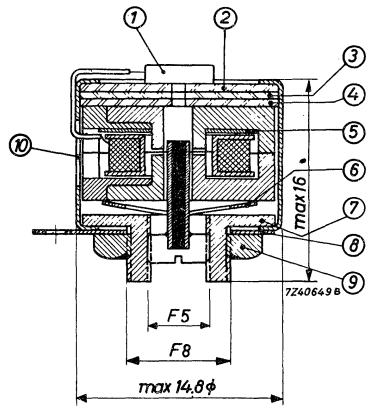


Fig. 3 Inductance variation for an effective permeability $\mu_e = 29.5$.

The figures show the inductance variation as a function of the number of revolutions of the adjustor.

MOUNTING PARTS

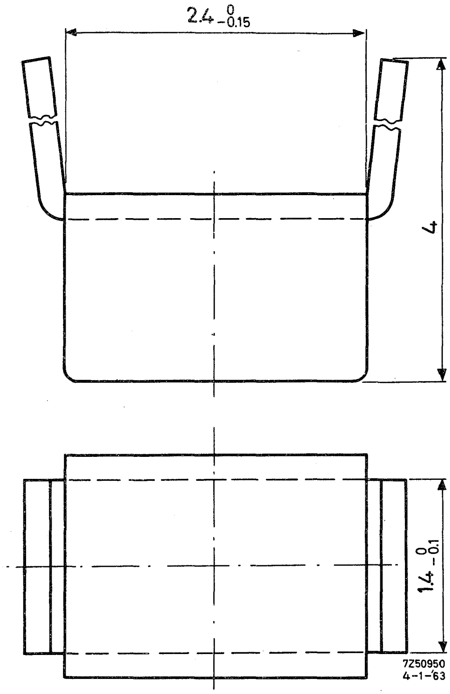


(1)	2 x soldering lug	3522 289 91650
(2)	1 x insulating disc	3522 289 96540
(3)	1 x insulating ring	3522 289 94160
(4)	1 x insulating disc	3522 289 94320
(5)	1 x insulating ring	3522 289 94150
(6)	1 x circular spring	3522 101 00000
(7)	1 x flange	3522 289 93910
(8)	1 x soldering tag	3522 289 93820
(9)	1 x nut	4322 012 30710
(10)	1 x container	3522 289 94050

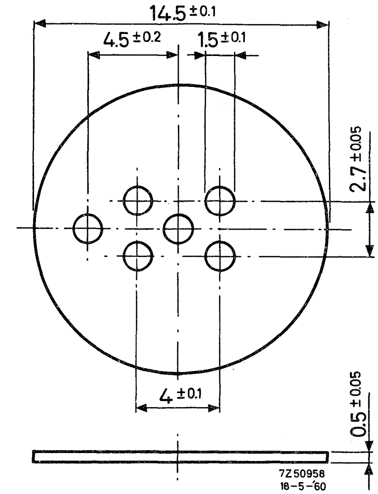
The container 3522 289 94050 (10) was developed for the potcores in the FXC 3 grades. Afterwards the potcores in the FXC 4 grades were added to the range on special request. The inner diameter of the container is $14.7^{+0.1}$ mm. So it may occur that potcores in the FXC 4 grades do no fit in the containers.

The core is spun at the flange side by means of a rotating spinning tool, like for instance our tool 710140. Data of this tool are given on request.

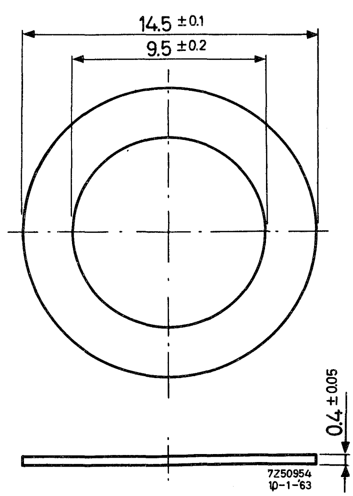
The tool is placed in a normal drilling machine with a speed of about 1300 turns per minute.



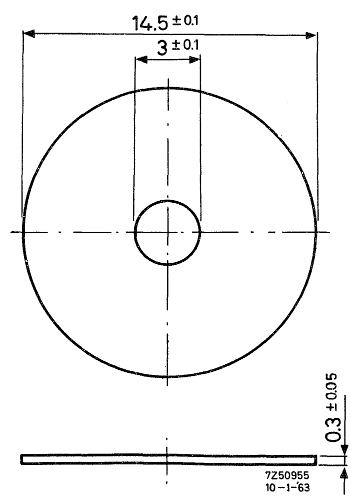
(1) Soldering lug 3522 289 91650
Material: brass, hot tin dipped



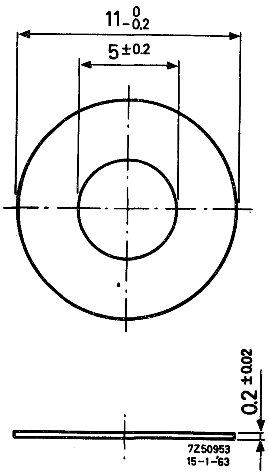
(2) Insulating disc 3522 289 96540
Material: phenolic board



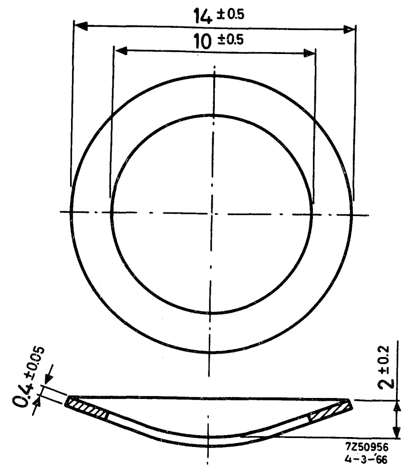
(3) Insulating ring 3522 289 94160
Material: phenolic board



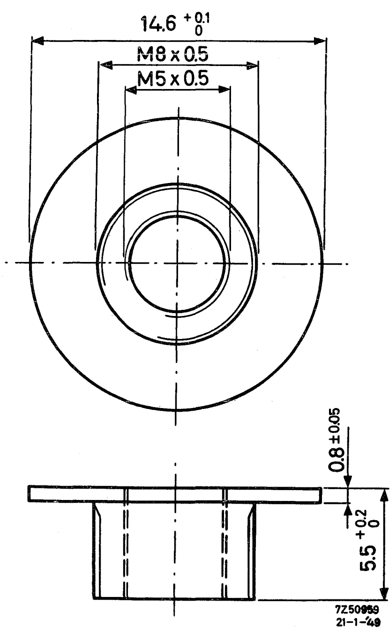
(4) Insulating disc 3522 289 94320
Material: phenolic board



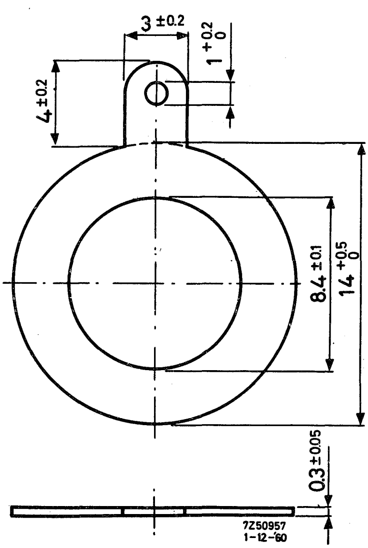
(5) Insulating ring 3522 289 94150
Material: cellulose acetate butyrate



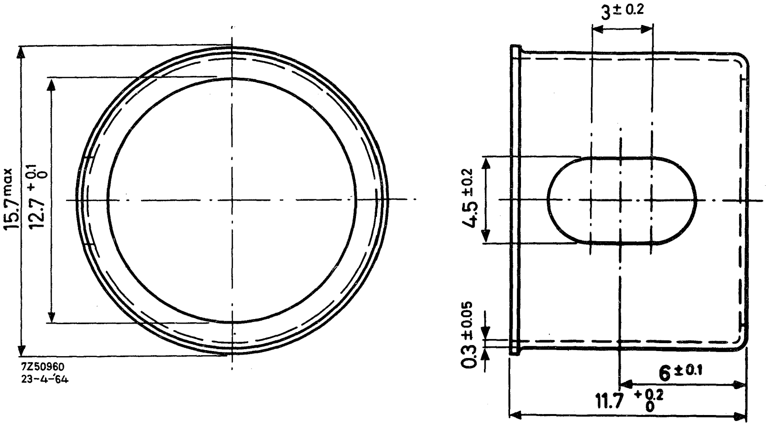
(6) Circular spring 3522 101 00000
Material: steel



(7) Flange 3522 289 93910
Material: brass, nickel plated



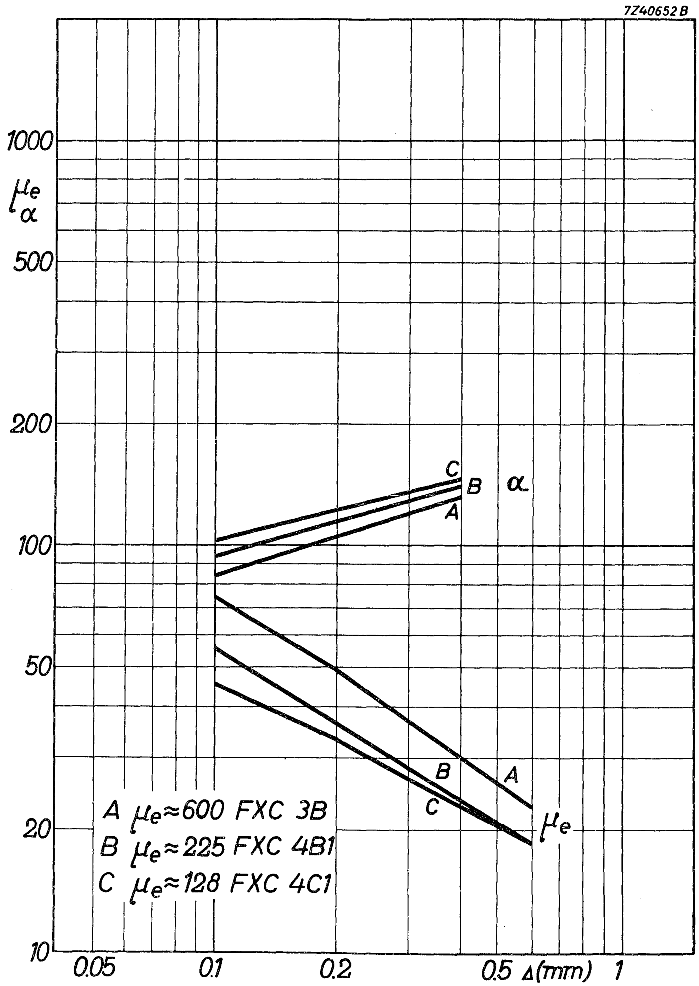
(8) Soldering tag 3522 289 93820
Material: brass, hot tin dipped



(10) Container 3522 289 94050
Material: brass, nickel plated

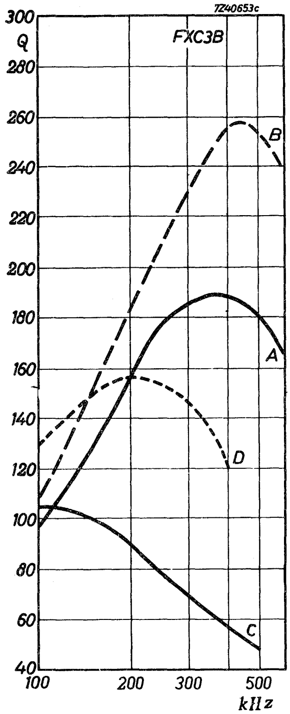
CHARACTERISTIC CURVES

μ_e - α CURVES



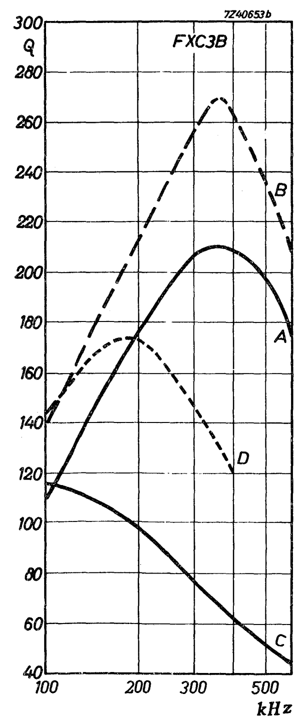
Effective permeability and turn factor for 1 mH as a function of the air gap length.

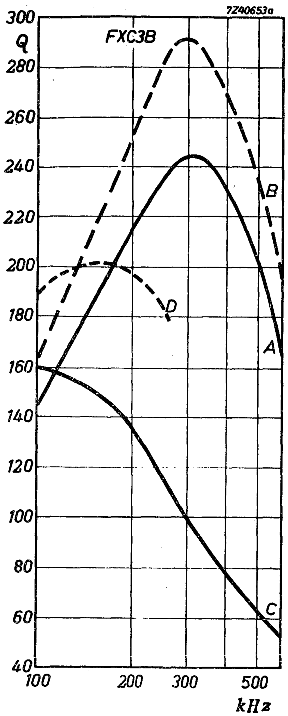
Q-CURVES



μ_e = 29.5	number of turns	wire	L(μH)
A	37	12 x 0.07	75
B	36	36 x 0.04	71
C	78	0.2 E.S.	334
D	240	0.1 E.S.	3170

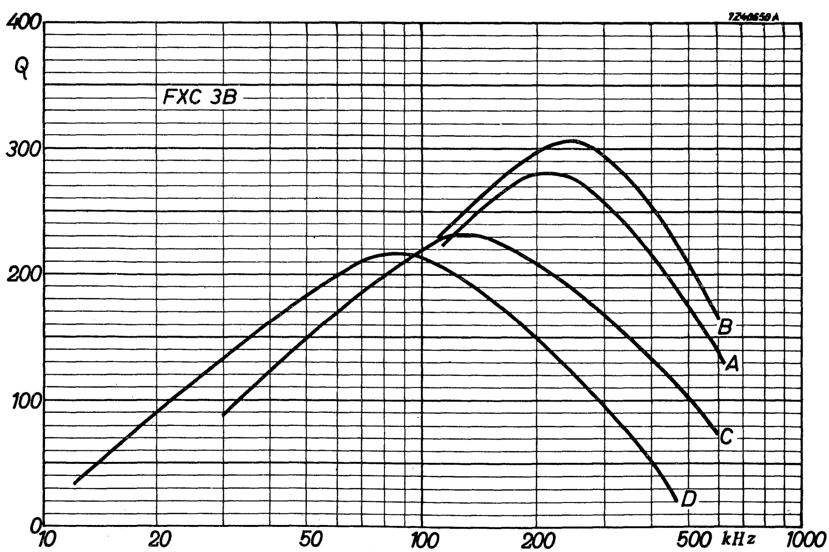
μ_e = 36	number of turns	wire	L(μH)
A	37	12 x 0.07	91
B	36	36 x 0.04	87
C	78	0.2 E.S.	410
D	240	0.1 E.S.	3860



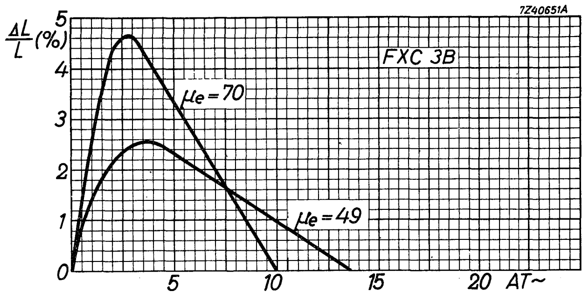


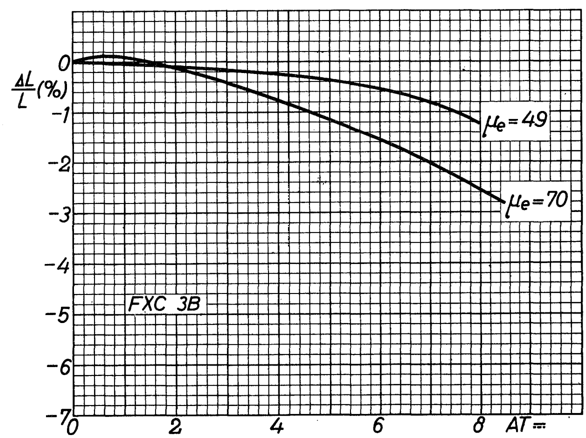
μ_e = 49	number of turns	wire	L(μH)
A	37	12 x 0.07	122
B	36	36 x 0.04	115
C	78	0.2 E.S.	540
D	240	0.1 E.S.	5130

μ_e = 74	number of turns	wire	L(μH)
A	37	12 x 0.07	189
B	36	36 x 0.04	180
C	78	0.2 E.S.	843
D	240	0.1 E.S.	7960



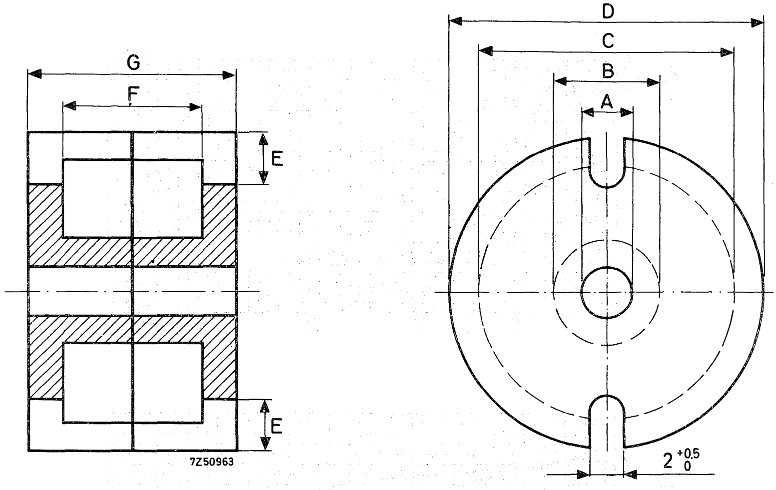
INDUCTANCE VARIATION





Inductance variation as a function of a.c. or d.c. ampere turns (AT).

POTCORES



Two versions of cores can be supplied:

1. Complete potcores with adjusted effective permeability.
2. Separate core halves to be adjusted by the user himself.

The effective permeability of the cores without air gap is determined by the initial permeability of the material, the size of the core and the smoothness of the ground surfaces at the joint between the core halves.

When ordering, the desired core should be indicated by its cat. number. These numbers are for separate core halves.

core half without airgap	FXC	dimensions in mm						
		A	B	C	D	E	F	G
4322 020 20250	3B2	$2.85^{+0.3}_{0}$	$6.12^{0}_{-0.24}$	$15^{+0.6}_{0}$	18.3 ±0.3	3 ±0.2	$8^{+0.4}_{0}$	12 ±0.1
4322 020 20260	3B3	$2.85^{+0.3}_{0}$	$6.12^{0}_{-0.24}$	$15^{+0.6}_{0}$	18.3 ±0.3	3 ±0.2	$8^{+0.4}_{0}$	12 ±0.1
4322 020 20310	4E1	$2.85^{+0.3}_{0}$	$6.12^{0}_{-0.24}$	$15^{+0.6}_{0}$	18.3 ±0.3	3 ±0.2	$8^{+0.4}_{0}$	12 ±0.1
4322 020 20320	4B1	$2.85^{+0.3}_{0}$	$6.22^{0}_{-0.24}$	$15.2^{+0.6}_{0}$	18.5 ±0.3	3 ±0.2	$8^{+0.4}_{0}$	12 ±0.1

core half with airgap	FXC	airgap mm	see for dimensions
4322 020 20280	3B3	0.1 ±0.03	4322 020 20260
4322 020 20290	3B3	0.3 ±0.03	4322 020 20260
4322 020 20300	3B3	0.5 ±0.03	4322 020 20260
4322 020 20330	4B1	0.3 ±0.03	4322 020 20320
4322 020 20340	4B1	0.5 ±0.03	4322 020 20320

On the toroidal wound core halves the following properties are guaranteed:

	temp. in °C	catalog number 4322 021			
		20250	20260	20310	20320
T.F. $\times 10^6$	+23 to +55	0 to +2	0 to +2		
D.F. $\times 10^6$ (10 min. - 100 min.)	+ 23 ±1	≤ 11.0	≤ 11.0		

For the combination of two potcore halves chosen at random from a lot the following properties are guaranteed at 25 ± 10 °C:

catalog number	μ_e at 100 kHz B ≤ 1 gauss T = 25 ± 10 °C	$\frac{\tan\delta}{\mu_i}$ (B ≤ 1 G, T = 25 ± 10 °C)				$q_{2-24-100}$ at 4 kHz, between 15 and 30 G T = 25 ± 10 °C
		at 4 kHz	at 100 kHz	at 250 kHz	at 450 kHz	
4322 020 20250	> 615	$\leq 7\times10^{-6}$	$\leq 18\times10^{-6}$	-	-	≤ 12
4322 020 20260	> 615	-	$\leq 15\times10^{-6}$	$\leq 27\times10^{-6}$	$\leq 50\times10^{-6}$	≤ 12
4322 020 20310	> 1275	-	-	-	-	-
4322 020 20320	> 190	-	-	-	-	-

The mechanical force at which above mentioned values are determined is 110 Newton.

Package: The primary pack contains 20 potcore halves or 10 pre-adjusted potcores S 18/12. Please order in multiples of these quantities.

PRE-ADJUSTED POTCORES

μ_e	α	tolerance on inductance %	potcore assembly number 4322 020 ..... ferroxcube grade 3B2	3B3	3E1
28.5	142	±1.5	-	99530	-
46	113	±1.5	-	99550	-
65	96	±1	99540	-	-
100	79	±2	99570	-	-
160	64	±2.5	99590	-	-
1700	19.1	±25	-	-	99560

Number of turns for L_{mH} is $N = \alpha\sqrt{L}$.

The inductance will be only within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force l_e for 3B2, 3B3, 3E1 = 2.36 cm
for 4B1 = 2.40 cm

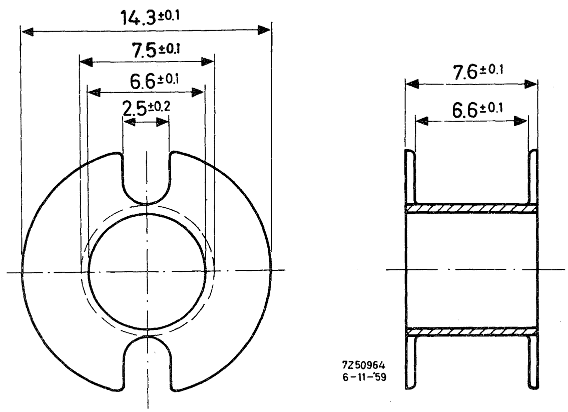
$\Sigma \frac{l_e}{A_e}$ for 3B2, 3B3, 3E1 = 7.95 cm^{-1}
for 4B1 = 7.74 cm^{-1}

Effective volume V_e for 3B2, 3B3, 3E1 = 0.700 cm^3
for 4B1 = 0.743 cm^3

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 15.22 \times 10^3$ Ω/H

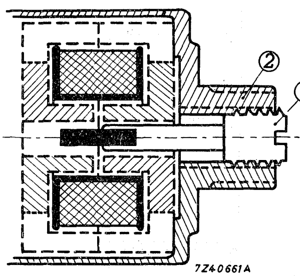
Approximate weight of pre-adjusted potcore 8 g

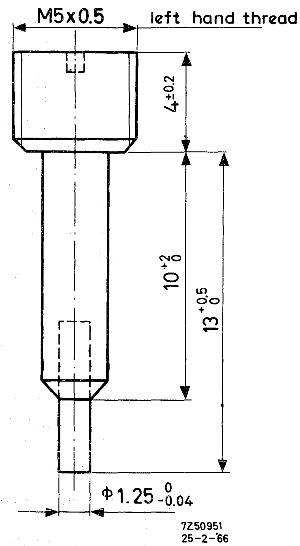
COIL FORMER

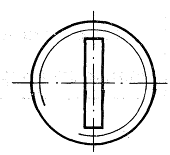


catalog number	4312 021 28150
material	Polycarbonate
window area in mm^2	22.4
mean length of turn in cm	3.42
approximate weight in g	0.25
maximum temperature in °C	130

CONTINUOUS INDUCTANCE ADJUSTMENT







(1) Catalog number of adjustor 4322 021 31400

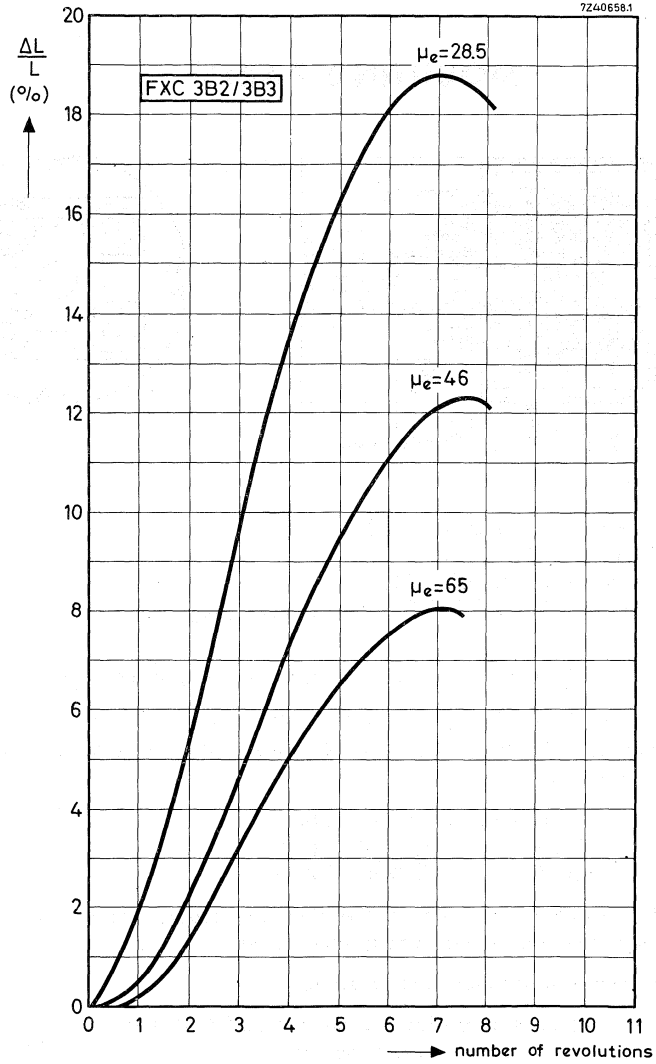
Material body: nylon
pin: FXC

The adjustor (1) with a left-hand thread turns in the top of the aluminium container (2).

The adjustor consists of a nylon body carrying a ferroxcube rod.

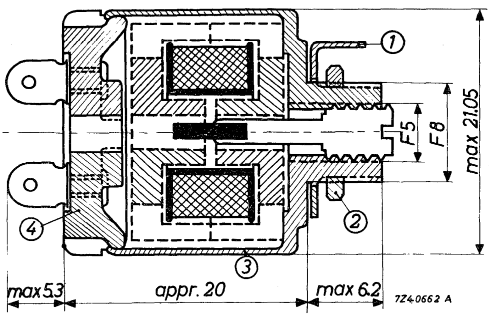
See for rate of adjustment next page.

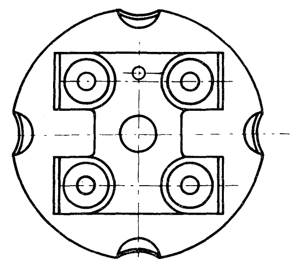
It should be taken into account that the inductance of a coil having the adjustor in zero position (i.e., screwed completely down) will be about 1 % higher than that of a similar coil without adjustor.



Inductance variation as a function of the number of revolutions of the adjustor.

MOUNTING PARTS





(1) soldering tag 3522 289 93820
(2) nut 4322 021 30710
(3) container 4322 021 31410
(4) cover 4322 021 31420 (with 4 soldering tags)

The coil is fitted on a plate or chassis by means of a nut (2).

The container (3) may be earthed by means of a soldering tag (1).

The recommended way of coil assembly is as described below. Use is made of a special set of mounting accessories. viz:

clamping screw	4322 021 31460
clamping disc	4322 021 31470
nut M3	2522 401 04008

These accessories may be used repeatedly. They should be ordered separately, in a quantity in accordance with the daily series to be manufactured.

The following components are thoroughly cleaned:

inside of aluminium container 4322 021 31410
in- and outside of core halves,
one side of the coil former 4312 021 28150

Next the core halves are glued to each other by a narrow rim of adhesive over the joint between them.

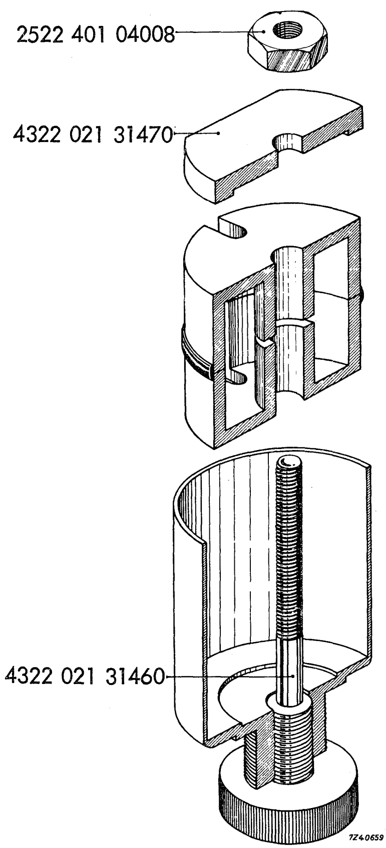
Finally some adhesive must be applied between potcore and bottom face of the container.

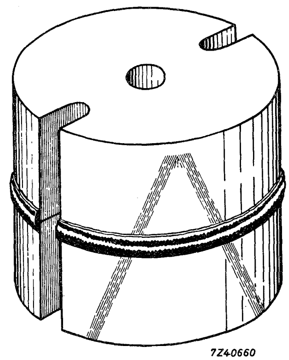
The pot is brought in the container, the clamping disc is placed upon the pot and the nut 2522 401 04008 is firmly tightened by hand. Tightening by means of tools should be avoided to prevent the pot from being damaged. A useful adhesive is, e.g. hot setting Araldite type XV of the Swiss firm Ciba in Basel.

Depending on the kind of adhesive the assembly is put in a furnace for several hours. In order not to damage the coil former, the maximum temperature may not exceed 130 °C.

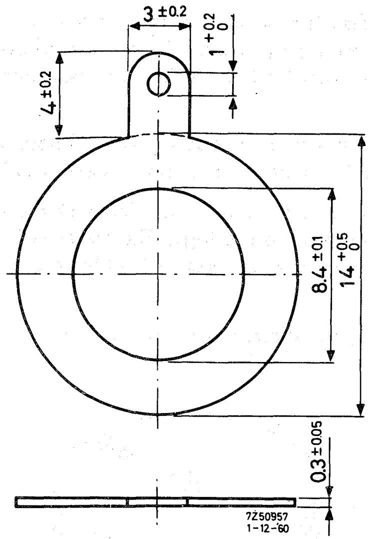
After that the nut and disc are removed and replaced by the cover, the leads of the coil being slipped through the relevant holes and soldered on to the tags. The cover is fixed by firmly pressing the wall of the casing down into the four recesses with which the cover is provided.

Now the pot may be impregnated and, after that, the clamping screw replaced by the adjusting pin.

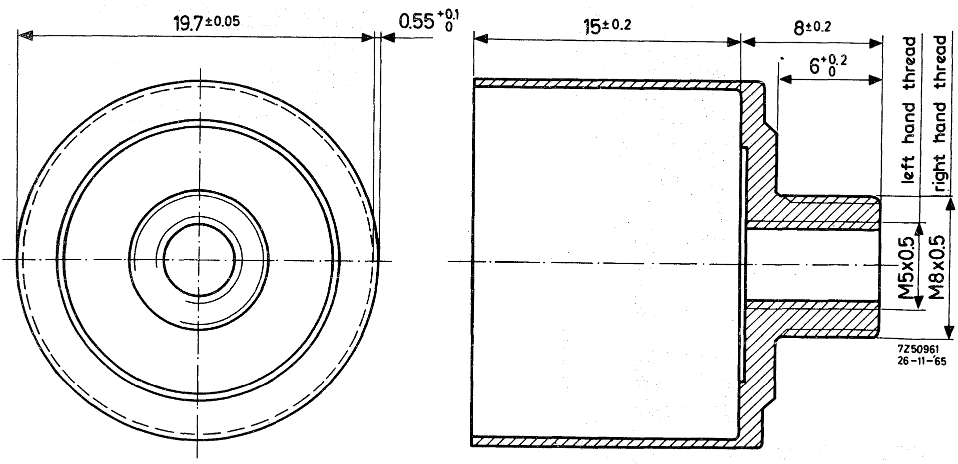




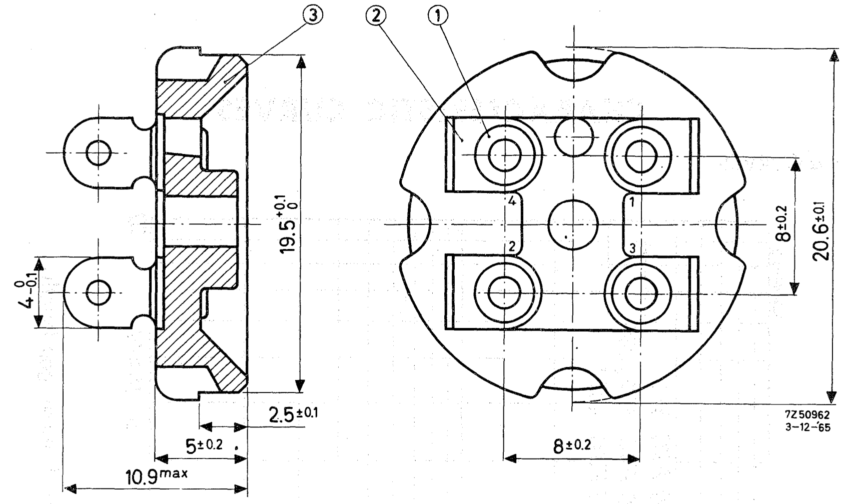
Exploded view of potcore S 18/12
with mounting accessories



(1) Soldering tag 3522 289 93820
Material: brass, hot tin dipped



(3) Container 4322 021 31410
Material: aluminium



(4) Cover 4322 021 31420

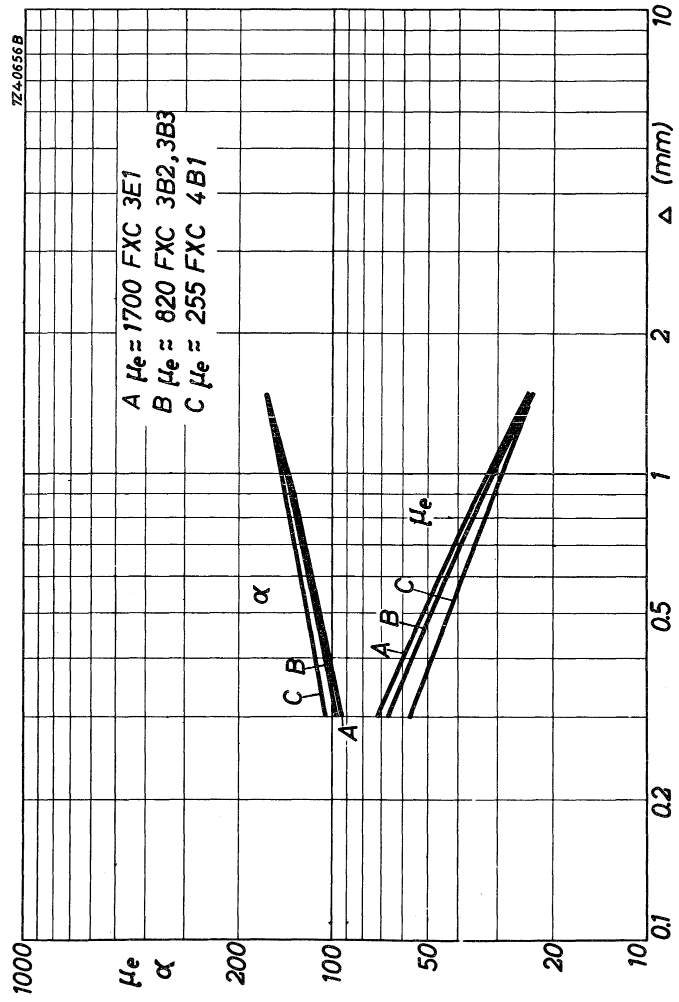
Material: (1) brass, silver plated

(2) brass, tin plated

(3) Philite

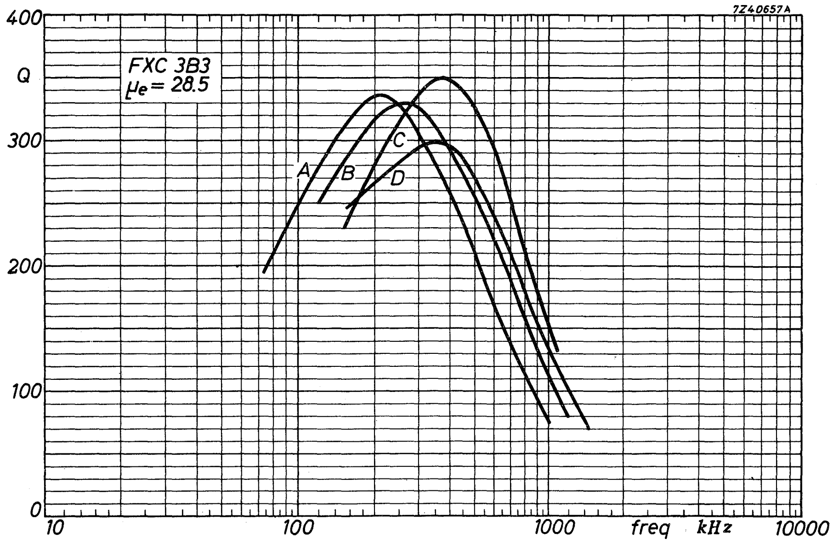
CHARACTERISTIC CURVES

μ_e - α CURVES

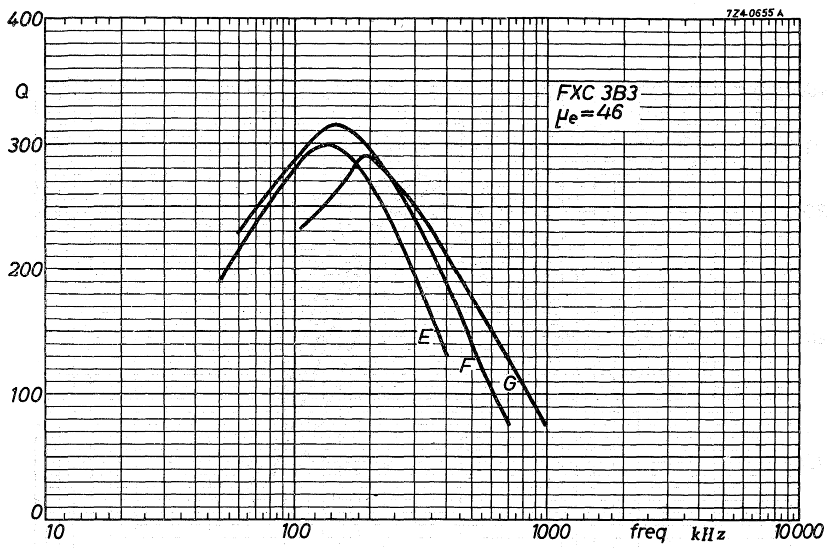


Effective permeability and turn factor for 1 mH as a function of the air gap length.

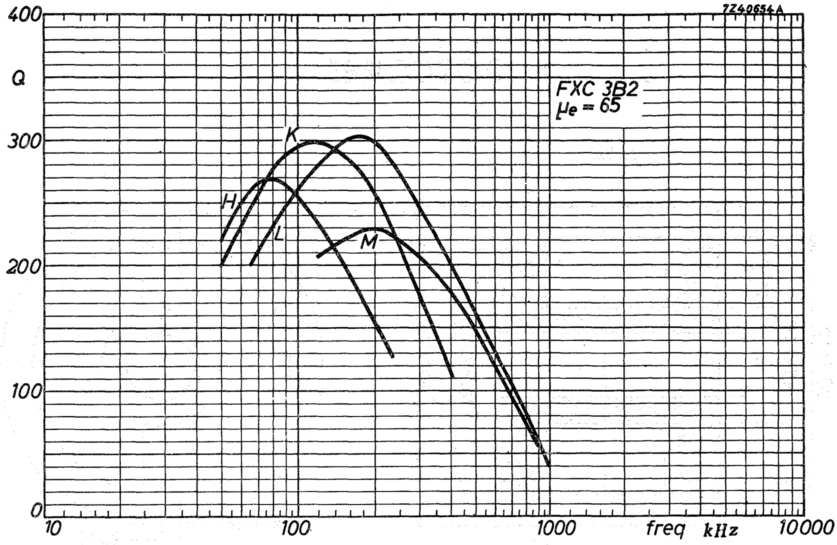
Q-CURVES



	A	B	C	D
wire N L_{mH}	56 x 0.04 105 0.51	70 x 0.04 74 0.27	30 x 0.04 100 2 sections 0.48	100 x 0.04 47 0.11

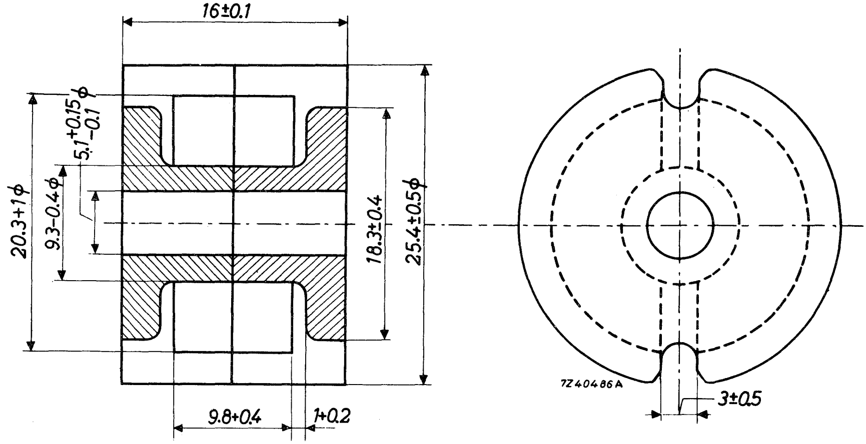


	E	F	G
wire	8 x 0.07	20 x 0.07	36 x 0.07
N	195	113	57
L_{mH}	2.96	1.01	0.22



	H	K	L	M
wire N L_{mH}	5 x 0.07 304 9.88	12 x 0.07 166 2.99	20 x 0.07 87 0.84	40 x 0.07 48 0.255

POTCORES



Two versions of cores can be supplied:

1. Complete potcores with adjusted effective permeability.
2. Separate core halves to be adjusted by the user himself.

The effective permeability of the cores without air gap is determined by the initial permeability of the material, the size of the core and the smoothness of the ground surfaces at the joint between the core halves.

When ordering, the desired core should be indicated by its cat. number. These numbers are for separate core halves.

core half without air gap	FXC	
4322 020 20500	3B2	
4322 020 20510	3B3	
4322 020 20610	3E1	
core half with air gap	**FXC**	**airgap in mm**
4322 020 20520	3B2	0.2 ± 0.015
4322 020 20530	3B2	0.6 ± 0.02
4322 020 20540	3B3	0.25 ± 0.015
4322 020 20550	3B3	0.5 ± 0.02
4322 020 20560	3B3	0.6 ± 0.02
4322 020 20570	3B3	1.0 ± 0.02

On the toroidal wound core halves the properties according table I are guaranteed:

Table I

	temperature °C	catalog number 4322 020		
		20500	20510	20610
T.F $\times 10^6$	+23 to +55	0 to +2	0 to +2	
D.F $\times 10^6$*	23 ± 1	≤11	≤11	

*(10 min - 100 min)

For the combination of two potcore halves chosen at random from a lot the following properties are guaranteed at 25 ± 10 °C:

Table II

catalog number 4322 020	μ_e at 100 kHz $\hat{B} \leq 1$ gauss T = 25 ± 10 °C	$\frac{\tan\delta}{\mu_i}$ ($B \leq 1$ G, T = 25 ± 10 °C)				$q_{2-24-100}$ at 4 kHz, between 15 and 30 G T = 25 ± 10 °C
		at 4 kHz	at 100 kHz	at 250 kHz	at 450 kHz	
20500	> 635	$\leq 7 \times 10^{-6}$	$\leq 18 \times 10^{-6}$	-	-	≤ 12
20510	> 635	-	$\leq 15 \times 10^{-6}$	$\leq 27 \times 10^{-6}$	$\leq 50 \times 10^{-6}$	≤ 12
20610	> 1395	-	-	-	-	-

The mechanical force at which above mentioned values are determined is 230 Newton.

Package: The primary pack contains 20 potcore halves or 10 pre-adjusted potcores S 25/16. Please order in multiples of these quantities.

PRE-ADJUSTED POTCORES

μ_e	α	tolerance on inductance %	potcore assembly number 4322 022 ..... ferroxcube grade 3B2	3B3	3E1
20	134	± 1	-	99660	-
45	89.4	± 1	-	99650	-
60	77.5	± 1.5	-	99640	-
80	67	± 2	99630	-	-
100	60	± 2.5	99620	-	-
150	49	± 3	99610	-	-
1860	14.2	± 25	-	-	99600

Number of turns for L_{mH} is $N = \alpha\sqrt{L}$.

The inductance will be only within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force: $l_e = 2.99$ cm

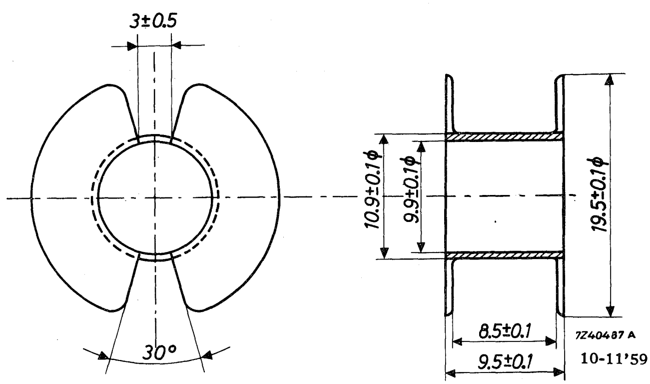
$\Sigma \frac{l_e}{A_e} = 4.70\ \text{cm}^{-1}$

Effective volume $V_e = 1.91\ \text{cm}^3$

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 8.65 \times 10^3\ \Omega/\text{H}$

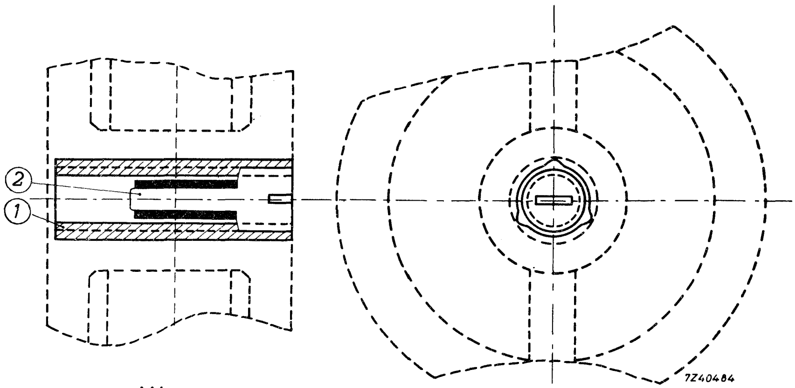
Approximate weight of pre-adjusted potcore 22.2 g

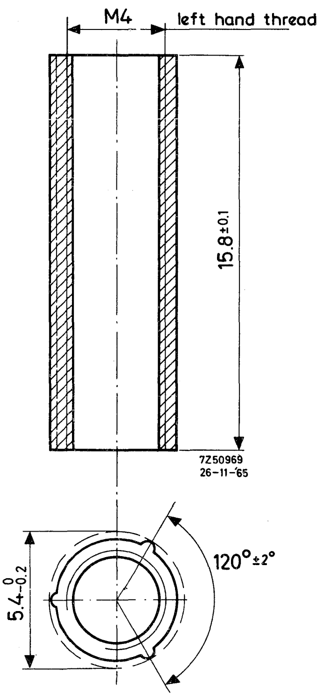
COIL FORMER

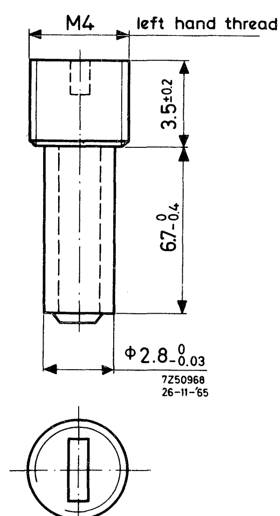


catalog number	4312 021 28130
material	Polycarbonate
window area in mm^2	36.5
mean length of turn in cm	4.76
approximate weight in grams	0.4
maximum temperature in °C	130

CONTINUOUS INDUCTANCE ADJUSTMENT







(1) Collet 4322 021 31480
Material: nylon

(2) Adjustor 4322 021 31490
Material body: nylon
tube : FXC

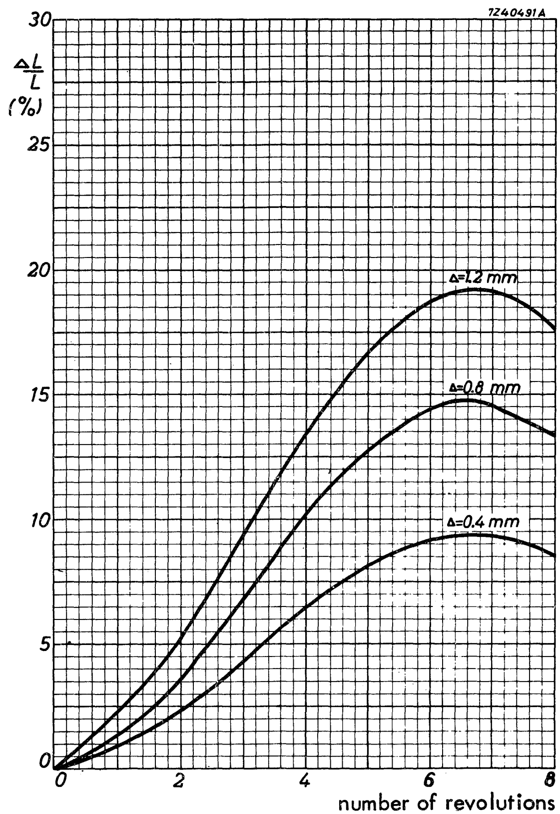
The nylon collet is glued in one of the pot core halves, for instance with Araldite D.

The adjustor consists of a ferroxcube tube situated on a nylon carrier.

Adjustor 4322 021 31490 has a ferroxcube tube of 6.5 mm length.

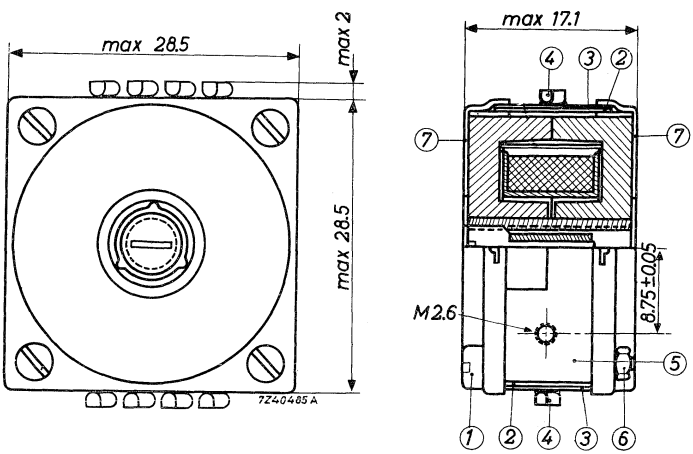
The adjustor has left-hand M4 thread.

For adjusting possibilities see below.



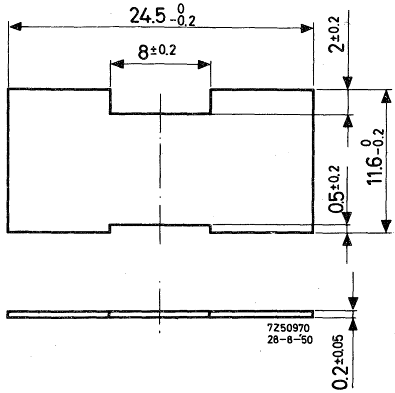
Inductance variation as a function of the number of revolutions of the adjustor.

MOUNTING PARTS

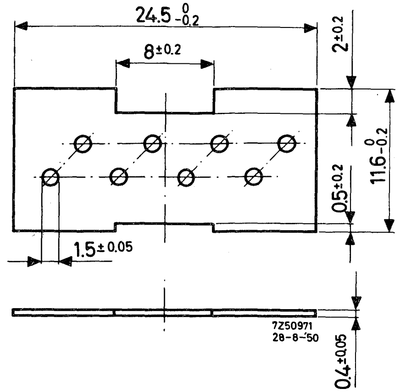


(1) 4 x screw M2 x 15 2522 001 07055
(2) 2 x insulating plate 3522 289 94220
(3) 2 x terminal plate 3522 289 94210
(4) 8 x soldering lug 3522 289 91650
(5) 1 x mounting plate 3522 289 93990
(6) 4 x nut M2 2522 401 04005
(7) 2 x clamping plate 4322 021 31500

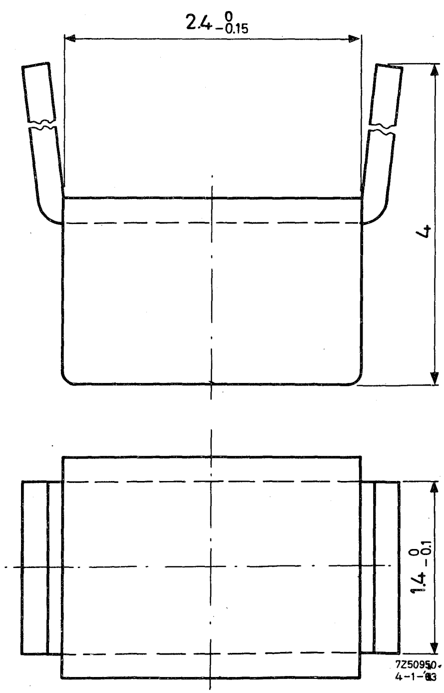
If the coil has four lead-out wires or less, one insulating plate 3522 289 94220, one terminal 3522 289 94210 and four or less soldering lugs 3522 289 91650 could be used. The mounting plate 3522 289 93990 serves for mounting the coil in the equipment by means of two screws M 2.6 (metric). These screws have to be ordered separately.



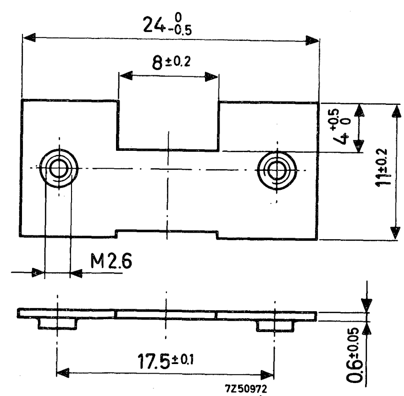
(2) Insulating plate 3522 289 94220
Material: phenolic board



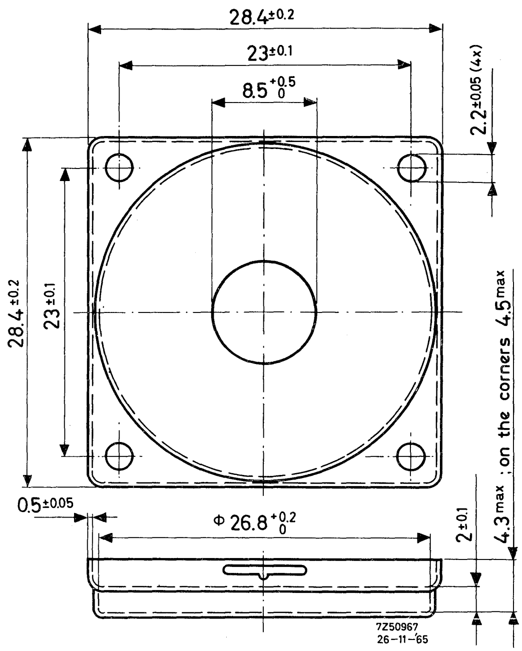
(3) Terminal plate 3522 289 94210
Material: phenolic board



(4) Soldering lug 3522 289 91650
Material: brass, hot tin dipped



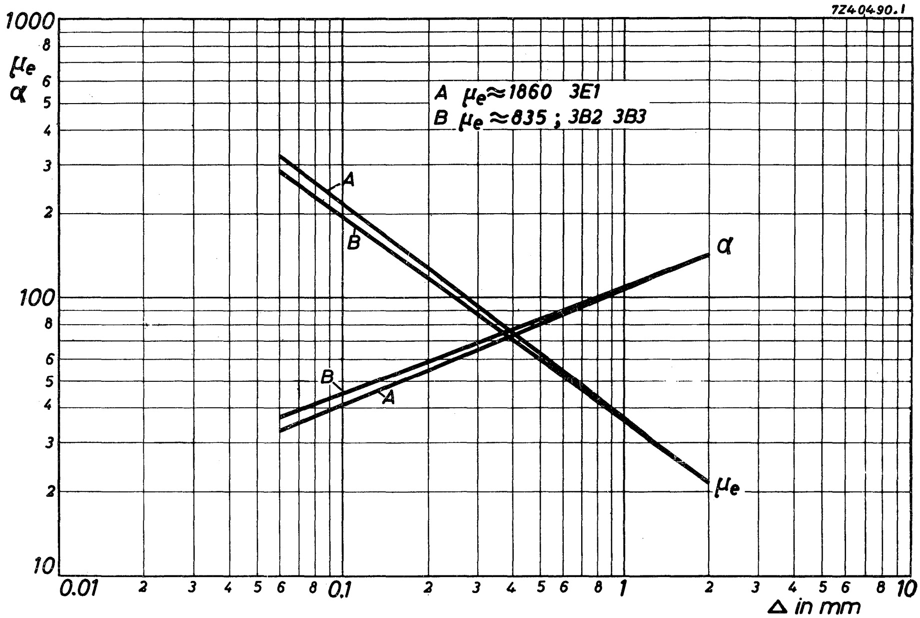
(5) Mounting plate 3522 289 93990
Material: steel, cadmium plated



(7) Clamping plate 4322 021 31500
Material: steel, nickel plated

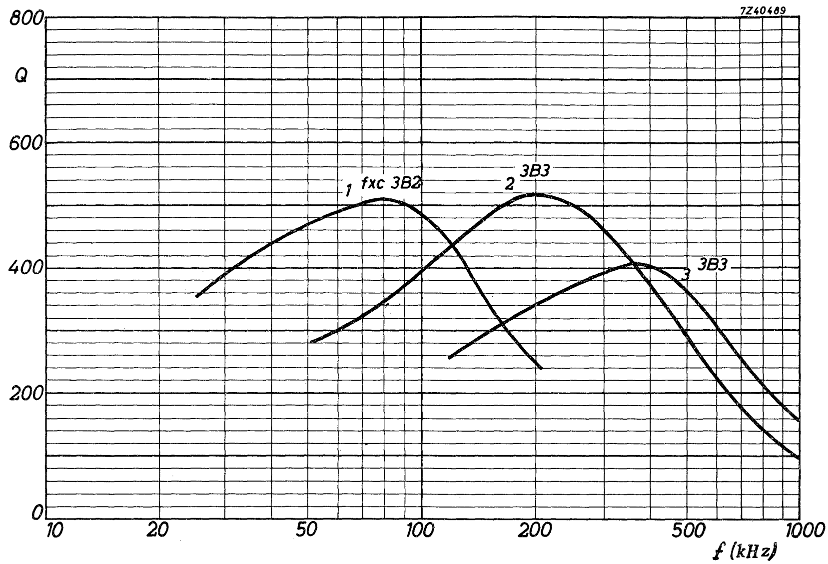
CHARACTERISTIC CURVES

μ_e - α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length.

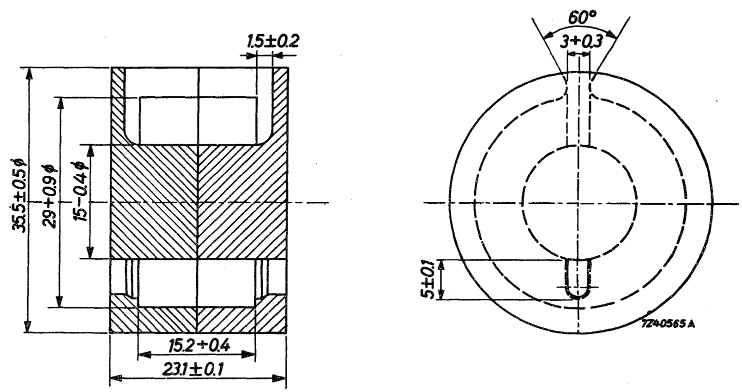
Q-CURVES



curve number	L	μ_e	winding width mm	N	wire
1	4.49 mH	73.5	8.3	150	120 x 0.07
2	299 µH	44	8.3	50	112 x 0.04
3	138 µH	35	2 x 2 *)	40	80 x 0.04

*) cross winding

POTCORES



Two versions of cores can be supplied:

1. Complete potcores with adjusted effective permeability.
2. Separate core halves to be adjusted by the user himself.

The effective permeability of the cores without air gap is determined by the initial permeability of the material, the size of the core and the smoothness of the ground surfaces at the joint between the core halves.

When ordering, the desired core should be indicated by its cat. number. These numbers are for separate core halves:

3522 200 03430 for ferroxcube 3B5
3522 020 20750 for ferroxcube 3E1

which are only supplied without air gap.

For the combination of two potcore halves chosen at random from a lot the following properties are guaranteed at 25 ± 10 °C

catalog number	μ_e at 4 kHz B ≤ 1 gauss	$\frac{\tan\delta}{\mu_i}$ at 4 kHz B ≤ 1 gauss	$q_{2-24-100}$ between 15 and 30 G at 4 kHz
3522 200 03430	> 1050	$\leq 2.8 \times 10^{-6}$	≤ 2.5
3522 020 20750	> 1770		

The mechanical force at which above mentioned values are determined is 500 Newton.

μ_e	α_{mH}	tol. on inductance %	potcore assembly number 4322 022	
			ferroxcube grade	
			3B5	3E1
80	51	± 1	99670	-
100	46	± 1.5	99680	-
125	41	± 2	99690	-
150	37	± 2	99700	-
200	32	± 3	99710	-
2250	9.7	± 25	-	99720

Number of turns for L_{mH} is $N = \alpha\sqrt{L}$.

The inductance will be only within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force

$$l_e = 5.36 \text{ cm}$$

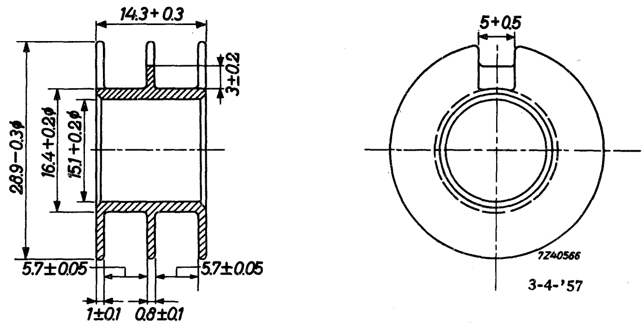
$$\Sigma \frac{l_e}{A_e} = 2.54 \text{ cm}^{-1}$$

Effective volume $V_e = 11.31 \text{ cm}^3$

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 3.8 \times 10^3 \ \Omega/\text{H}$

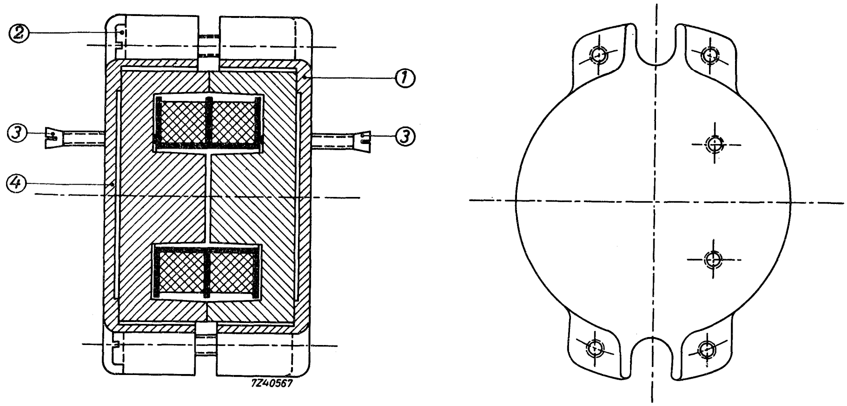
Approximate weight of pre-adjusted potcore 70 g

COIL FORMER



catalog number	3522 200 00910
material	Philite K 331
window area in mm^2	2 x 35.6
mean length of turn in cm	7.1
approximate weigth in g	2.0
maximum temperature in °C	130

MOUNTING PARTS



(1) clamping lug 4322 021 31510
(2) screw M2.6x20 2522 021 07092 (4x)
(3) screw 3522 289 95060 (2x)
(4) clamping lug B1 4322 021 31520

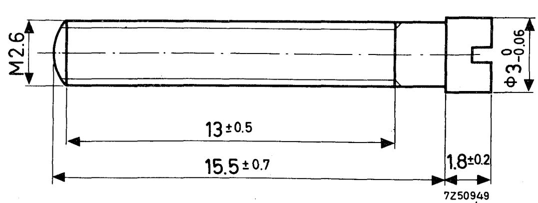
The clamping lugs are fixed together by means of four screws (pos.2).

Clamping lug (pos.1) is provided with thread for screws (pos.2), clamping lug (pos.4) has four holes only.

If the coil is used as a loading coil the inductance unbalance may be adjusted by means of the two solft aluminium screws (pos.3). After adjusting the screws (pos.3) are cut.

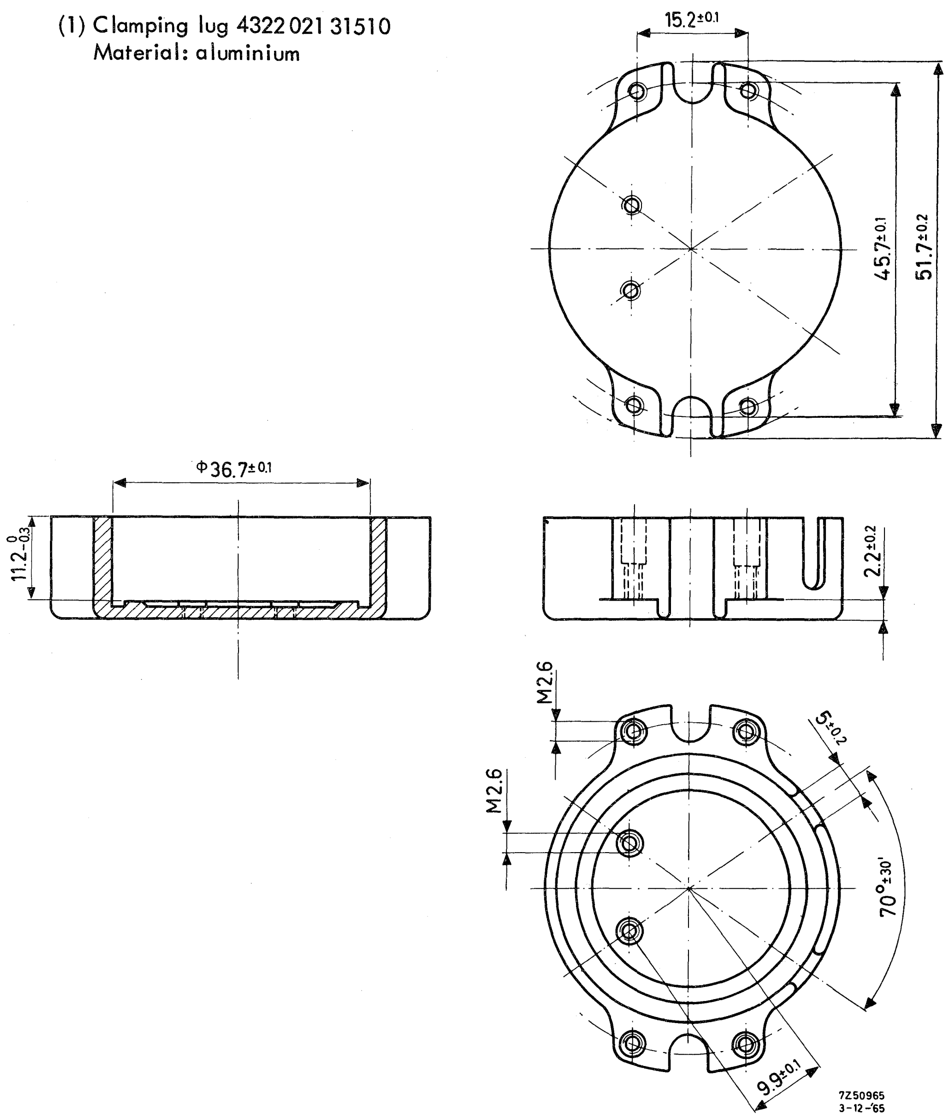
If the coil is used as a filter coil the aluminium screws (pos.3) may be omitted.

In that case glueing of the coilformer in one potcore half is recommended.

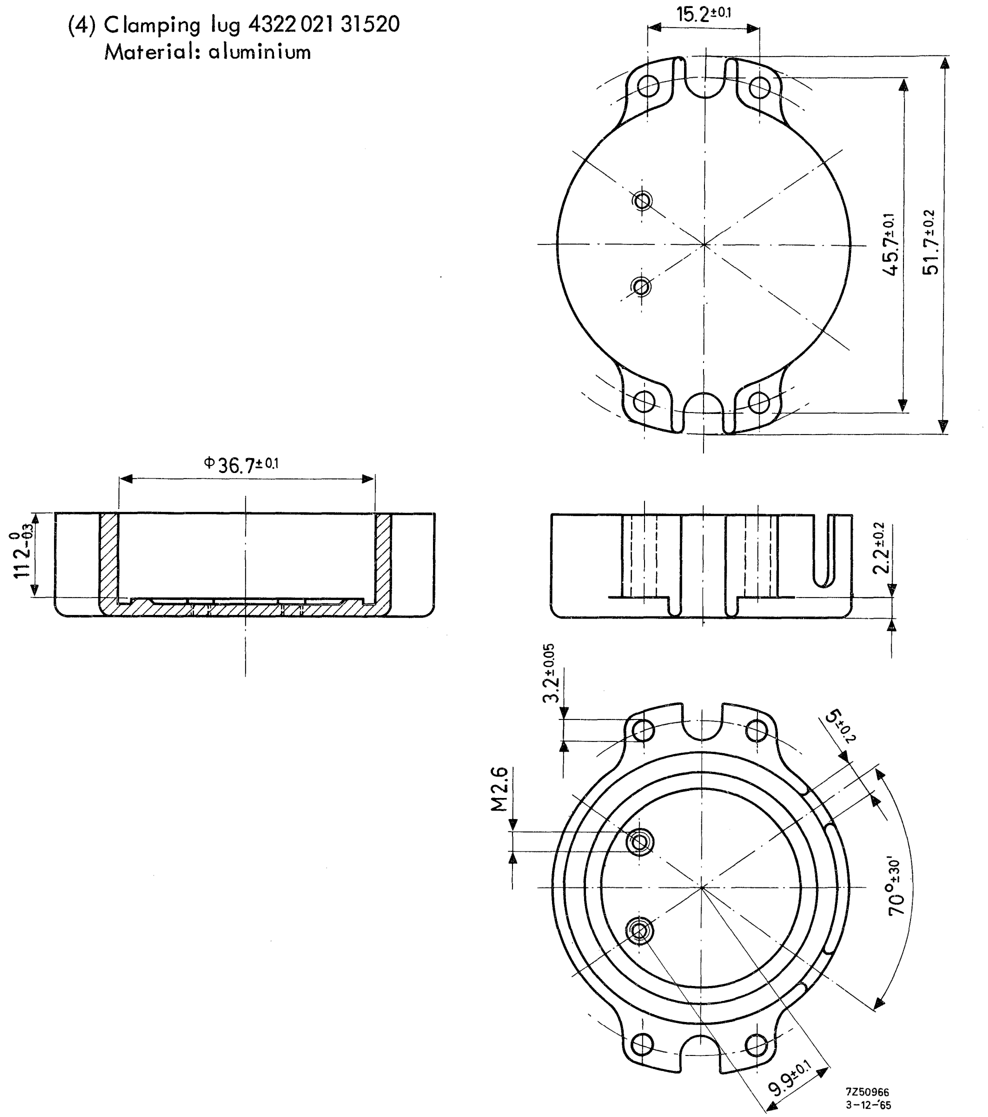


(3) Screw 3522 289 95060
Material: aluminium

(1) Clamping lug 4322 021 31510
Material: aluminium

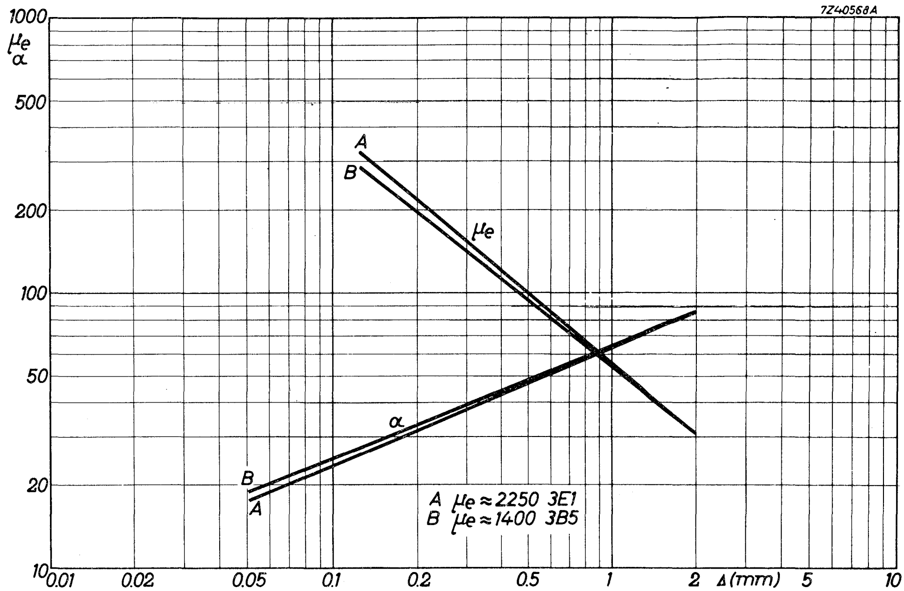


(4) Clamping lug 4322 021 31520
Material: aluminium



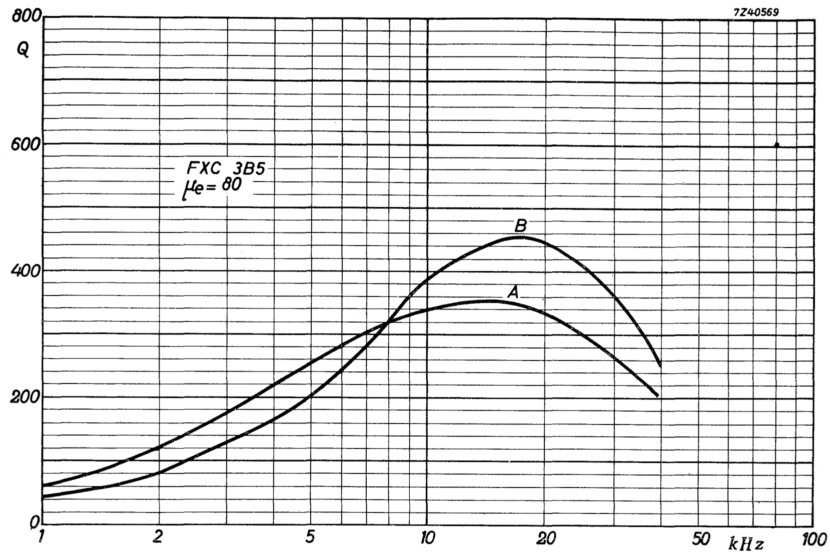
CHARACTERISTIC CURVES

μ_e - α CURVES

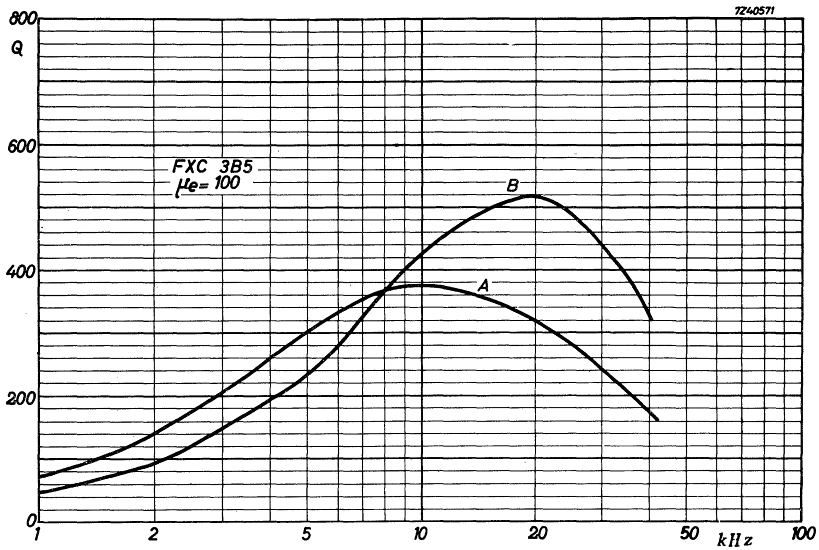


Effective permeability and turn factor for 1 mH as a function of the air gap length.

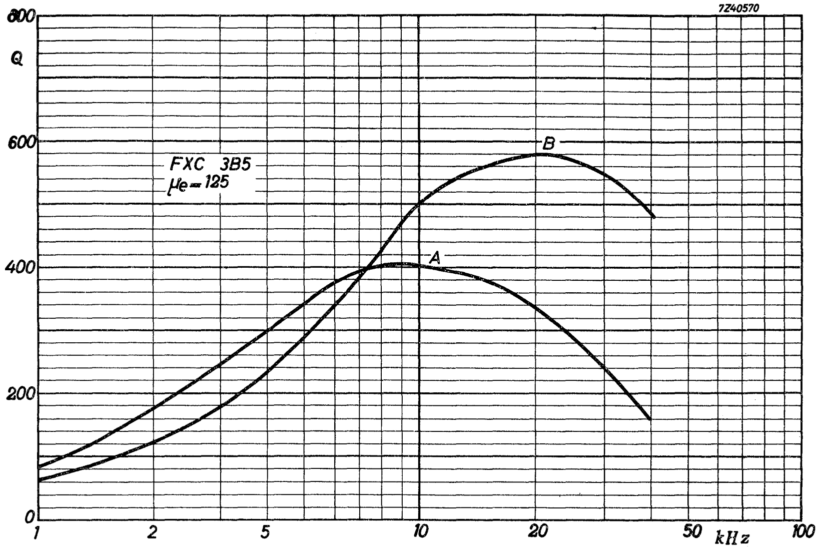
Q-CURVES



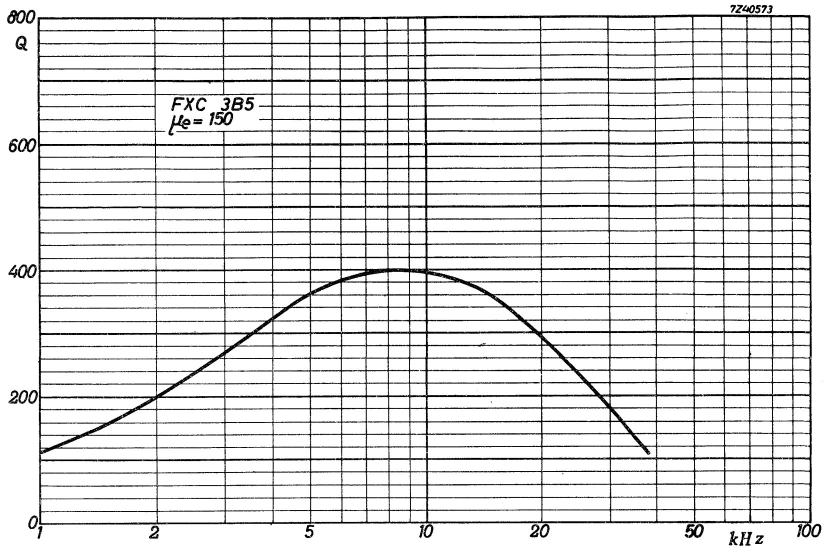
curve	N	wire	L_{mH}
A	320	0.35	39.4
B	110	50 x 0.07	4.7



curve	N	wire	L_{mH}
A	320	0.35	48.1
B	110	50 x 0.07	5.7

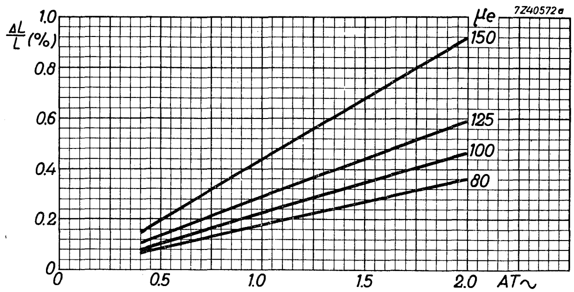


curve	N	wire	L_{mH}
A	320	0.35	61.0
B	110	50 x 0.07	7.2

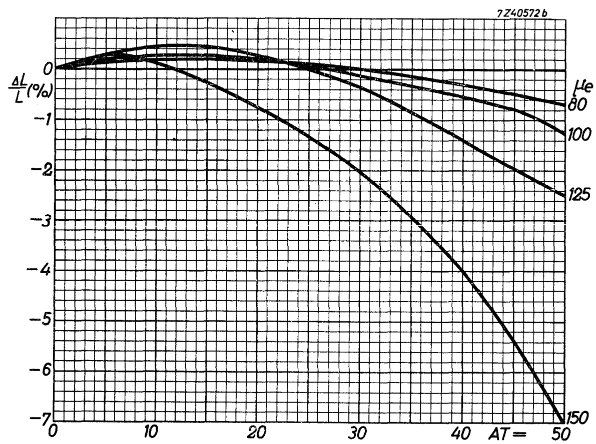


N	wire	L_{mH}
320	0.35	75.0

INDUCTANCE VARIATION

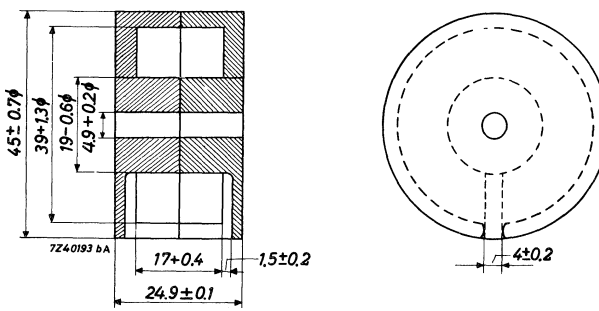


FXC3B5



Inductance variation as a function of a.c. or d.c. ampere turns (AT).

POTCORES



Two versions of cores can be supplied:

1. Complete potcores with adjusted effective permeability.
2. Separate core halves to be adjusted by the user himself.

The effective permeability of the cores without air gap is determined by the initial permeability of the material, the size of the core and the smoothness of the ground surfaces at the joint between the core halves.

When ordering, the desired core should be indicated by its cat. number. These numbers are for separate core halves:

4322 020 20850 for fxc 3B5
4322 020 20860 for fxc 3E1

which are only supplied without air gap.

For the combination of two potcore halves chosen at random from a lot the following properties are guaranteed at 25 ± 10 °C

catalog number 4322 020	μ_e at 100 kHz $\hat{B} \leq 1$ gauss	$\frac{\tan\delta}{\mu_i}$ at 4 kHz $\hat{B} \leq 1$ gauss	$q_{2-24-100}$ between 15 and 30 G at 4 kHz
20850	> 1000	$\leq 2.5 \times 10^{-6}$	≤ 2.5
20860	> 1810		

The mechanical force at which above mentioned values are determined is 550 Newton.

PRE-ADJUSTED POTCORES

μ_e	α_{mH}	tol. on inductance %	potcore assembly number 4322 022	
			terroxcube grade	
			3B5	3E1
80	47.5	± 1	99730	-
100	42.5	± 1.5	99740	-
125	38	± 1.5	99750	-
160	33	± 1.5	99760	-
200	30	± 3	99770	-
1330	11.5	± 25	99780	-
2420	8.65	± 25	-	99790

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

The inductance will be only within the guaranteed limits if the winding space of the coil is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force:

$$l_e = 6.50 \text{ cm}$$

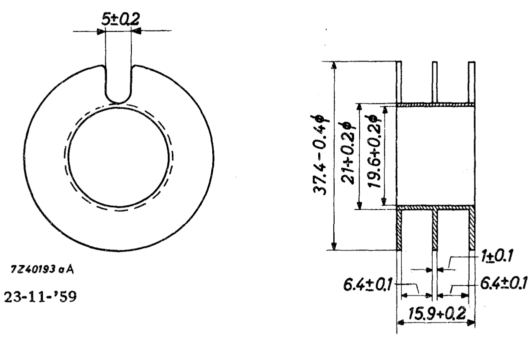
$$\Sigma \frac{l_e}{A_e} = 2.23 \text{ cm}^{-1}$$

$$V_e = 18.9 \text{ cm}^3$$

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 2.83 \times 10^3 \ \Omega/H$

Approximate weight of pre-adjusted potcore 104 g

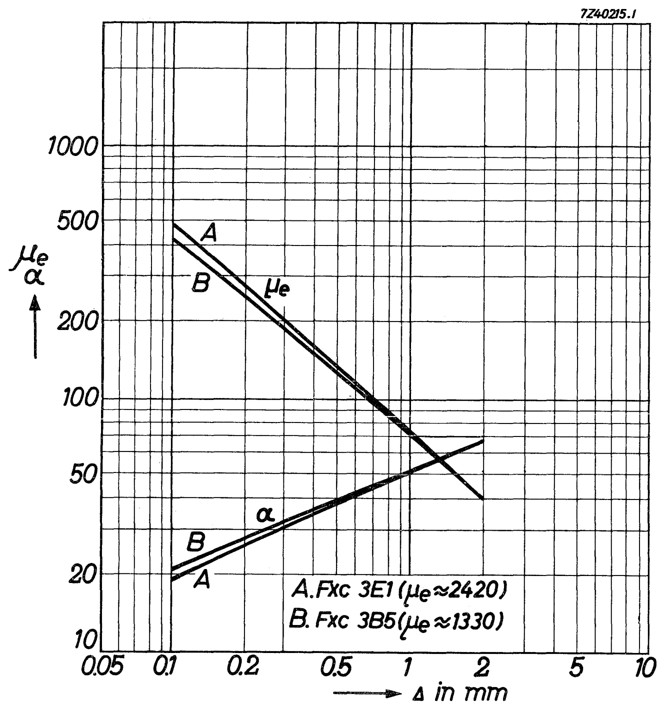
COIL FORMER



catalog number	4322 021 31530
material	nylon
window area in mm^2	2 x 52.5
mean length of turn in cm	9.1
approximate weight in g	3.3
maximum temperature in °C	70

CHARACTERISTIC CURVES

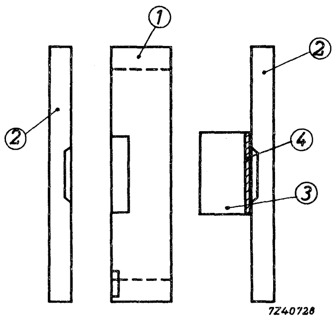
μ_e - α CURVES



Effective permeability and turn factor for 1 mH as a function of the air gap length.

D-POTCORES

POTCORES



(1) Ring
(2) Disc
(3) Slug
(4) Spacer

Fig.1. Assembly

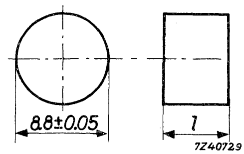


Fig.2. Slug

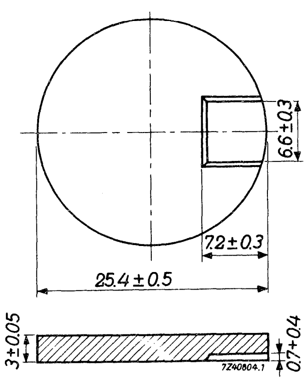


Fig.3. Disc

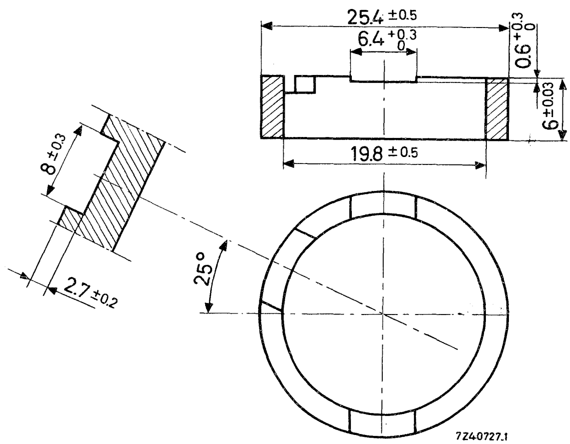


Fig.4. Ring

The potcore consists of two discs, one ring and one slug.
The slug is cemented on one of the discs.

Two versions can be supplied:
I. Complete potcores with adjusted effective permeability.
II. Separate core parts to be assembled and adjusted by the user himself.

The effective permeability of the cores is determined by the air gap, the initial permeability of the material, the size of the core and the smoothness of the ground surfaces and the joints between the core parts.
In order to limit the influence of the stray field and small displacement of the coil former it is recommended for air gaps of 0.50 mm and larger to divide this gap in two approx. equal parts at both ends of the slug using a non-metallic spacer between slug and one disc (Fig.1).

The following spacers are available:

NK 72808,	thickness 0.3 mm
3522 289 94290,	thickness 0.4 mm
3522 289 94300,	thickness 1.0 mm

These spacers have to be ordered separately.

When ordering, the desired core components should be indicated by their catalog number. These catalog numbers are for:

discs (Fig.3)	3522 200 03860	
	3522 200 03850	
rings (Fig.4)	3522 200 03900	
	3522 200 12690	
slugs (Fig.2)	3522 200 03700	l = 4.75 ± 0.03
	3522 200 03730	5.40 ± 0.03
	3522 200 03710	5.65 ± 0.03
	3522 200 03740	5.85 ± 0.03
	4322 020 25750	6 ± 0.05
	4322 020 25760	6 ± 0.05

It is recommended to order slugs of somewhat greater length than necessary. In this way it is recommended to carry out the adjustment by grinding the slug only. Grinding the ring should be avoided, since it may result in instability. Besides, it takes more time.
The mechanical force, with which the FXC parts have to be clamped together, is 220 Newton.

PRE-ADJUSTED POTCORES

μ_e	α	tol. on inductance %	potcore assembly number
			ferroxcube grade 3B2
60	65	±1.5	4322 022 99800

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

The inductance will only be within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force: $l_e = 2.74$ cm

$\Sigma \frac{l_e}{A_e} = 3.19$ cm^{-1}

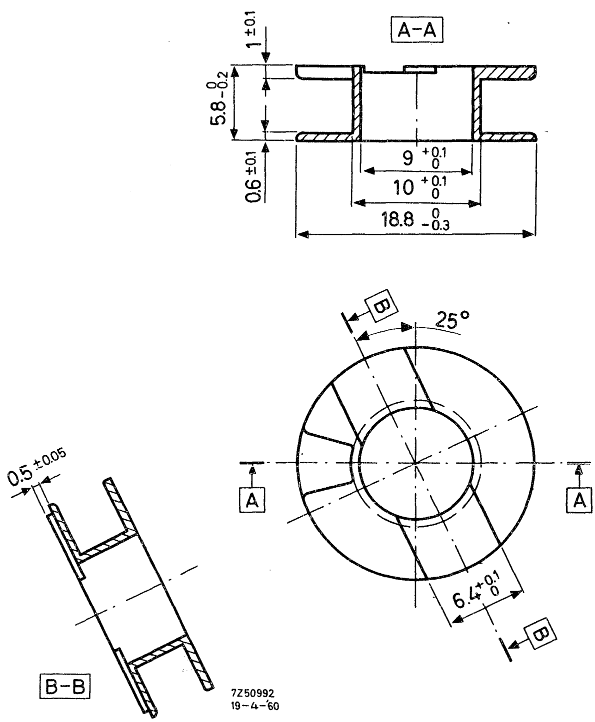
Effective volume $V_e = 2.35$ cm^3

D.C. losses $\frac{R_Q}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 11.4 \times 10^3$ Ω/H

Approx. weight of pre-adjusted potcore 22 g

The eccentricity of the cemented slug on the disc is ≤ 0.4 mm.

COIL FORMER



catalog number	4312 021 28060
material	Hostaform C
window area in mm^2	18
mean length of turn in cm	4.5
approx. weight in g	0.3
max. temperature in ^{o}C	100

Maximum number of turns (N_{max}) and copper space factor (f_{cu}) for various types and gauges of wire on coil former 4312 021 28060.

Enamelled			Enamelled, silk covered			Litz wire			Litz wire		
Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}
0.10	1300	0.565	0.10	620	0.270	3x0.04	810	0.167	5x0.07	192	0.205
0.12	900	0.565	0.11	610	0.322	5x0.04	560	0.195	8x0.07	146	0.250
0.14	590	0.505	0.12	550	0.345	8x0.04	415	0.230	10x0.07	107	0.229
0.16	480	0.535	0.14	400	0.341	10x0.04	410	0.286	12x0.07	107	0.274
0.18	360	0.510	0.16	380	0.423	12x0.04	352	0.295	16x0.07	85	0.290
0.20	320	0.557	0.18	240	0.339	16x0.04	270	0.301	20x0.07	75	0.320
0.22	280	0.590	0.20	230	0.400	20x0.04	188	0.261	24x0.07	55	0.282
0.25	215	0.525	0.22	200	0.421	24x0.04	180	0.304	28x0.07	52	0.310
0.28	184	0.626	0.25	160	0.435	28x0.04	140	0.273	32x0.07	46	0.287
0.30	155	0.608	0.28	140	0.476	32x0.04	132	0.294	36x0.07	44	0.338
0.35	110	0.586	0.30	110	0.432	36x0.04	107	0.268	40x0.07	33	0.282
0.40	80	0.558	0.35	83	0.442	40x0.04	103	0.287	45x0.07	30	0.288
0.45	75	0.560	0.40	74	0.515	45x0.04	100	0.314	50x0.07	29	0.309
0.50	51	0.555	0.45	52	0.458	50x0.04	80	0.279	56x0.07	24	0.287
			0.50	48	0.522	56x0.04	74	0.288	63x0.07	15	0.202
			0.55	32	0.421	63x0.04	70	0.306	70x0.07	14	0.209
			0.60	30	0.470	70x0.04	69	0.337	80x0.07	12	0.205
			0.65*)	16	0.294	80x0.04	48	0.267	90x0.07	11	0.211
			0.70*)	15	0.320	90x0.04	44	0.275	100x0.07	10	0.214
			0.75*)	14	0.343	100x0.04	40	0.276	112x0.07	10	0.240
			0.80*)	13	0.362	112x0.04	30	0.234	120x0.07	10	0.256
						120x0.04	27	0.225	133x0.07	5	0.142
						140x0.04	27	0.263	160x0.07	4	0.137
						150x0.04	22	0.234	180x0.07	4	0.154
						160x0.04	21	0.235			
						180x0.04	14	0.176			
						200x0.04	12	0.173			
						252x0.04	12	0.212			
						280x0.04	11	0.214			
						315x0.04	10	0.220			
						350x0.04	5	0.122			
						392x0.04	5	0.135			
						441x0.04	5	0.154			
						490x0.04	4	0.136			

*) Enamelled, double silk covered

CONTINUOUS INDUCTANCE ADJUSTMENT

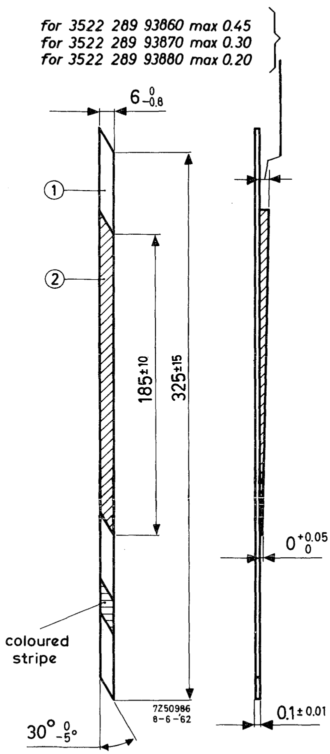


Fig.1. Trimmer

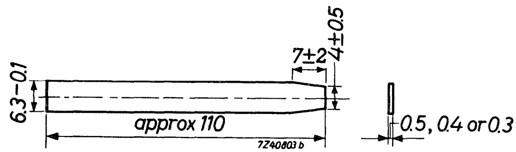


Fig.2. Metal dummy adjustor

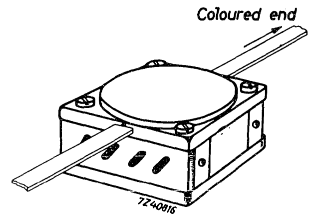


Fig.3.

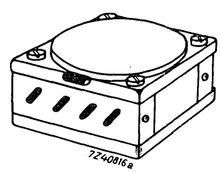


Fig.4.

Inductance adjustment may be obtained by means of strip-type trimmers.

At the top side of the ferroxcube ring are two diametrically opposite slots, 6.4 mm wide, for passing the trimmer through the air gap of the completely mounted coil. The coil formers are also provided with a 6.4 mm wide slot.

Each trimmer consists of a plastic bearer, provided with a tapered layer of magnetic material (see Fig. 1).

Impregnating must preferably be done before inductance adjustment. Before impregnating it is necessary to insert a metal dummy strip (see Fig.2) in the trimmer channel of the assembled coil. This dummy should have slightly larger dimensions than the trimmer itself.

The trimmers must be inserted into the coils with the coloured end first and with the magnetic material facing the slug (see Fig.3).

After adjustment has been made the trimmers are fixed in the slots of the clamping lugs. The protruding ends are then cut off at a distance of approximately 5 mm from the clamping lugs.

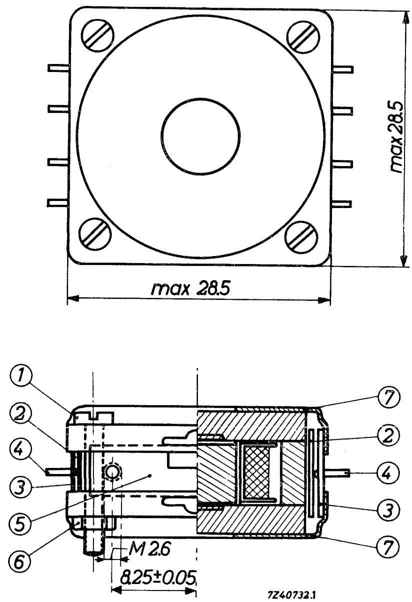
The remaining ends are folded over against the clamping lug sides and secured with a suitable adhesive, for instance "Pliobond" (see Fig.4).

It should be noted that in air gaps below 0.35 mm the trimmers cannot be pulled through completely. This results in a reduced adjustment range.

Three types of trimmers are available:

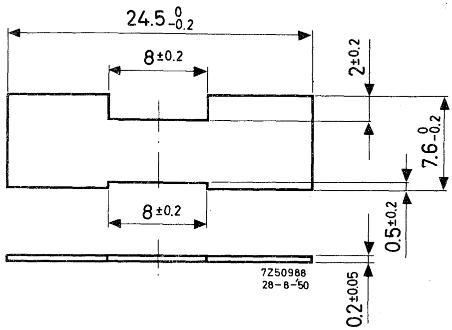
for air gaps of approx. 2 mm	3522 289 93860 with a yellow-coloured end;
for air gaps of approx. 1 mm	3522 289 93870 with a red-coloured end;
for air gaps of approx. 0.5 mm	3522 289 93880 with a green-coloured end.

MOUNTING PARTS

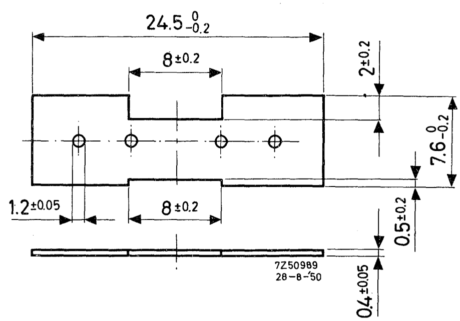


(1)	4 x screw M2 x 12	2522 001 07054
(2)	2 x insulating plate	3522 289 94230
(3)	2 x terminal plate	3522 289 94240
(4)	4 x soldering lug	3522 289 93850
(5)	1 x mounting plate	3522 289 92900
(6)	4 x nut M2	2522 401 04005
(7)	2 x clamping plate	4322 021 31500

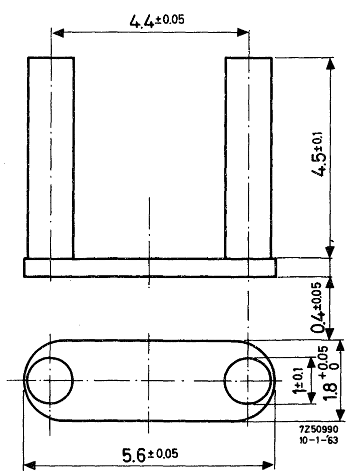
If the coil has two lead-out wires, one insulating plate 3522 289 94230, one terminal plate 3522 289 94240, two soldering lugs 3522 289 93850 and two soldering springs 3522 289 93840 can be used; this must be indicated on the order. The mounting plate 3522 289 92900 serves for mounting in the equipment by means of two screws M2.6 (metric). As a rule these screws are not supplied, unless expressly ordered.



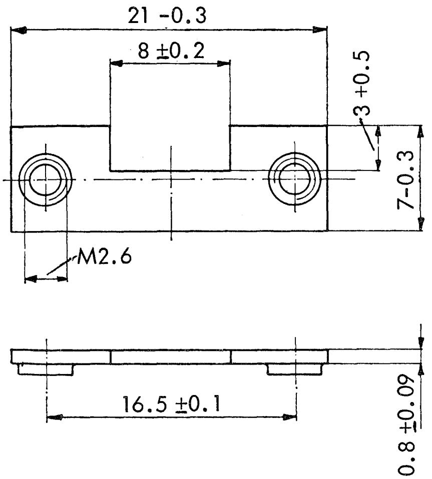
(2) Insulating plate 3522 289 94230
Material: phenolic board



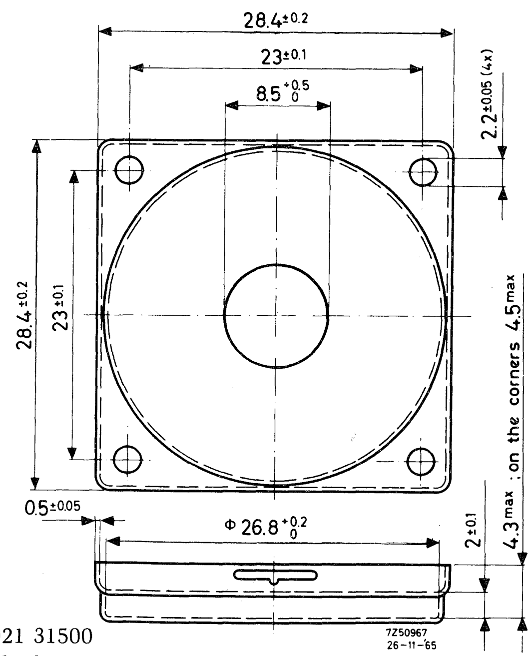
(3) Terminal plate 3522 289 94240
Material: phenolic board



(4) Soldering lug 3522 289 93850
Material: copper, hot tin dipped



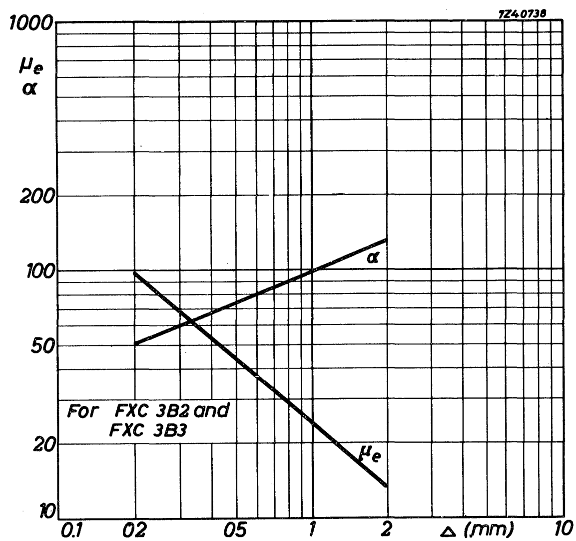
(5) Mounting plate 3522 289 92900
Material: steel, nickel-plated



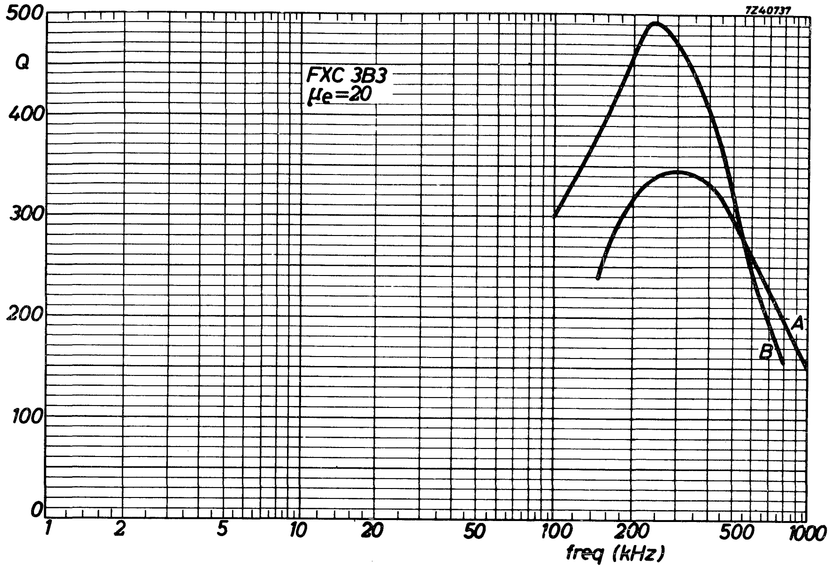
(7) Clamping plate 4322 021 31500
Material: steel, nickel-plated

CHARACTERISTIC CURVES

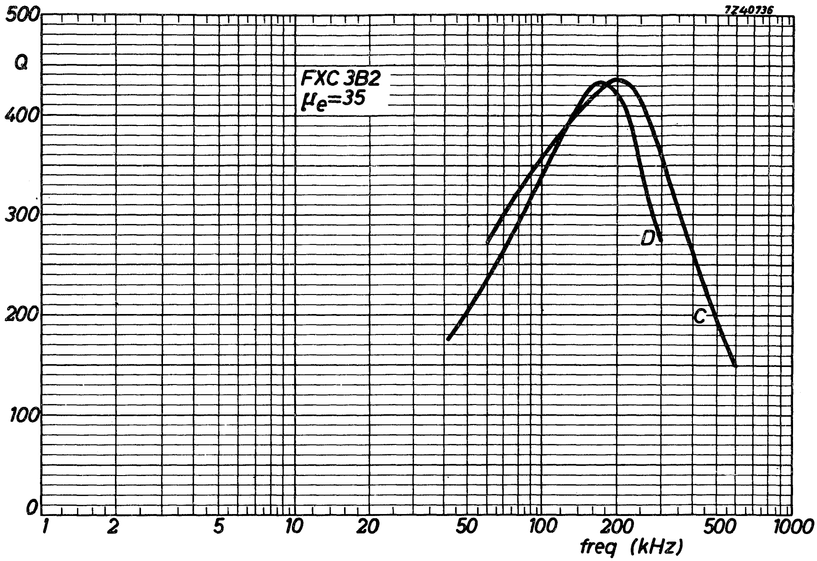
μ_e -α CURVES



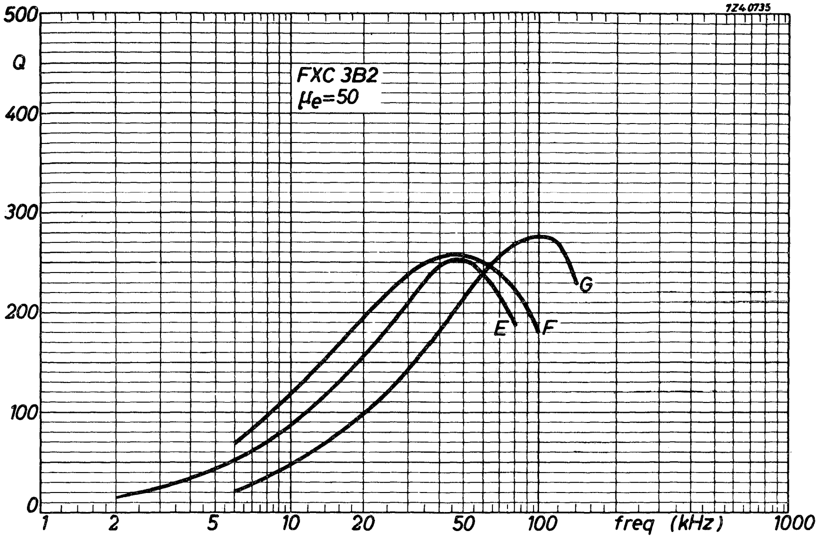
Effective permeability and turns factor as a function of the air gap length.



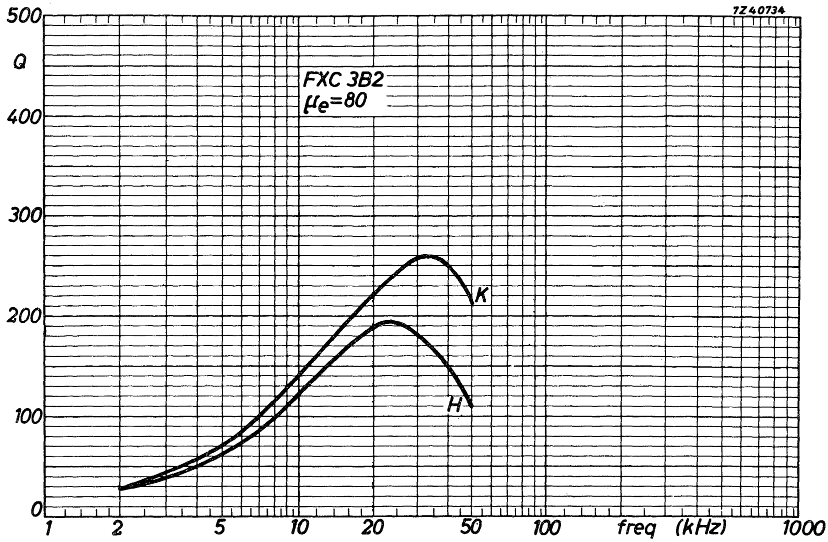
curve	wire	N	L μH
A	180 x 0.04	19	30.1
B	56 x 0.04	69	400



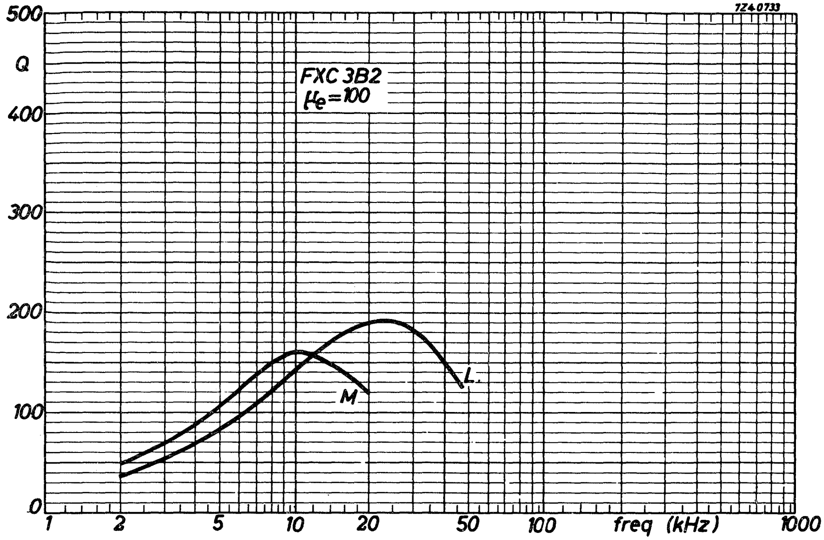
curve	wire	N	L mH
C	28 x 0.07	61	0.5
D	8 x 0.07	122	2.0



curve	wire	N	L mH
E	0.12	517	50
F	0.25	164	5.0
G	5 x 0.07	164	5.0

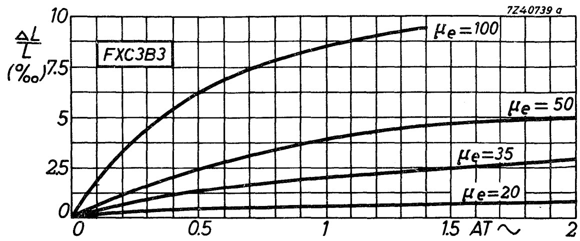


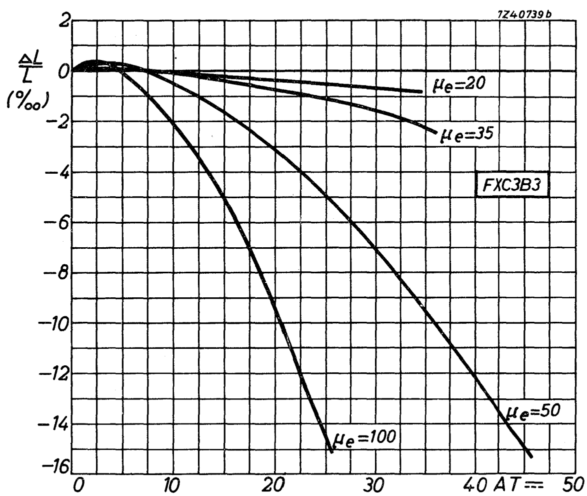
curve	wire	N	L mH
H	0.10	710	150
K	0.12	520	80



curve	wire	N	L mH
L M	0.10 0.09	743 1285	200 600

INDUCTANCE VARIATION





Inductance variation as a function of the number of AT∼ and AT⎓ for FXC 3B3.

POTCORES

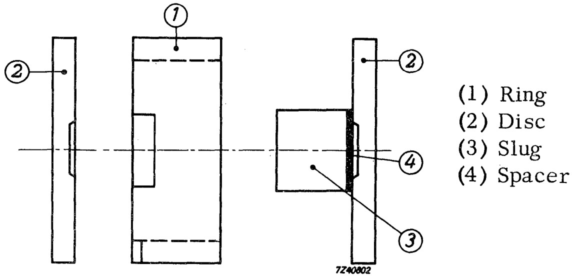


Fig. 1 Assembly

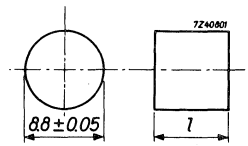


Fig. 2 Slug

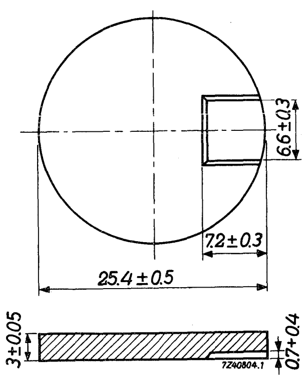


Fig. 3 Disc

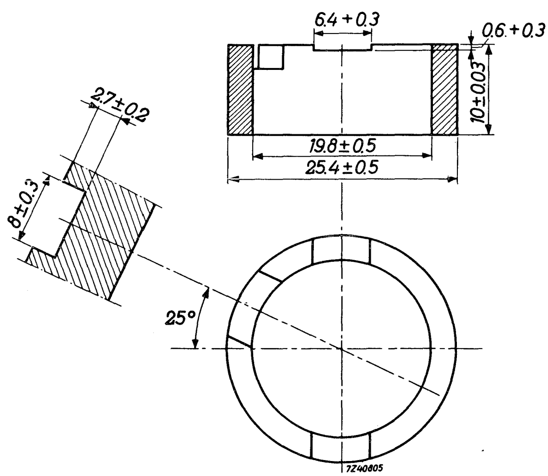


Fig. 4 Ring

The potcore consists of two discs, one ring and one slug.
The slug is cemented on one of the two discs.

Two versions can be supplied:
I. Complete potcores with adjusted effective permeability.
II. Separate core parts to be assembled and adjusted by the user himself.

The effective permeability of the cores is determined by the air gap, the initial permeability of the material, the size of the core and the smoothness of the ground surfaces and the joints between the core parts.

In order to limit the influence of the stray field and small displacement of the coil former it is recommended for air gaps of 0.50 mm and larger to divide this gap in two approx. equal parts at both ends of the slug using a non-metallic spacer between slug and one disc (see Fig.1)

The following spacers are available:

NK 72808,	thickness 0.3 mm
3522 289 94290,	thickness 0.4 mm
3522 289 94300,	thickness 1.0 mm

These spacers have to be ordered separately.

When ordering, the desired core parts should be indicated by their catalog number. These catalog numbers are for:

discs (Fig.3)	3522 200 03860	
	3522 200 03850	
rings (Fig.4)	3522 200 12690	
	3522 200 03910	
slugs (Fig.2)	3522 200 03720	l = 8.2 ±0.03
	3522 200 04130	9.15 ±0.03
	4322 020 26080	9.15 ±0.03
	3522 200 03780	9.55 ±0.03
	4322 020 25980	9.75 ±0.03
	4322 020 25970	9.85 ±0.03
	4322 020 25950	10 ±0.05
	4322 020 25960	10 ±0.05

It is recommended to order slugs of somewhat greater length then necessary. In this way it is recommended to carry out the adjustment by grinding the slug only. Grinding the ring should be avoided, since it may result in instability. Besides, it takes more time.

The mechanical force, with which the FXC parts have to be clamped together is 500 Newton.

PRE-ADJUSTED POTCORES

μ_e	α (for coil former 3522 200 13180)	tol. on inductance %	potcore assembly number	
			ferroxcube grade	
			3B2	3B3
20	122	±1.5		4322 022 99860 [1])
35	96	±1.5		4322 022 99840 [2])
60	72	±1.5	4322 022 99830	4322 022 99850
83	62	±2.5	4322 022 99820	
115	53	±2.5	4322 022 99810	

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

The inductance will only be within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force $l_e = 3.33$ cm

$\Sigma \frac{l_e}{A_e} = 4.05$ cm^{-1}

Effective volume $V_e = 2.74$ cm^3

D.C. losses (for coil former 4312 021 28040) $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 7.32 \times 10^3$ Ω/H

D.C. losses (for coil former 3522 200 00610) $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 14.32 \times 10^3$ Ω/H

Approx. weight of the pre-adjusted potcore 25 g

The eccentricity of the cemented slug on the disc is ≤ 0.4 mm.

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1) Delivered with spacer 3522 289 94300 (1 mm thickness). Recommended coil former for this μ_e value 3522 200 00610.

2) Delivered with spacer NK 728 08 (0.3 mm thickness). Recommended coil former for this and higher μ_e values 4312 021 28040.

COIL FORMERS

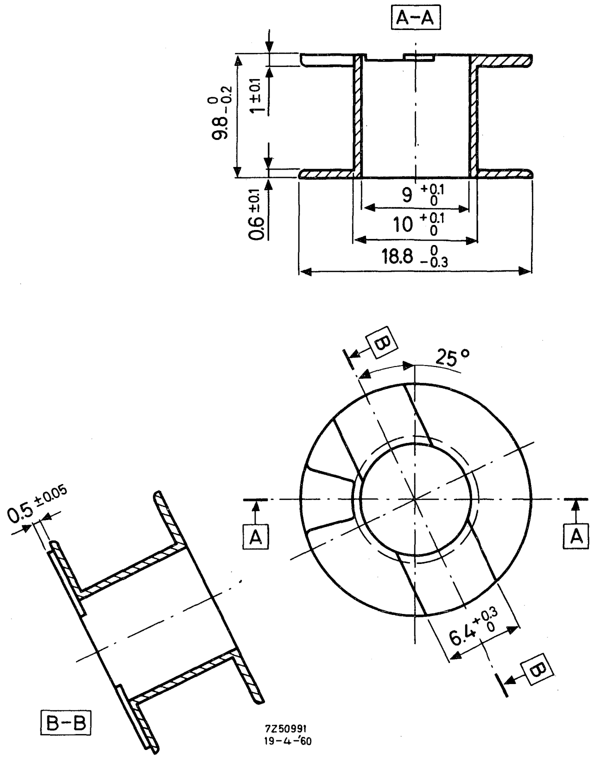


Fig. 1

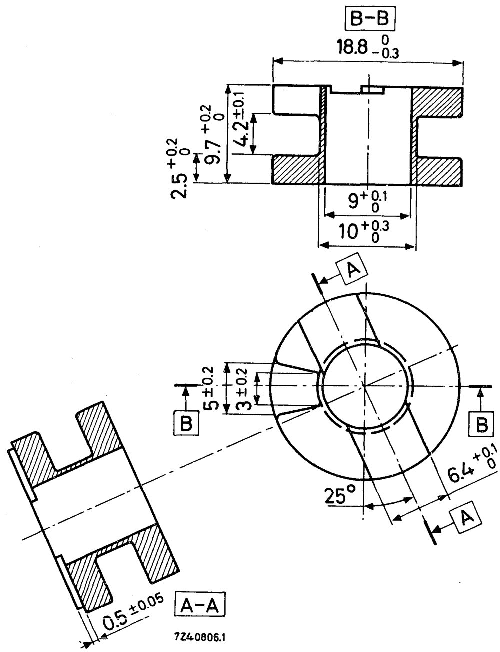


Fig. 2

catalog number	4312 021 28040	3522 200 00610
figure	1	2
Material	Polycarbonate	Philite
Window area in mm^2	35.6	18.5
Mean length of turn in cm	4.5	4.5
Approx. weight in g	0.4	1.5
Max. temperature in ^{o}C	130	130

Maximum number of turns (N_{max}) and copper space factor (f_{cu}) for various types and gauges of wire on coil former 4312 021 28040.

enamelled			enamelled, silk covered			Litz wire			Litz wire		
wire diam. mm	N_{max}	f_{cu}	wire diam. mm	N_{max}	f_{cu}	wire diam. mm	N_{max}	f_{cu}	wire diam. mm	N_{max}	f_{cu}
0.10	2500	0.550	0.10	1250	0.275	3x0.04	1700	0.180	5x0.07	400	0.216
0.12	1750	0.556	0.11	1230	0.328	5x0.04	1100	0.194	8x0.07	305	0.262
0.14	1200	0.518	0.12	1120	0.355	8x0.04	840	0.240	10x0.07	244	0.262
0.16	1040	0.586	0.14	815	0.352	10x0.04	800	0.282	12x0.07	239	0.309
0.18	770	0.550	0.16	770	0.434	12x0.04	725	0.308	16x0.07	173	0.299
0.20	680	0.598	0.18	506	0.361	16x0.04	520	0.294	20x0.07	158	0.341
0.22	603	0.639	0.20	476	0.419	20x0.04	404	0.286	24x0.07	109	0.295
0.25	435	0.538	0.22	420	0.447	24x0.04	370	0.313	28x0.07	108	0.326
0.28	382	0.659	0.25	330	0.460	28x0.04	293	0.290	32x0.07	96	0.381
0.30	315	0.625	0.28	285	0.491	32x0.04	263	0.297	36x0.07	92	0.357
0.35	225	0.606	0.30	244	0.484	36x0.04	216	0.274	40x0.07	66	0.285
0.40	169	0.595	0.35	174	0.469	40x0.04	207	0.292	45x0.07	60	0.291
0.45	150	0.568	0.40	159	0.556	45x0.04	204	0.323	50x0.07	59	0.318
0.50	108	0.594	0.45	109	0.459	5x10x0.04	154	0.271	7x10x0.07	51	0.295
			0.50	96	0.528	7x 8x0.04	150	0.295	7x 9x0.07	32	0.218
			0.55	67	0.444	7x 9x0.04	140	0.311	7x10x0.07	30	0.227
			0.60	62	0.490	7x10x0.04	140	0.345	4x20x0.07	25	0.216
			0.65*	36	0.335	4x20x0.04	99	0.279	3x30x0.07	24	0.233
			0.70*	32	0.345	3x30x0.04	92	0.292	5x20x0.07	21	0.226
			0.75*	32	0.397	5x20x0.04	91	0.320	4x28x0.07	21	0.254
			0.80*	30	0.423	4x28x0.04	60	0.237	3x40x0.07	10	0.259
						4x30x0.04	57	0.241	7x19x0.07	10	0.146
						7x20x0.04	56	0.276	8x20x0.07	9	0.156
						5x30x0.04	50	0.265	9x20x0.07	8	0.1555
						5x 4x 8x0.04	48	0.270			
						5x 3x12x0.04	44	0.279			
						10x20x0.04	26	0.183			
						7x 4x 9x0.04	23	0.204			
						28x10x0.04	24	0.237			
						7x 5x 9x0.04	22	0.244			
						7x 5x10x0.04	20	0.247			
						7x 7x 8x0.04	20	0.276			
						7x 7x 9x0.04	10	0.156			
						7x 7x10x0.04	9	0.155			

*) enamelled, double silk covered

CONTINUOUS INDUCTANCE ADJUSTMENT

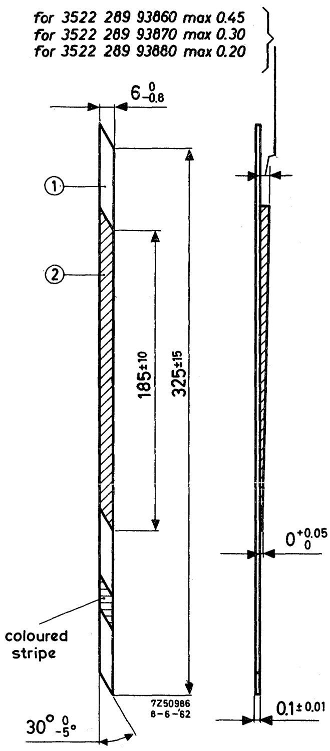


Fig. 1. Trimmer

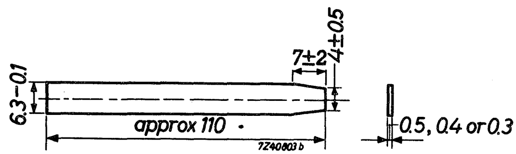


Fig. 2. Metal dummy adjustor

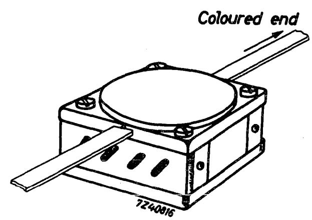


Fig. 3

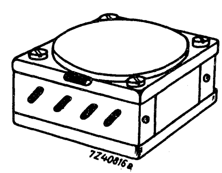


Fig. 4.

Inductance adjustment may be obtained by means of strip-type trimmers.

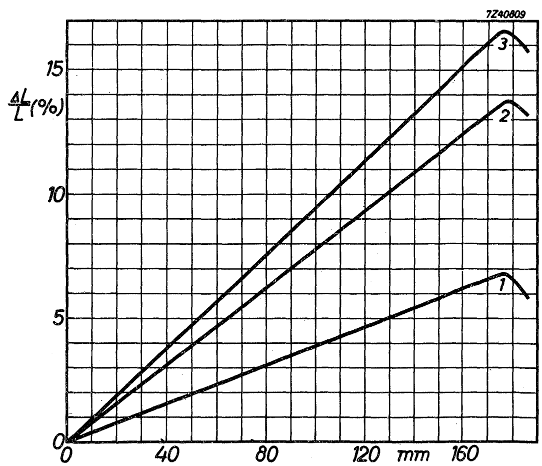
At the top side of the ferroxcube ring are two diametrically opposite slots, 6.4 mm wide, for passing the trimmer through the air gap of the completely mounted coil. Also the coil formers are provided with a 6.4 mm wide slot.

Each trimmer consists of a plastic bearer; provided with a tapered layer of magnetic material (see fig. 1).

Impregnating has to be done preferably before inductance adjustment.
Before impregnating it is necessary to insert a metal dummy strip (see fig.2) in the trimmer channel of the assembled coil.
This dummy should have slightly larger dimensions than the trimmer itself.
The trimmers have to be inserted into the coils with the coloured end first and with the magnetic material facing the slug.
After adjustment has been made the trimmers are fixed in the slots of the clamping lugs. The protruding ends are then cut off at a distance of approximately 5 mm from the clamping lugs.
The remaining ends are folded over against the clamping lug sides and secured with a suitable adhesive, for instance "Pliobond" (see fig.4).

It should be noted that in air gaps below 0.35 mm the trimmers cannot be pulled through completely. This results in a reduced adjustment range.

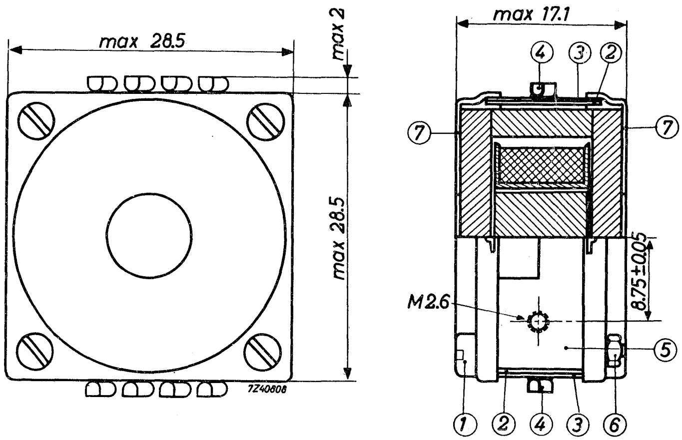
Three types of trimmers are available, namely:
for air gaps of approx. 2 mm — 3522 289 93860 with a yellow coloured end;
for air gaps of approx. 1 mm — 3522 289 93870 with a red coloured end;
for air gaps of approx. 0.5 mm — 3522 289 93880 with a green coloured end.



Inductance variation as a function of the displacement of the trimmer.

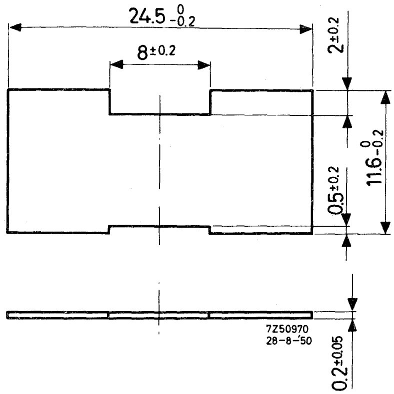
curve	trimmer	μ_e
1	3522 289 93860	60
2	3522 289 93870	60
3	3522 289 93880	35

MOUNTING PARTS

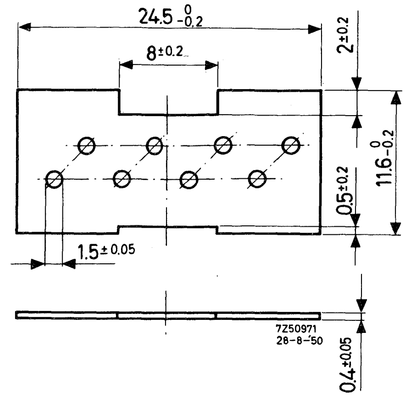


(1). 4 x screw M2x15 2522 001 07055
(2). 2 x insulating plate 3522 289 94220
(3). 2 x terminal plate 3522 289 94210
(4). 8 x soldering lug 3522 289 91650
(5). 1 x mounting plate 3522 289 93990
(6). 4 x nut M2 2522 401 04005
(7). 2 x clamping plate 4322 021 31500

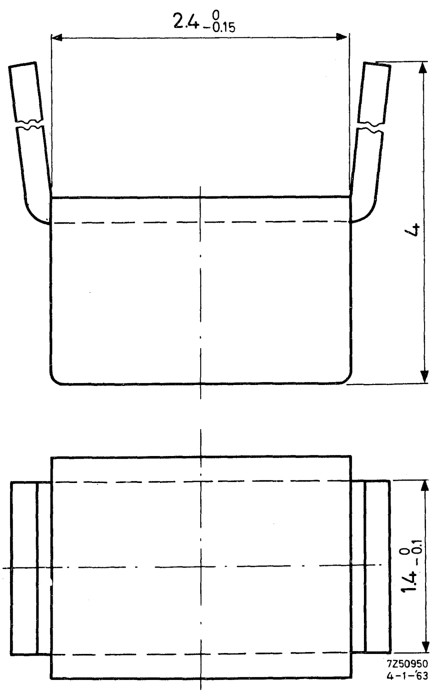
If the coil has four lead-out wires or less, one insulating plate 3522 289 94220, one terminal 3522 289 94210 and 4 or less soldering lugs 3522 289 91650 can be used. The mounting plate 3522 289 93990 serves for mounting the coil in the equipment by means of two screws M 2.6 (metric).
As a rule these screws are not supplied.



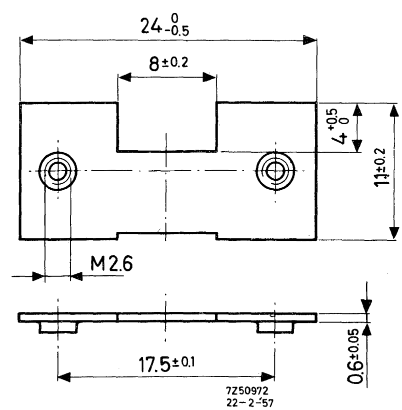
(2) Insulating plate 3522 289 94220
Material: phenolic board



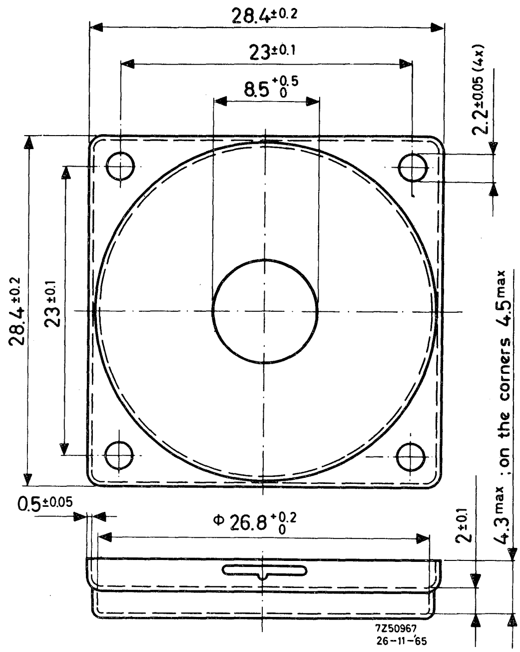
(3) Terminal plate 3522 289 94210
Material: phenolic board



(4) Soldering lug 3522 289 91650
Material: brass, tin-dipped



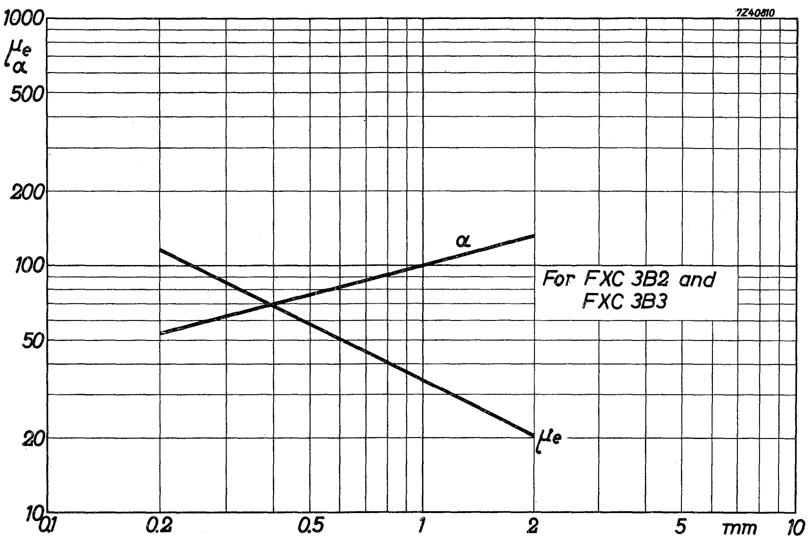
(5) Mounting plate 3522 289 93990
Material: steel, cadmium plated



(7) Clamping plate 4322 021 31500
Material: steel, nickel plated

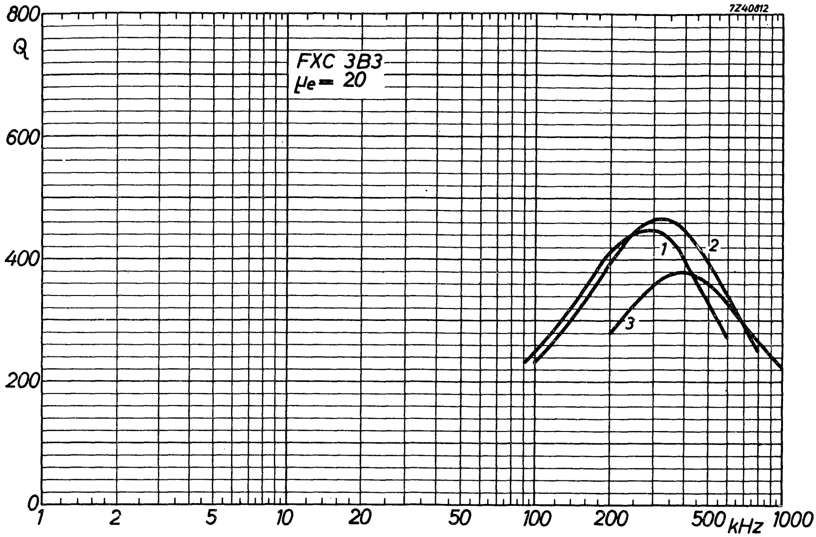
CHARACTERISTIC CURVES

μ_e-α CURVES



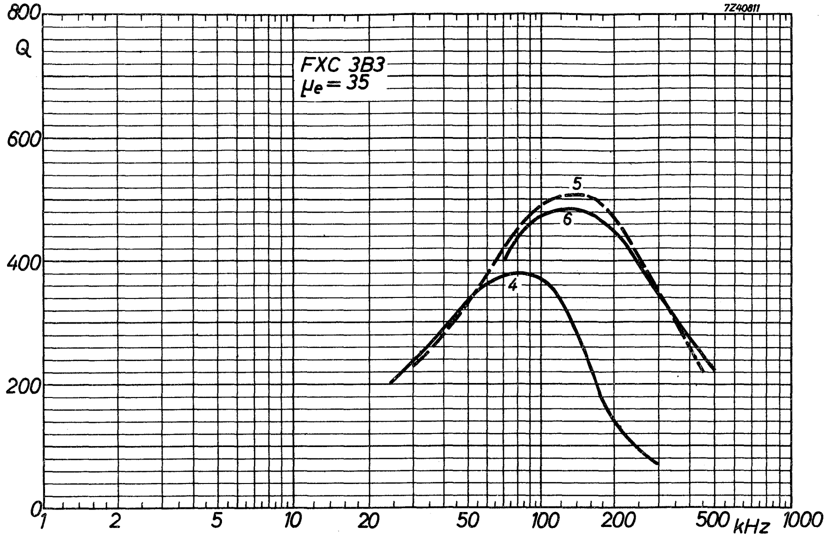
Effective permeability and turns factor as a function of the air gap length.

Q-CURVES



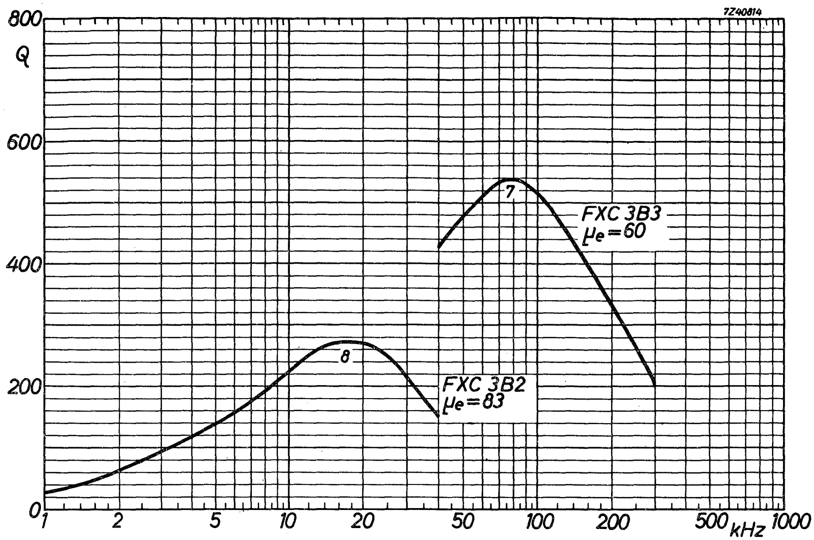
Q-curves of core with coil former 3522 200 00610

curve	wire	N	L mH
1	36 x 0.04	95	0.59
2	90 x 0.04	39	0.10
3	160 x 0.04	21	0.029



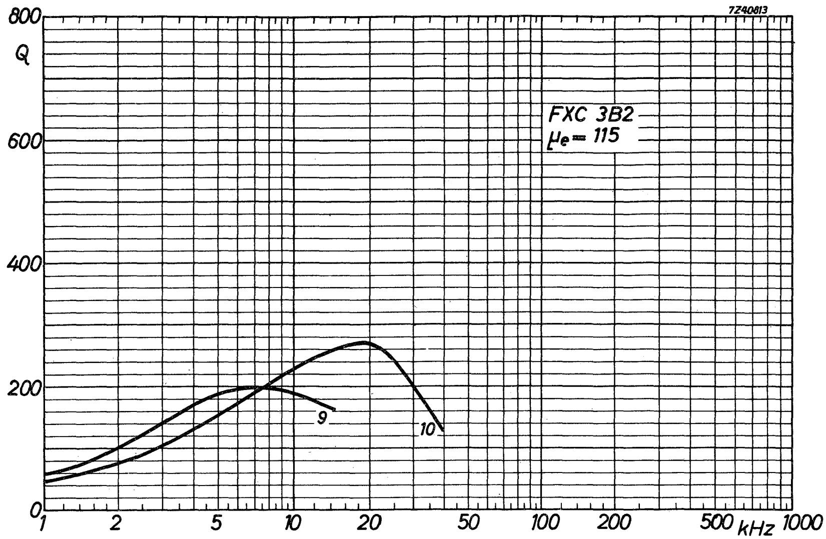
Q-curves of core with coil former 4312 021 28040

curve	wire	N	L mH
4	20 x 0.07	135	2.02
5	28 x 0.07	96	0.98
6	56 x 0.07	52	0.30



Q-curves core with coil former 4312 021 28090

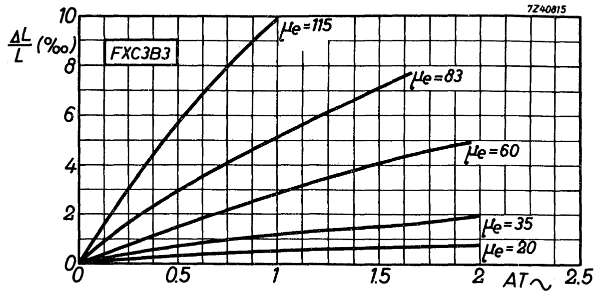
curve	wire	N	L mH
7	45 x 0.07	72	1
8	0.18 E.S.	620	100

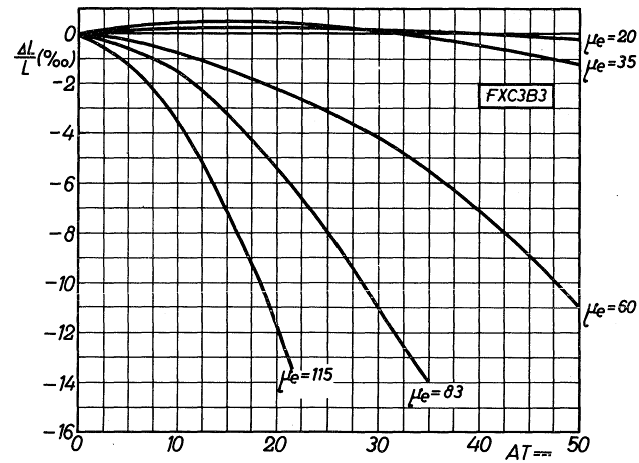


Q-curves of core with coil former 4312 021 28040

curve	wire	N	L mH
9	0.14 E	1282	586
10	0.16 E	743	196

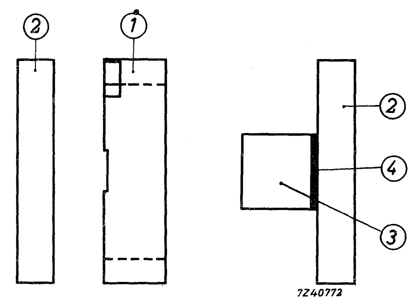
INDUCTANCE VARIATION





Inductance variation as a function of the number of AT∼ and AT⎓ for FXC 3B3.

POTCORES



(1) Ring;
(2) Disc;
(3) Slug;
(4) Spacer.

Fig.1. Assembly

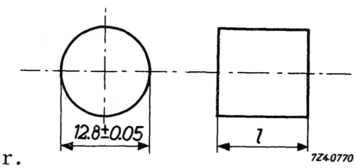


Fig.2. Slug

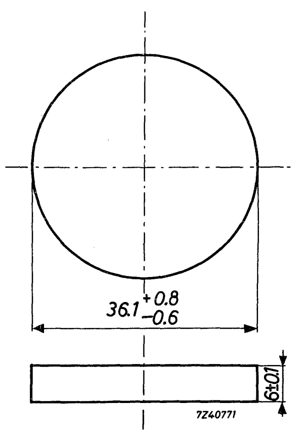


Fig.3. Disc

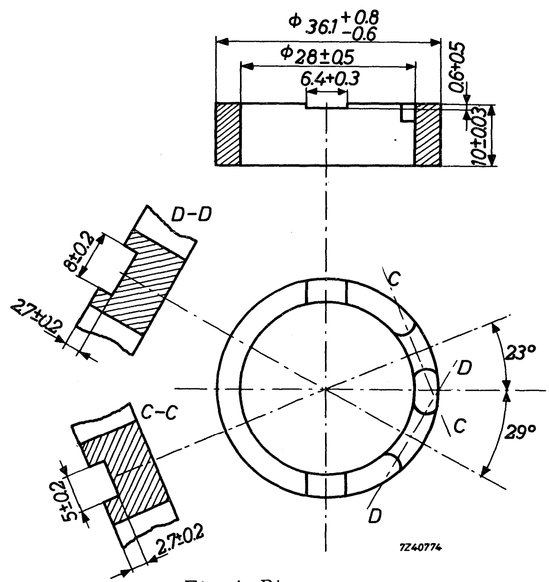


Fig.4. Ring

The potcore consists of two discs, one ring and one slug. The slug is cemented on one of the discs.

Two versions can be supplied:
I. Complete potcores with adjusted effective permeability.
II. Separate core parts to be assembled and adjusted by the user himself.

The effective permeability of the cores is determined by the air gap, the initial permeability of the material, the size of the core and the smoothness of the ground surfaces and the joints between the core parts.

In order to limit the influence of the stray field and small displacement of the coil former it is recommended for air gaps of 0.50 mm and larger to divide this gap in two approx. equal parts at both ends of the slug using a non-metallic spacer between slug and one disc (Fig.1).

The following spacers are available:

3522 289 94250 thickness 0.3 mm
3522 289 94260 thickness 0.5 mm
3522 289 94270 thickness 1.0 mm

These spacers have to be ordered separately.

When ordering, the desired core components should be indicated by their catalog number. These catalog numbers are for:

discs (Fig.3)	3522 200 03820	
	3522 200 03830	
rings (Fig.4)	3522 200 03980	
	3522 200 03990	
slugs (Fig.2)	3522 200 03610	l = 8 ± 0.03
	3522 200 03580	9 ± 0.03
	4322 020 25900	9.35 ± 0.03
	3522 200 03590	9.5 ± 0.03
	4322 020 25930	9.65 ± 0.03
	3522 200 03670	9.8 ± 0.03
	4322 020 25910	10 ± 0.03
	4322 020 25920	10 ± 0.03

It is recommended to order slugs of somewhat greater length than necessary. In this way it is possible to carry out the adjustment by grinding the slug only. Grinding the ring should be avoided, since it may result in instability. Besides, it takes more time.
The mechanical force, with which the FXC parts have to be clamped together is 500 Newton.

PRE-ADJUSTED POTCORES

μ_e	α	tol. on inductance %	potcore assembly number ferroxcube grade 3B2	3B3
20	91	± 1.5		4322 022 99930[1)]
35	71	± 1.5	4322 022 99920[2)]	
49	60	± 1.5	4322 022 99910	
60	54	± 1.5	4322 022 99900	
83	46	± 2.5	4322 022 99890	
115	37	± 2.5	4322 022 99880	

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

The inductance will only be within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force $l_e = 5.25$ cm

$\Sigma \frac{l_e}{A_e} = 2.14$ cm^{-1}

Effective volume $V_e = 12.9$ cm^3

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 4.0 \times 10^3$ Ω/H

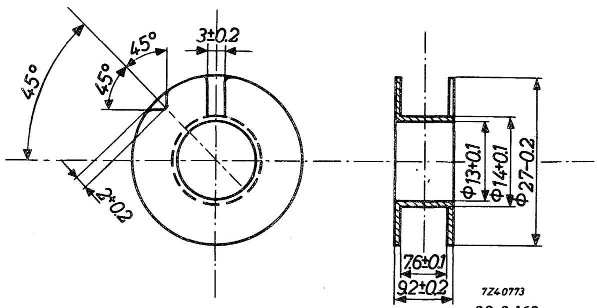
Approx. weight of the pre-adjusted potcore 88 g

The eccentricity of the cemented slug on the disc is ≤ 0.5 mm.

1) With spacer 3522 289 94270 (1.0 mm thickness)

2) With spacer 3522 289 94250 (0.3 mm thickness)

COIL FORMER



Catalog number	3122 794 35270
Material	Philite
Window area in mm^2	49.4
Mean length of turn in cm	6.4
Approx. weight in g	1.1
Max. temperature in ^{o}C	130

Maximum number of turns (N_{max}) and copper space factor (f_{cu}) for various types and gauges of wire on coil former 3122 794 35270.

Enamelled			Enamelled, silk covered			Litz wire					
Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}	Wire diam. mm	N_{max}	f_{cu}
0.10	3500	0.556	0.10	1900	0.302	3x0.04	2200	0.168	5x0.07	550	0.214
0.12	2500	0.570	0.11	1700	0.322	5x0.04	1600	0.204	8x0.07	440	0.274
0.14	1600	0.570	0.12	1600	0.360	8x0.04	1200	0.245	10x0.07	340	0.265
0.16	1400	0.57	0.14	1150	0.368	10x0.04	1100	0.281	12x0.07	324	0.302
0.18	1040	0.54	0.16	1050	0.427	12x0.04	1020	0.312	20x0.07	194	0.302
0.20	890	0.57	0.18	900	0.464	16x0.04	785	0.321	24x0.07	173	0.324
0.22	780	0.60	0.20	650	0.413	20x0.04	550	0.270	28x0.07	143	0.312
0.25	625	0.61	0.22	600	0.461	24x0.04	530	0.337	32x0.07	131	0.327
0.28	510	0.64	0.25	500	0.497	28x0.04	456	0.342	36x0.07	102	0.286
0.30	440	0.61	0.28	400	0.490	32x0.04	344	0.281	40x0.07	100	0.312
0.35	330	0.64	0.30	322	0.461	36x0.04	307	0.282	45x0.07	95	0.333
0.40	240	0.61	0.35	256	0.498	40x0.04	286	0.292	50x0.07	90	0.355
0.45	200	0.64	0.40	198	0.505	45x0.04	280	0.322	56x0.07	63	0.275
0.50	180	0.71	0.45	144	0.465	50x0.04	230	0.293	63x0.07	59	0.290
			0.50	137	0.545	56x0.04	226	0.323	70x0.07	56	0.306
			0.55	110	0.52	63x0.04	196	0.319	90x0.07	35	0.246
			0.60	100	0.57	70x0.04	180	0.315	100x0.07	31	0.242
			0.65*)	68	0.46	80x0.04	139	0.284	112x0.07	30	0.262
			0.70*)	64	0.50	90x0.04	132	0.303	120x0.07	28	0.261
			0.75*)	61	0.55	100x0.04	126	0.322	133x0.07	20	0.207
			0.80*)	43	0.44	112x0.04	95	0.272	160x0.07	17	0.212
						120x0.04	91	0.279	180x0.07	16	0.224
						140x0.04	85	0.303			
						150x0.04	70	0.269			
						160x0.04	61	0.249			
						180x0.04	58	0.266			
						200x0.04	39	0.199			
						252x0.04	34	0.219			
						280x0.04	33	0.236			
						315x0.04	32	0.258			
						350x0.04	31	0.276			
						392x0.04	30	0.300			
						441x0.04	19	0.214			
						490x0.04	18	0.255			

*) Enamelled, double silk covered

CONTINUOUS INDUCTANCE ADJUSTMENT

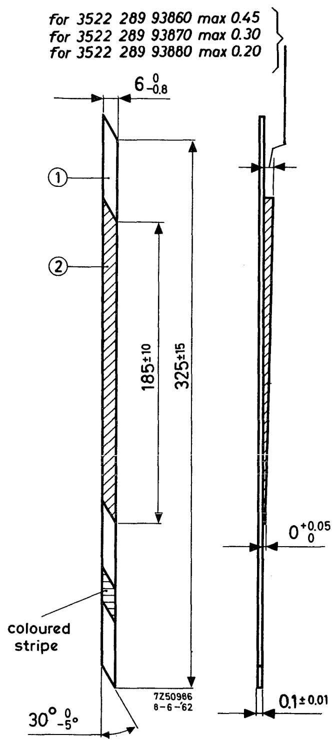


Fig.1. Trimmer

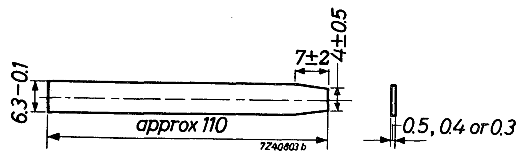


Fig.2. Metal dummy adjustor

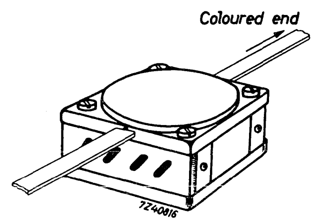


Fig.3.

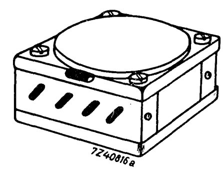


Fig.4.

Inductance adjustment may be obtained by means of strip-type trimmers.

At the top side of the ferroxcube ring are two diametrically opposite slots, 6.4 mm wide, for passing the trimmer through the air gap of the completely mounted coil. Each trimmer consists of a plastic bearer, provided with a tapered layer of magnetic material (see fig. 1).

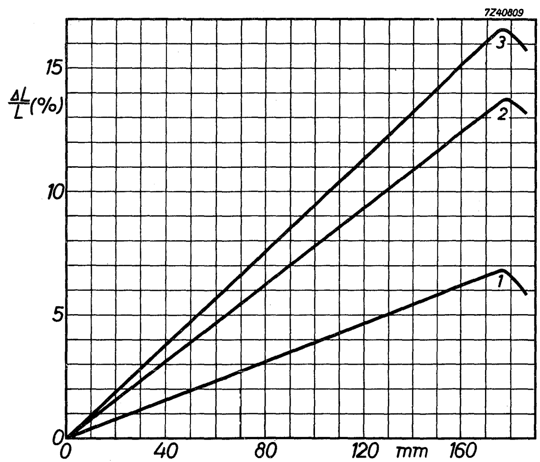
Impregnating has to be done preferably before inductance adjustment.
Before impregnating it is necessary to insert a metal dummy strip (see fig. 2) in the trimmer channel of the assembled coil.
This dummy should have slightly larger dimensions than the trimmer itself.

The trimmers have to be inserted into the coils with the coloured end first and with the magnetic material facing the slug.
After adjustment has been made the trimmers are fixed in the slots of the clamping lugs. The protruding ends are then cut off at a distance of approximately 5 mm from the clamping lugs.
The remaining ends are folded over against the clamping lug sides and secured with a suitable adhesive, for instance "Pliobond" (see fig.4).

It should be noted that in air gaps below 0.35 mm the trimmers cannot be pulled through completely. This results in a reduced adjustment range.

Three types of trimmers are available, namely:

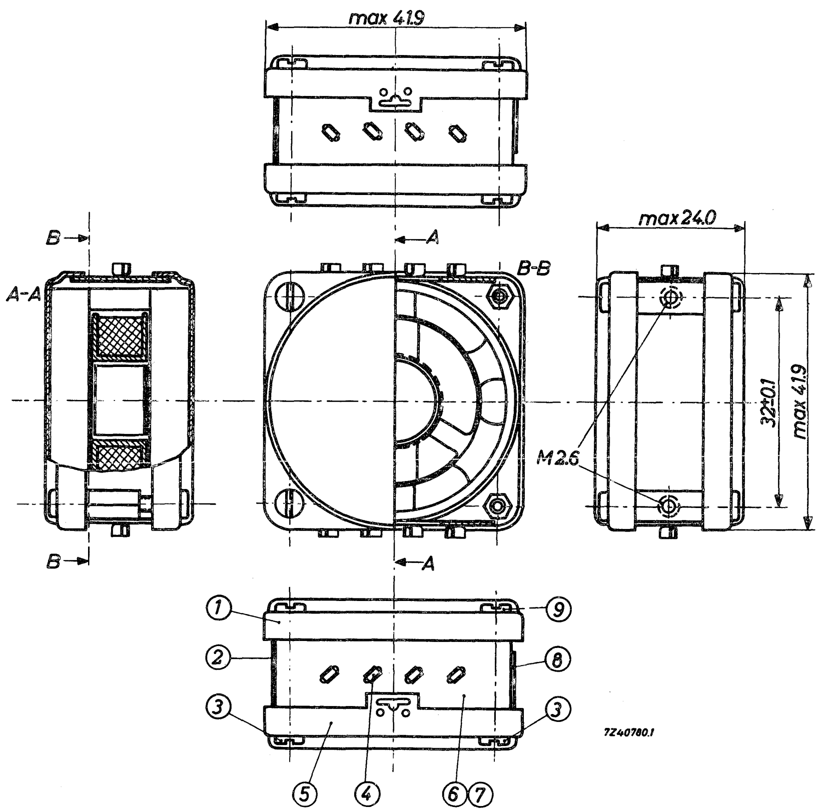
for air gaps of approx.	2 mm	3522 289 93860 with a yellow coloured end;
for air gaps of approx.	1 mm	3522 289 93870 with a red coloured end;
for air gaps of approx.	0.5 mm	3522 289 93880 with a green coloured end.



Inductance variation as a function of the displacement of the trimmer.

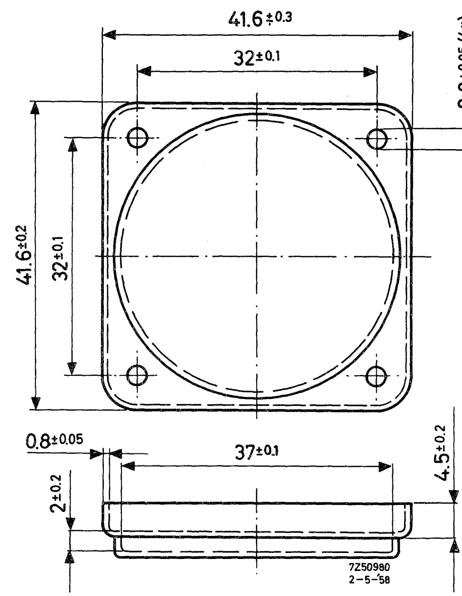
curve	trimmer	μ_e
1	3522 289 93880	60
2	3522 289 93870	60
3	3522 289 93860	35

MOUNTING PARTS

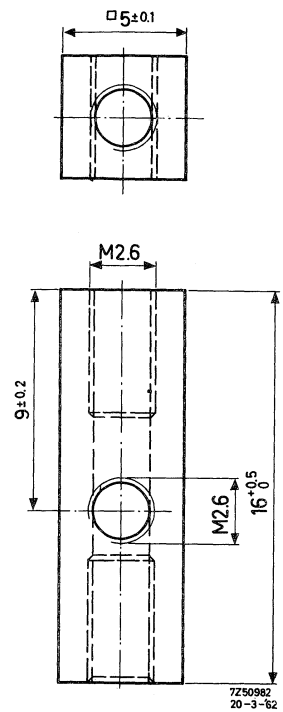


(1)	Clamping plate	1x	3522 200 24260
(2)	Collet	2x	3522 289 92620
(3)	Screw M2.6x6	6x	2522 001 07078
(4)	Soldering lug	8x	3522 289 91650
(5)	Clamping plate	1x	3522 289 94010
(6)	Terminal plate	2x	3522 289 94340
(7)	Insulating plate	2x	3522 289 94170
(8)	Collet	2x	3522 289 92610
(9)	Screw M2.6x10	2x	2522 001 07081

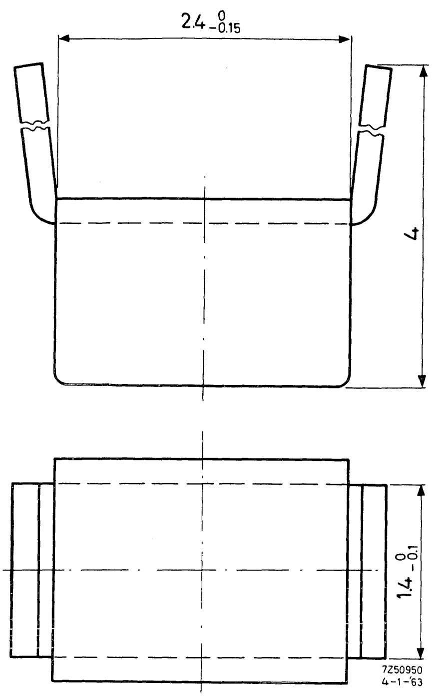
If the coil has four or less leading-out wires
4 or less soldering lugs (4),
1 terminal plate (6),
1 insulating plate (7) can be used.



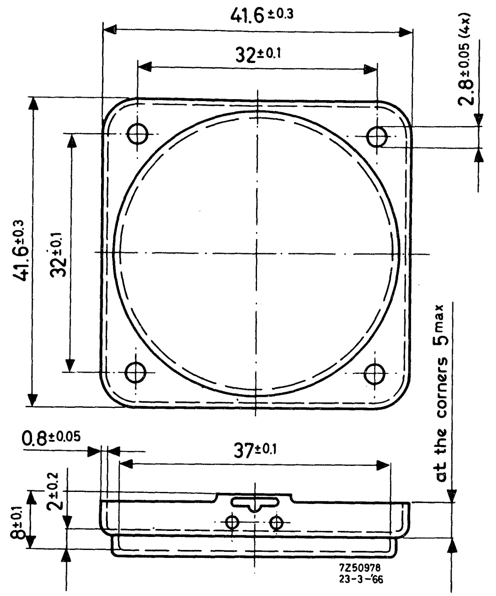
(1) Clamping plate 3522 200 24260
Material: steel, nickel plated



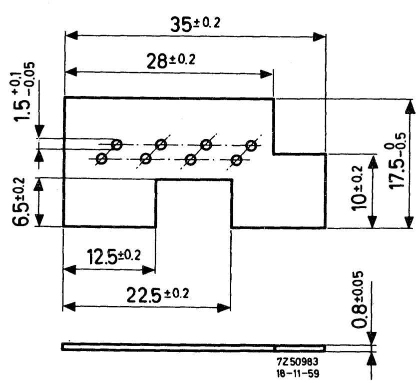
(2) Collet 3522 289 92620
Material: brass



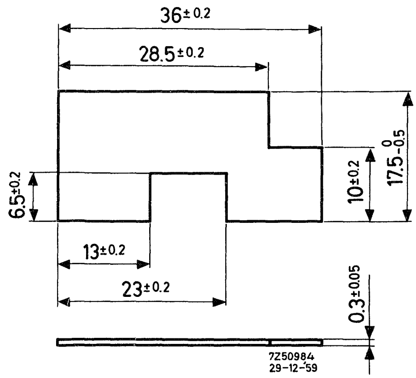
(4) Soldering lug 3522 289 91650
Material: brass, hot tin dipped



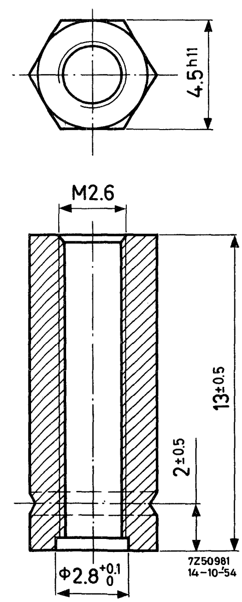
(5) Clamping plate 3522 289 94010
Material: steel, nickel plated



(6) Terminal plate 3522 289 94340
Material: phenolic board.



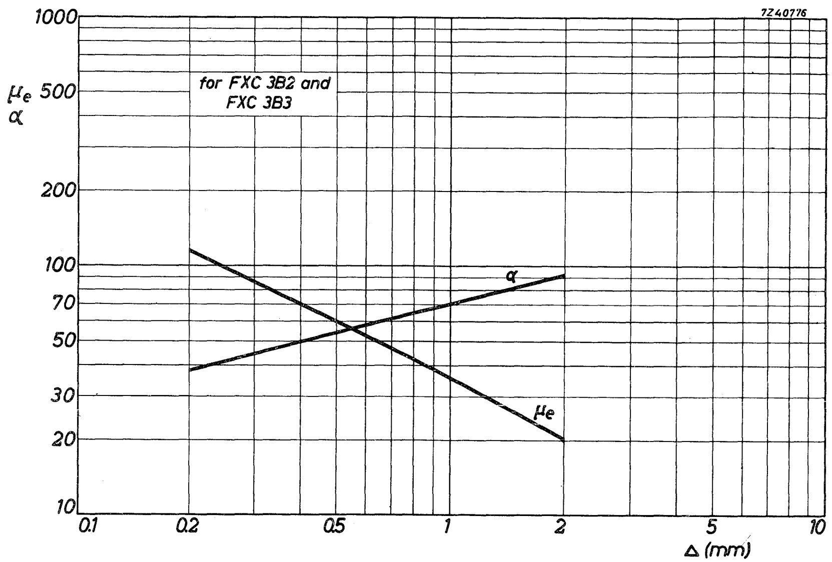
(7) Insulating plate 2522 289 94170
Material: phenolic board



(8) Collet 3522 289 92610
Material: brass

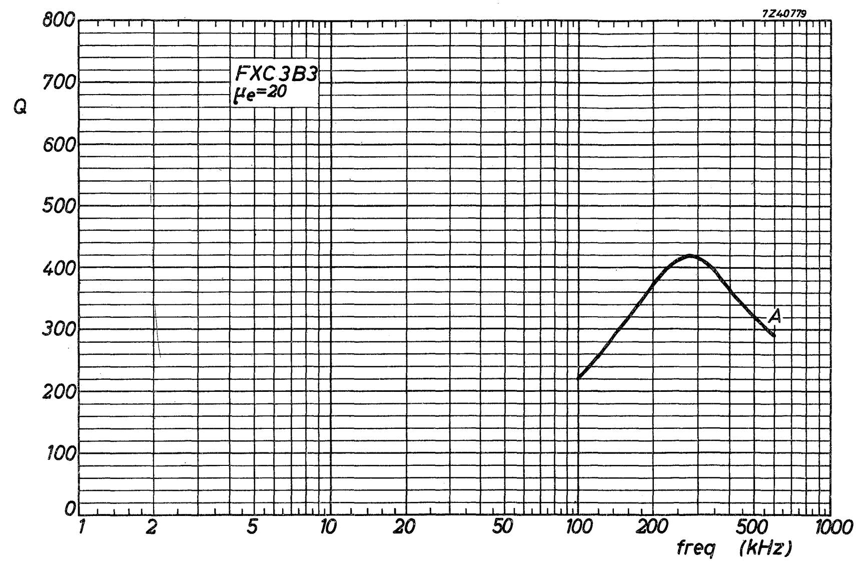
CHARACTERISTIC CURVES

μ_e - α CURVES

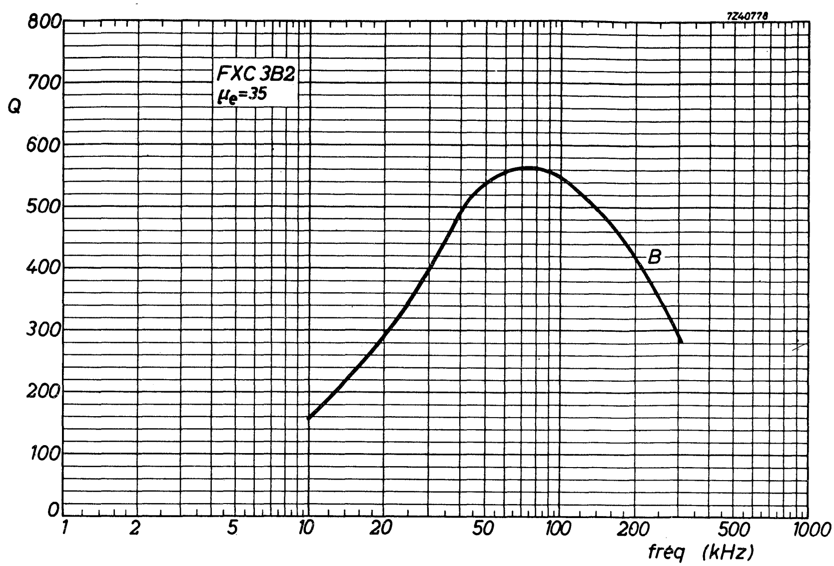


Effective permeability and turn factor as a function of the air gap length.

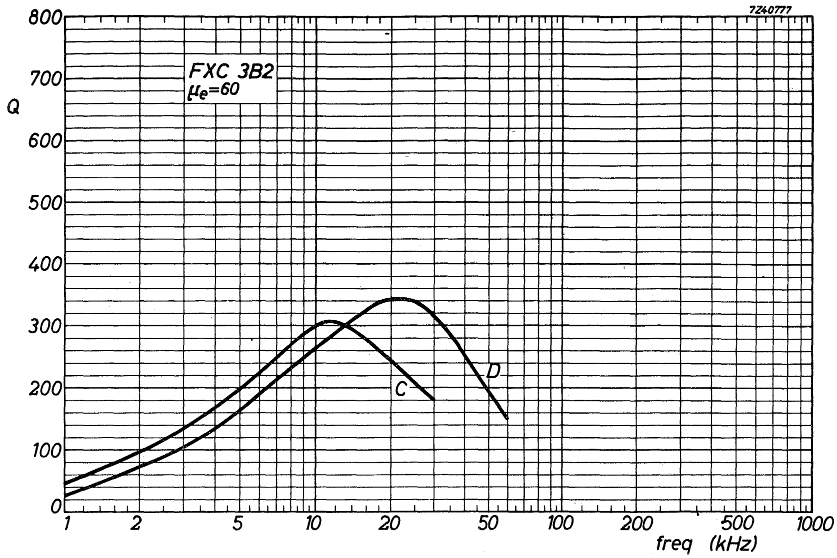
Q-CURVES



curve	wire	N	L (mH)	winding width (mm)
A	229x0.04	25	0.081	4.0

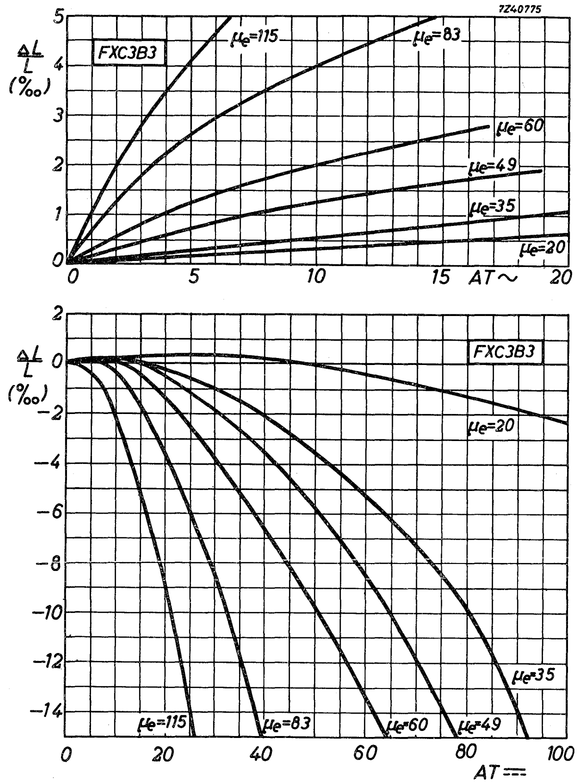


curve	wire	N	L (mH)	winding width (mm)
B	63x0.07	59	0.70	7.6



curve	wire	N	L (mH)	winding width (mm)
C	0.4	203	14.6	7.6
D	20x0.07	208	15.3	7.6

INDUCTANCE VARIATION



Inductance variation as a function of the numbers of AT~ and AT= for FXC 3B3.

POTCORES

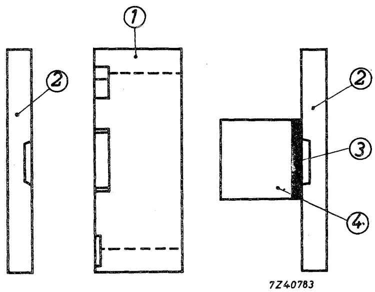


Fig.1. Assembly

(1) Ring
(2) Disc
(3) Spacer
(4) Slug

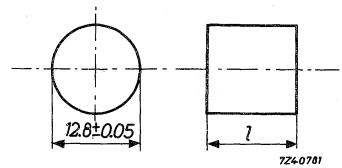


Fig.2. Slug

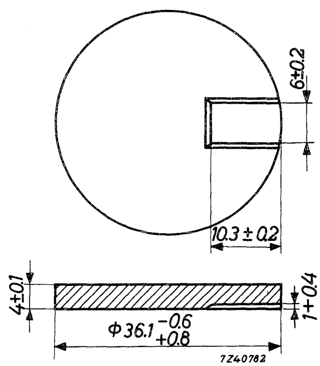


Fig.3 Disc

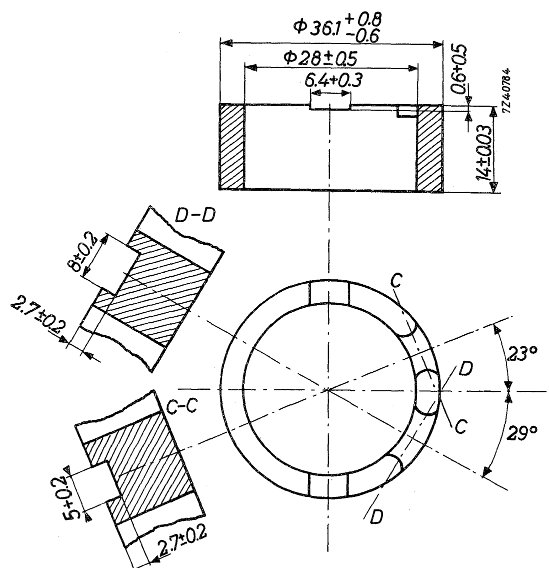


Fig.4 Ring

The potcore consists of two discs, one ring and one slug.
The slug is cemented on one of the discs.

Two versions can be supplied:
I. Complete potcores with adjusted effective permeability.
II. Separate core parts to be assembled and adjusted by the user himself.

The effective permeability of the cores is determined by the air gap, the initial permeability of the material, the size of the core and the smoothness of the ground surfaces and the joints between the core parts.

In order to limit the influence of the stray field and small displacement of the coil former it is recommended for air gaps of 0.50 mm and larger to divide this gap in two approx. equal parts at both ends of the slug using a non-metallic spacer between slug and one disc (see Fig.1).

The following spacers are available:

3522 289 94250 thickness 0.3 mm
3522 289 94260 thickness 0.5 mm
3522 289 94270 thickness 1.0 mm

These spacers have to be ordered separately.

When ordering the desired core components should be indicated by their catalog number. These catalog numbers are for:

discs (Fig.3)	3522 200 03870	
	3522 200 03880	
rings (Fig.4)	3522 200 03960	
	3522 200 03970	
slugs (Fig.2)	3522 200 03640	l = 12 ± 0.03
	3522 200 26150	13 ± 0.03
	4322 020 26090	13.5 ± 0.03
	4322 020 26100	13.65 ± 0.03
	4322 020 26110	13.8 ± 0.03
	4322 020 26120	14 ± 0.03
	4322 020 26130	14 ± 0.03

It is recommended to order slugs of somewhat greater length than necessary. In this way it is recommended to carry out the adjustment by grinding the slug only. Grinding the ring should be avoided, since it may result in instability. Besides, it takes more time.
The mechanical force, with which the FXC' parts have to be clamped together is 500 Newton.

PRE-ADJUSTED POTCORES

μ_e	α	tol. on inductance %	potcore assembly number	
			ferroxcube grade	
			3B2	3B3
20	105	± 1.5		4322 022 99990[1]
45	70	± 1.5		4322 022 99980[2]
60	61	± 1.5		4322 022 99970
80	52	± 2	4322 022 99960	
100	47	± 2.5	4322 022 99950	
150	38	± 3	4322 022 99940	

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

The inductance will only be within the guaranteed limits if the winding space of the coil former is completely filled with the number of turns determining the desired inductance.

Mean length of lines of force: $l_e = 4.86$ cm

$\Sigma \frac{l_e}{A_e} = 2.79$ cm^{-1}

Effective volume $V_e = 8.48$ cm^3

D.C. losses $\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 3.5 \times 10^3$ Ω/H

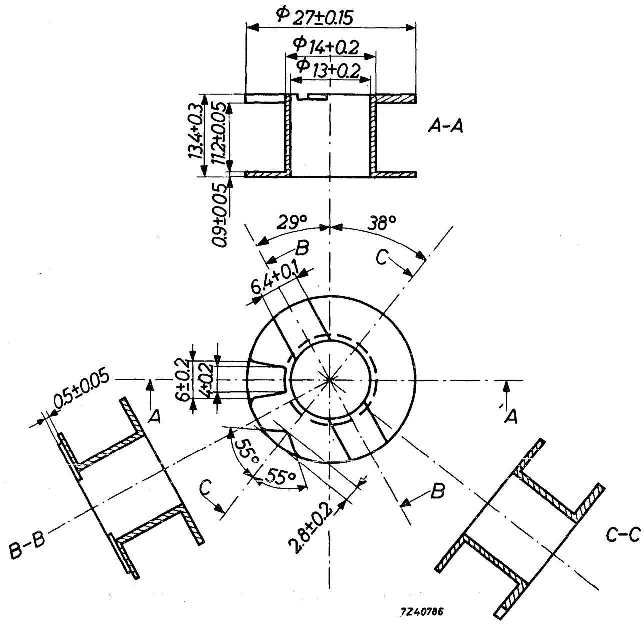
Approx. weight of the pre-adjusted potcore 73 g

The eccentricity of the cemented slug on the disc is ≤ 0.5 mm.

1) With spacer 3522 289 94270 (1.0 mm thickness)

2) With spacer 3522 289 94260 (0.5 mm thickness)

COIL FORMER



Catalog number	3522 200 03200
Material	Philite
Window area in mm^2	73
Mean length of turn in cm	6.4
Approx. weight in g	1.4
Max. working temperature in ^{o}C	130

CONTINUOUS INDUCTANCE ADJUSTMENT

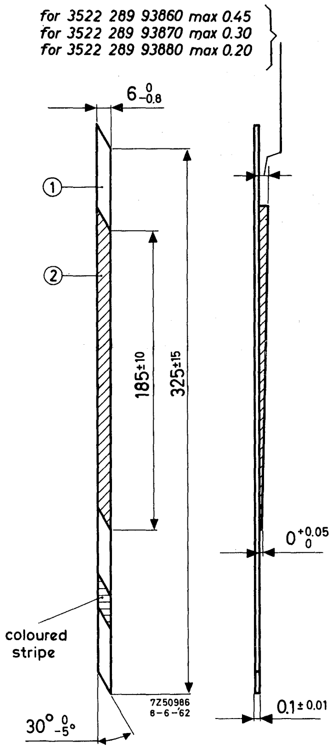


Fig.1. Trimmer

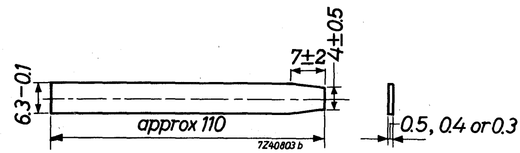


Fig.2. Metal dummy adjustor

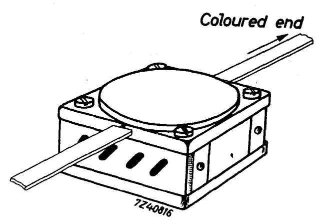


Fig.3.

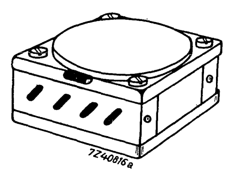


Fig.4

Inductance adjustment may be obtained by means of strip-type trimmers.

At the top side of the ferroxcube ring are two diametrically opposite slots, 6.4 mm wide, for passing the trimmer through the air gap of the completely mounted coil. Also the coil formers are provided with a 6.4 mm wide slot.

Each trimmer consists of a plastic bearer, provided with a tapered layer of magnetic material (see fig.1).

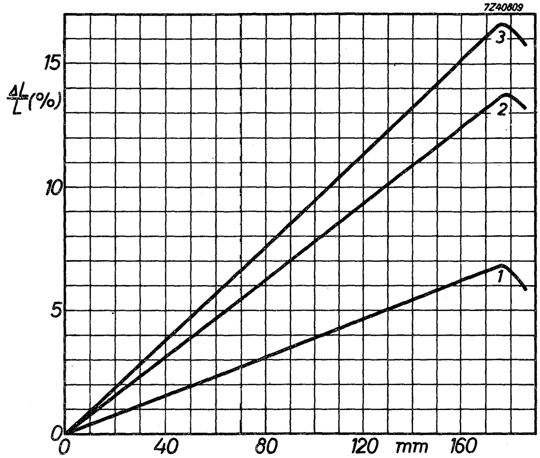
Impregnating has to be done preferably before inductance adjustment.
Before impregnating it is necessary to insert a metal dummy strip (see fig.2) in the trimmer channel of the assembled coil.
This dummy should have slightly larger dimensions than the trimmer itself.

The trimmers have to be inserted into the coils with the coloured end first and with the magnetic material facing the slug.
After adjustment has been made the trimmers are fixed in the slots of the clamping lugs. The protruding ends are then cut off at a distance of approximately 5 mm from the clamping lugs.
The remaining ends are folded over against the clamping lug sides and secured with a suitable adhesive, for instance "Pliobond" (see fig.4).

It should be noted that in air gaps below 0.35 mm the trimmers cannot be pulled through completely. This results in a reduced adjustment range.

Three types of trimmers are available, namely:

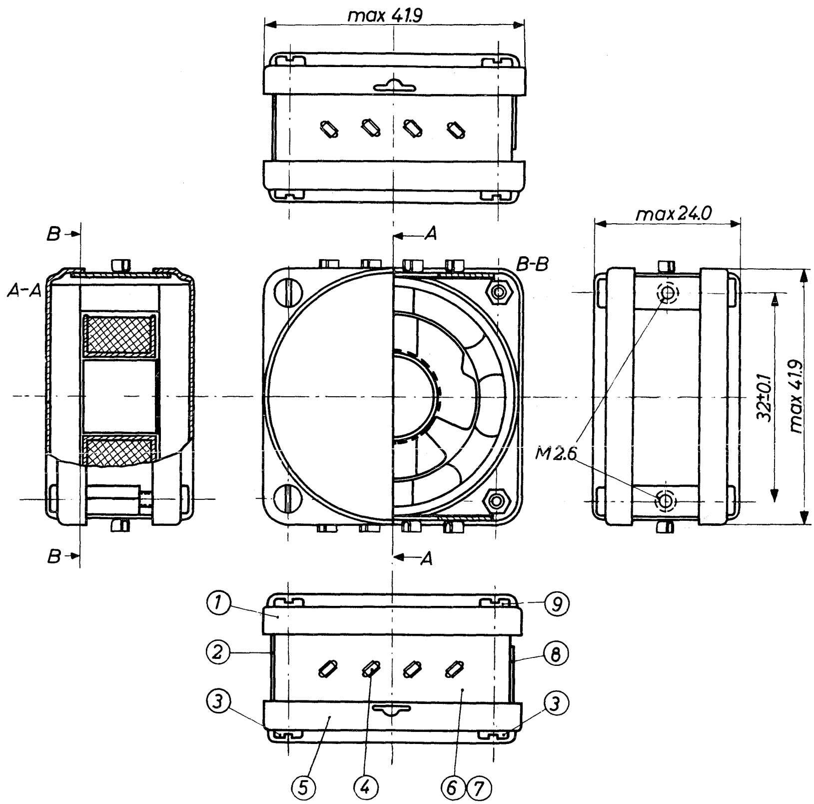
for air gaps of approx.	2 mm	3522 289 93860	with a yellow coloured end
for air gaps of approx.	1 mm	3522 289 93870	with a red coloured end
for air gaps of approx.	0.5 mm	3522 289 93880	with a green coloured end.



Inductance variation as a function of the displacement of the trimmer.

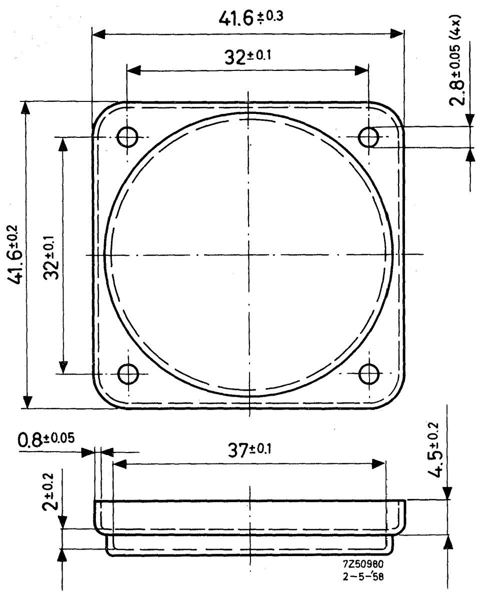
curve	trimmer	μ_e
1	3522 289 93880	60
2	3522 289 93870	60
3	3522 289 93860	35

MOUNTING PARTS

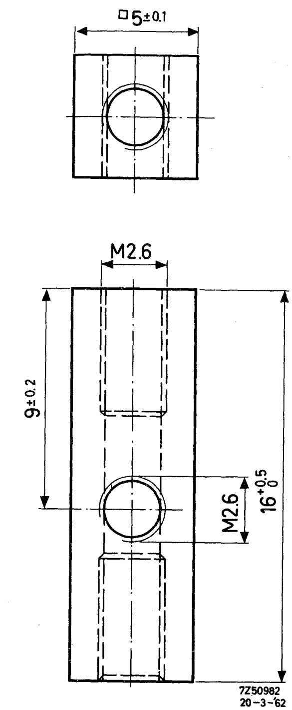


(1)	Clamping plate	1x	3522 200 24260
(2)	Collet	2x	3522 289 92620
(3)	Screw M2.6x6	6x	2522 001 07078
(4)	Soldering lug	8x	3522 289 91650
(5)	Clamping plate	1x	3522 289 94040
(6)	Terminal plate	2x	3522 289 94340
(7)	Insulating plate	2x	3522 289 94170
(8)	Collet	2x	3522 289 92610
(9)	Screw M2.6x10	2x	2522 001 07081

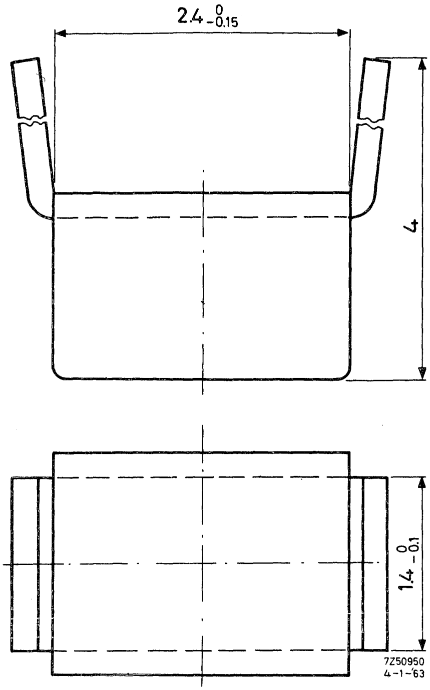
If the coil has four or less leading-out wires
4 or less soldering lugs (4),
1 terminal plate (6),
1 insulating plate (7) can be used.



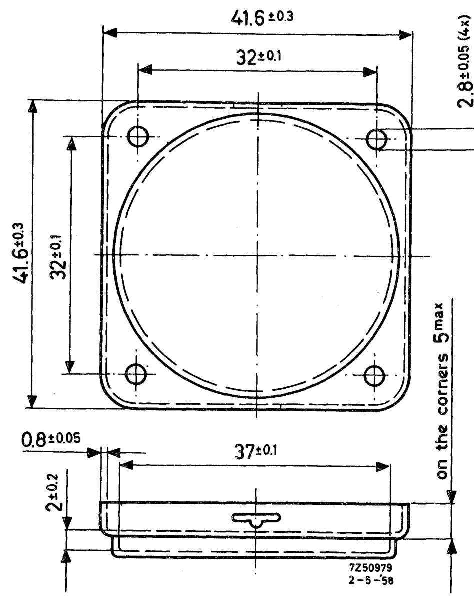
(1) Clamping plate 3522 200 24260
Material: steel, nickel plated



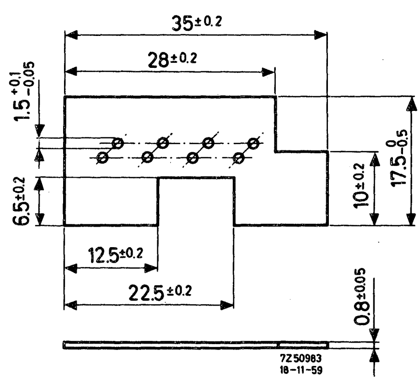
(2) Collet 3522 289 92620
Material: brass



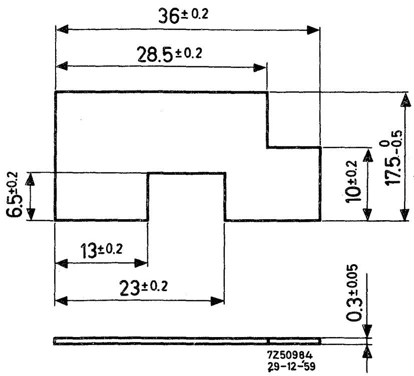
(4) Soldering lug 3522 289 91650
Material: brass, hot tin dipped



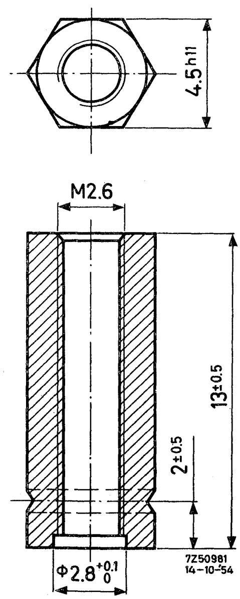
(5) Clamping plate 3522 289 94040
Material: steel, nickel plated



(6) Terminal plate 3522 289 94340
Material: phenolic board.



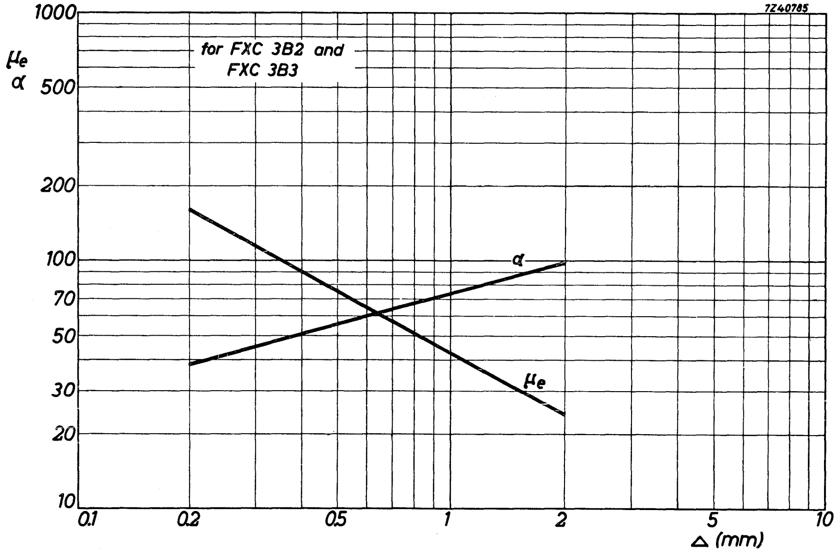
(7) Insulating plate 3522 289 94170
Material: phenolic board



(8) Collet 3522 289 92610
Material: brass

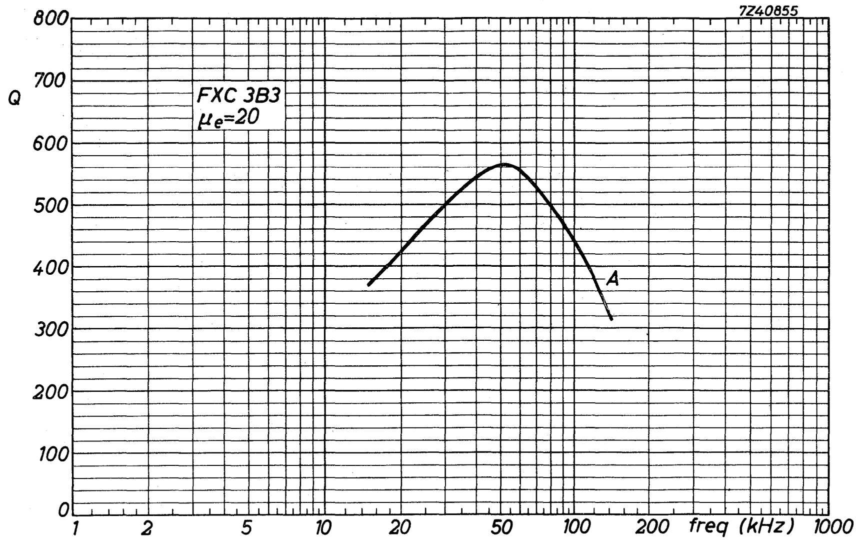
CHARACTERISTIC CURVES

μ_e-α CURVES

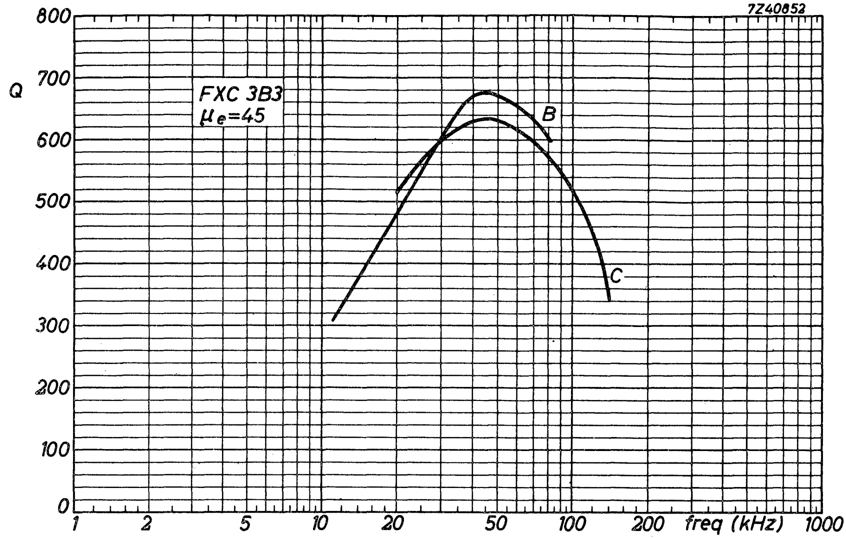


Effective permeability and turn factor as a function of the air gap length.

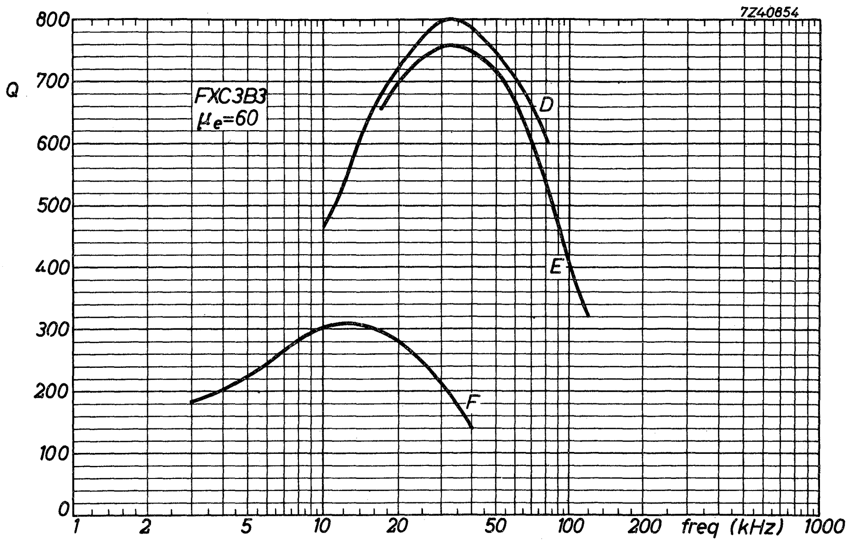
Q-CURVES



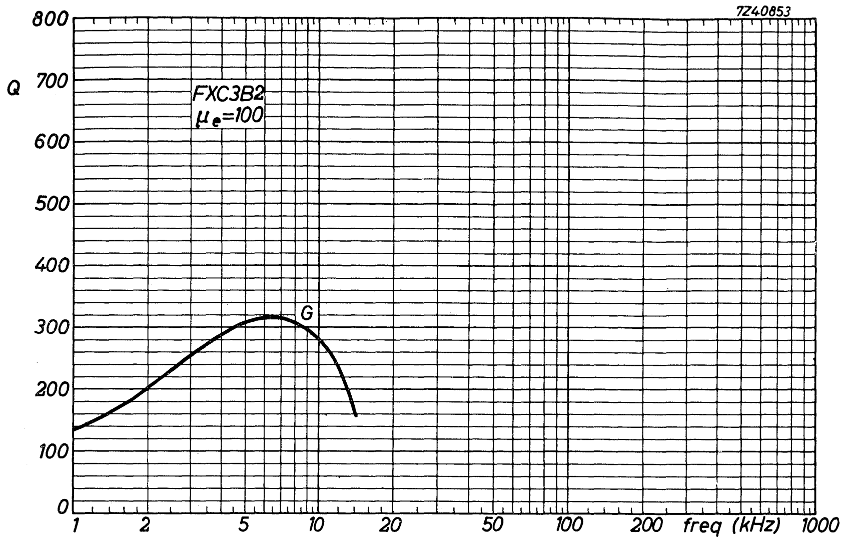
curve	wire	N	L (mH)
A	50x0.07	150	2.04



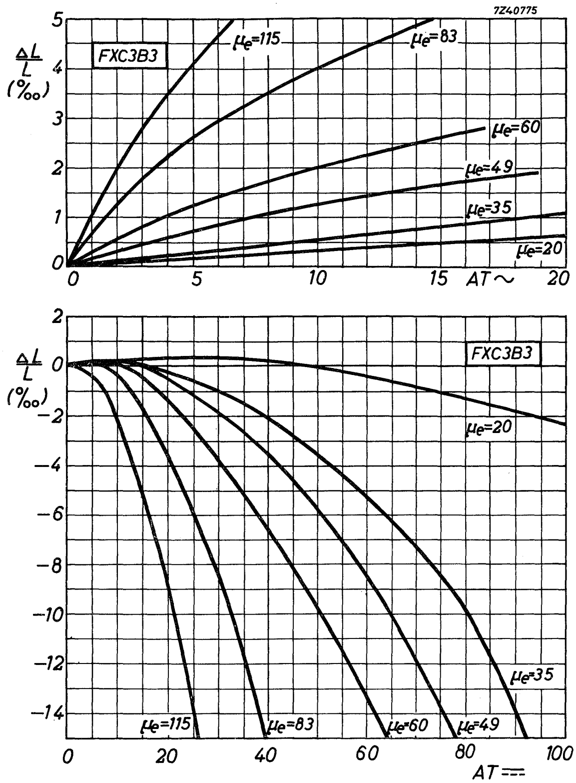
curve	wire	N	L (mH)
B	36x0.07	179	6.50
C	50x0.07	150	4.60



curve	wire	N	L (mH)
D	36x0.07	179	8.60
E	50x0.07	150	6.0
F	12x0.07	403	44



curve	wire	N	L (mH)
G	0.25	780	275



Inductance variation as a function of the number of $AT_{\sim}$ and $AT_{=}$ for FXC 3B3.

Ferroxcube transformer cores

GENERAL

INTRODUCTION

Although potcores can often be used with much success for transformers, there are a number of specific shapes available, such as E-, X-, H-cores and toroids, which have especially been designed for the purpose. For a short description of these shapes the relevant sections should be consulted.
At higher frequencies they are superior to dust or laminated cores because of the low eddy current losses of ferroxcube.
The high permeability of ferroxcube makes it suitable for low frequencies as well, especially H-cores and toroids in the 3E2 grade which has a $\mu_e > 5000$.
At frequencies of several kHz ferroxcube transformer cores are also very suitable for power applications. Preferred shapes for these applications are E-, U- and X-cores.

SURVEY OF SYMBOLS

l_e — effective length of the magnetic path in cm

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

μ_i — relative initial permeability, defined by

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

μ_e — relative effective permeability, defined by

$$\mu_e = \frac{\Sigma \frac{l_e}{A_e}}{\Sigma \frac{1}{\mu_i A_e}}$$

μ_{diff} — relative differential permeability, defined by

$$\mu_{diff} = \frac{dB}{dH}$$

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 by:

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

Δ — length of the air gap in mm

α — turns factor = number of turns for 1 mH

A_L — inductance factor = inductance per turn in nanohenry (10^{-9}H)

$\hat{H}$ — peak field strength in oerstedt

$\hat{B}$ — peak induction in gauss

AT — amperes x turns

N — number of turns

I_e — d.c. current in amperes

Curie point — critical temperature in °C above which the ferromagnetic body is paramagnetic

$D.F. = \frac{\mu_1 - \mu_2}{\mu_1^2 \log \frac{t2}{t_1}}$	disaccomodation factor, which gives the permeability variation of the core, measured between 10 and 100 minutes after demagnetisation.
$q_{2-24-100}$	constant for hysteresis losses standardized for an effective volume of 24 cm^3, $\mu_e = 100$ and measured between two currents, corresponding with two B_{max} values. At 800 Hz for a given volume V_e and for an equivalent permeability μ_e, we obtain: $q_{2-V-\mu} = q_{2-24-100} \times \left(\frac{\mu_e}{100}\right)^{3/2} \times \sqrt{\frac{24}{V_e}}$ $\Omega/H^{3/2}$ mA; $\frac{R_h}{L} = q_{2-V-\mu} \times \sqrt{L} \times i \times \frac{f}{800}$ Ω/H (L in henry, f in Hz and i in mA)
ρ	specific resistance in Ωcm measured with d.c. current
$\frac{\tan\delta}{\mu_i}$	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: $\frac{R}{L} = \frac{\tan\delta}{\mu_i} \times \mu_e \times 2\pi f$ Ω/H (f in Hz)

DETERMINING THE A_L-AND μ_e-VALUE

The A_L- or α-factor of transformer cores is determined with the following number of turns:

core type	number of turns	wire diam. (mm)	catalog number of measuring coil
E20	60	0.30	3U71065/14
E30	50	0.30	3U71065/15
E42	35	0.50	3U71065/16
E55	25	1.2	3U71065/3
E65	35	1.0	3U71065/10
X22	175	0.40 ortho-	7622 301 04011
X30	175	0.70 cyclic	7622 301 04111
X35	251	0.70 wound	7622 301 04211
H7	25 (one layer)	0.15	-
H10	20 (one layer)	0.20	-
H16			-
H20	30 (one layer)	0.30	-

From the measured value of L, A_L and α can be calculated using the following formulae:

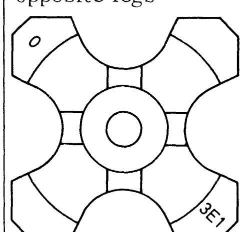
$$L = N^2 A_L \quad \text{and} \quad \alpha = \frac{10^3}{\sqrt{A_L}} \qquad \text{(L in nH)}$$

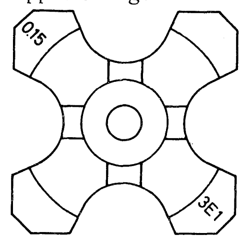
and the value of μ_e from

$$L = \frac{0.4\ \pi\ N^2 . \mu_e . 10^{-5}}{\Sigma \frac{l_e}{A_e}} \qquad \text{(L in mH)}$$

$\Sigma \frac{l_e}{A_e}$ can be found in the pages relevant to the transformer cores.

MARKING

type	type designation	example	position of marking
E cores without airgap length > 26 mm	E and dimensions material date manufacturer	E 42/21/15 3E1 B7A	on half of the backface E 42/21/15 3E1 B7A
length < 26 mm	material	3E1	on half of the backface 3E1
	E and dimensions date manufacturer	E 20/10/5 B7A	on the primary pack
E cores with airgap length > 26 mm	E and dimensions material airgap	E 42/21/15 3E1 0.9	on half of the backface E 42/21/15 3E1 0.9
	date manufacturer	B7A	on the primary pack
length < 26 mm	material, airgap	3E1 0.05	on the backface 3E1 | 0.05
	E and dimensions date manufacturer	E 20/10/5 B7A	on the primary pack
cross cores without airgap	material zero (0)	3E1 0	on the back of two opposite legs 
	catalog number date manufacturer	4322 020 23751 B7A	on the primary pack

type	type designation	example	position of marking
cross cores with airgap	material airgap	3E1 0.15	on the back of two opposite legs 
	catalog number date manufacturer	4322 020 23981 B7A	on the primary pack

MOUNTING DATA

Special tools have been designed for bending the lips of the containers of X and H-cores.
We do not supply these tools, but we are prepared to provide drawings of them on request.

Catalog numbers of the tools are:

for X22	4322 058 00080
X30	4322 058 00090
X35	4322 058 00100
H7	4322 058 00110
H10	4322 058 00120
H16	4E 40202
H20	4322 058 00130

See also the remarks with regard to the mounting parts in the pages relevant to the transformer cores.

E- AND I-CORES

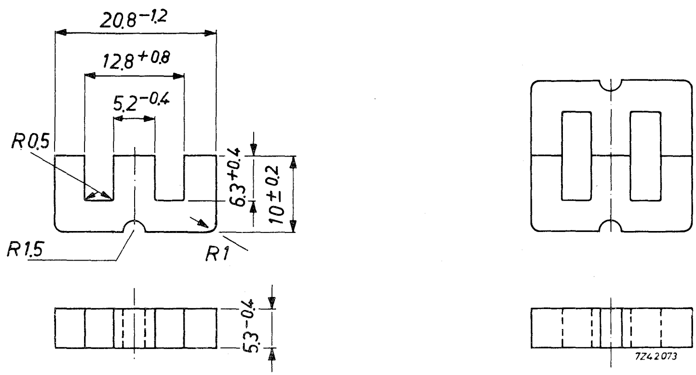
INTRODUCTION

The ferroxcube E and I-cores are typical transformer cores. They can be used from voice frequencies up to some MHz.
Ferroxcube E and I-cores can also be used successfully for power applications. In comparison with conventional laminated iron cores a much higher frequency can be chosen, as a result of the very low eddy current losses of the ferroxcube. In many cases the dimensions can be smaller as compared with the same conventional cores.

The hysteresis losses, and consequently the third harmonic distortion of ferroxcube cores are lower than that of other materials.
For the low induction applications an additional advantage of ferroxcube E and I-cores is, that the intitial permeability remains constant over a very large frequency range.

The mating surfaces are ground with a roughness of <32 rhu (1 rhu $= 2.54 \cdot 10^{-7}$ mm).

E-CORES



The dimensions are according to German specification D.I.N. 41295.

Ferroxcube grade	3E1	improved 3E1
Approximate weight	4 g	4g
Cat. number of E-core	4322 020 34530	4322 020 34831

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer 20/20/5 composed of two cores type E 20/10/5.

shell type transformer 20/20/5

Dimensional quantities:

mean length of lines of force	l_e =	4.28	cm
mean area of lines of force	A_e =	0.312	cm^2
	$\Sigma \frac{l_e}{A_e}$ =	13.7	cm^{-1}
effective volume	V_e =	1.34	cm^3

Electrical properties at 25 ±10 °C		3E1	improved 3E1	
at $\Delta = 0$:	μ_e =	1650-2760		
	A_L =	1515-2520	>2000	
	α ≤	25.7		
at 4 kHz and $\hat{B}$ between 15 and 30 gauss	$q_{2-24-100}$ ≤	7	4	$\Omega/(H^{3/2}.mA)$

Mechanical force at which the electrical properties are determined is 55 Newton

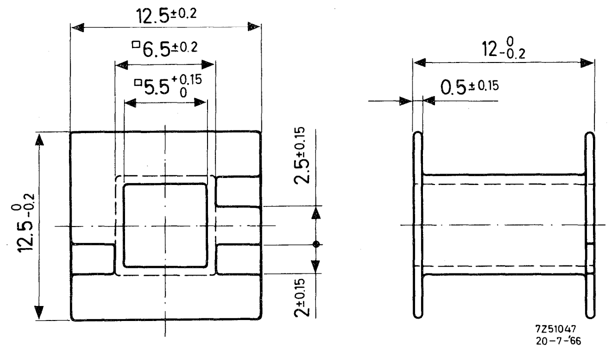
Number of turns for L mH $N = \alpha\sqrt{L}$.

The following E-core can be delivered with an airgap (ground in each E-core)

catalog number	Airgap length in mm
4322 020 34550	0.15 ± 0.015

COIL FORMER

for shell type transformer 20/20/5 (M 20)



catalog number	4312 021 28430
material	polycarbonate
minimum window area in mm^2	27
mean length of turn in cm	3.8
approximate weight in g	0.5
maximum temperature in °C	130

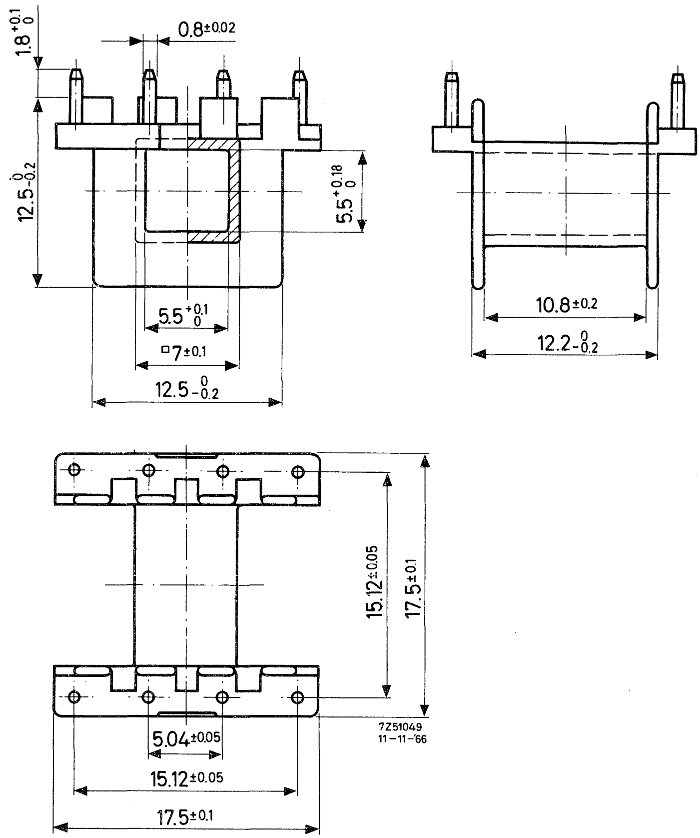
The dimensions are practically according to German specification D.I.N. 41305.

E 20/10/5 (E 20)

COIL FORMER

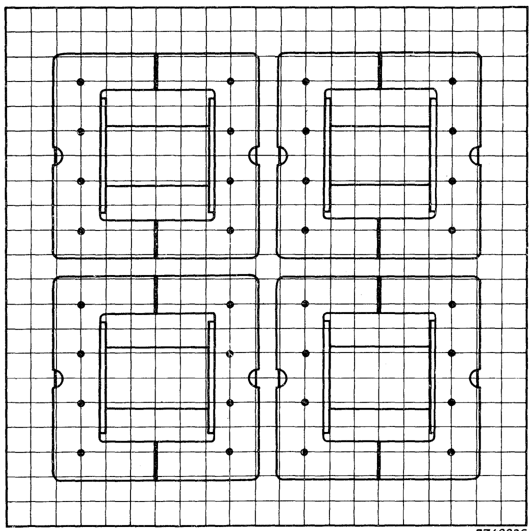
for shell type transformer 20/20/5 (M20)

With soldering pins.



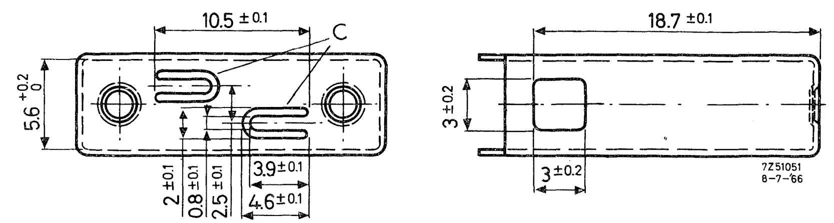
catalog number	4322 021 20240
material	reinforced polyester with brass dipsoldered pins
minimum window area in mm^2	27
mean length of turn in cm	3.8
approximate weight in g	
maximum temperature for dipsoldering during 5 - 6 s in °C	280
maximum working temperature in °C	130

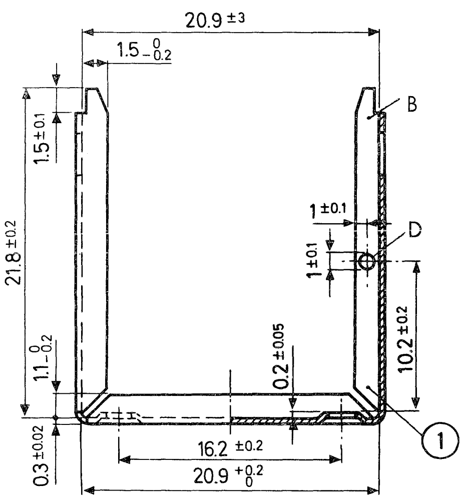
The coil former fits a shell type transformer 20/20/5 (M 20). The soldering pins are so arranged as to fit a grid of 2.52mm. They will fit printed wiring boards with 0.1" grid as well as those with a 2.50mm grid. The pin length is sufficient for a board thickness of up to 3mm. The board should be provided with holes of 1.3$\pm$0.1 mm diameter.



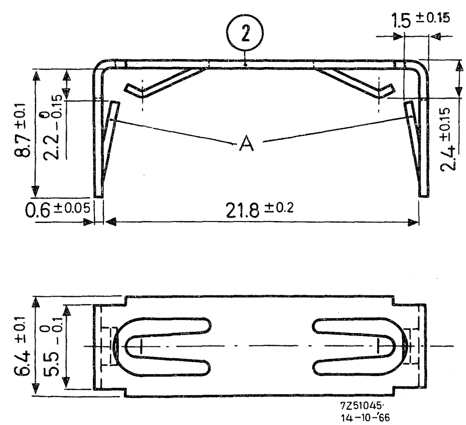
7Z49836

MOUNTING PARTS





(1). Clasp 4322 021 20160
Material: brass, tin-plated



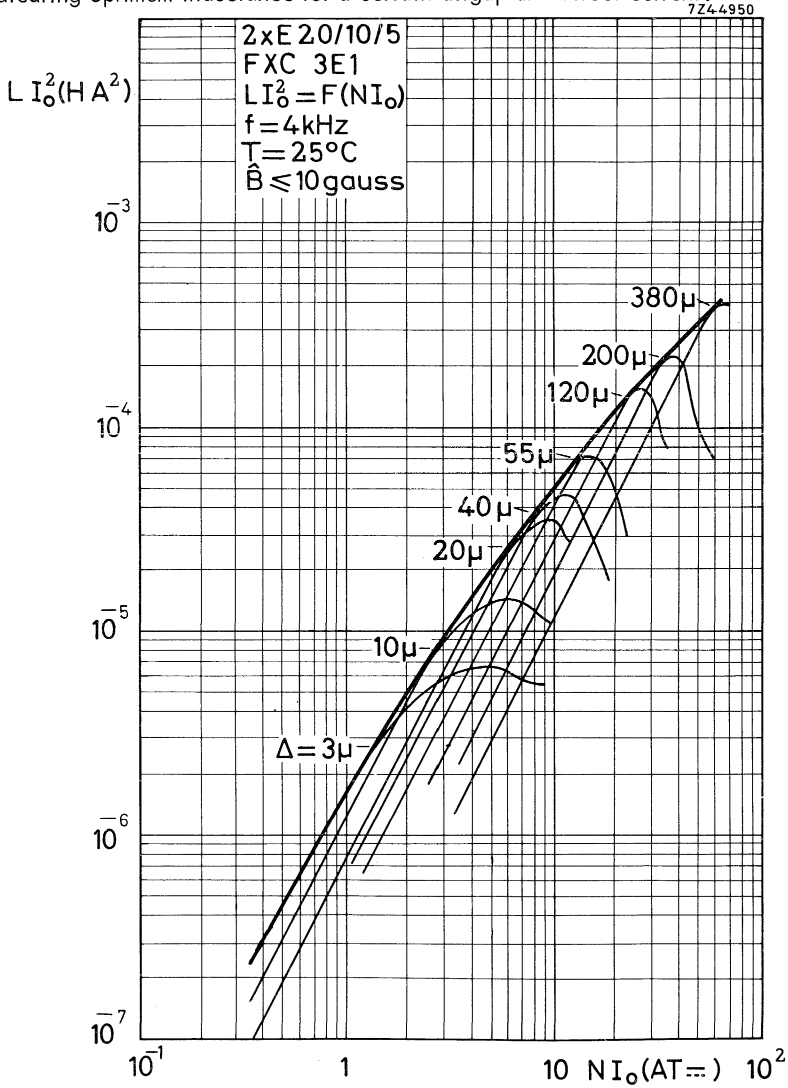
(2). Spring 4322 021 20220
Material: phosphorbronze, tin-plated

The construction is mounted by pushing the spring over the clasp in such a way that the lips A of the spring catch in the square holes B of the clasp. The mechanical pressure, required to keep the two E-cores together is exercised by means of two lips on top of the spring. No special tool is required for mounting the construction.

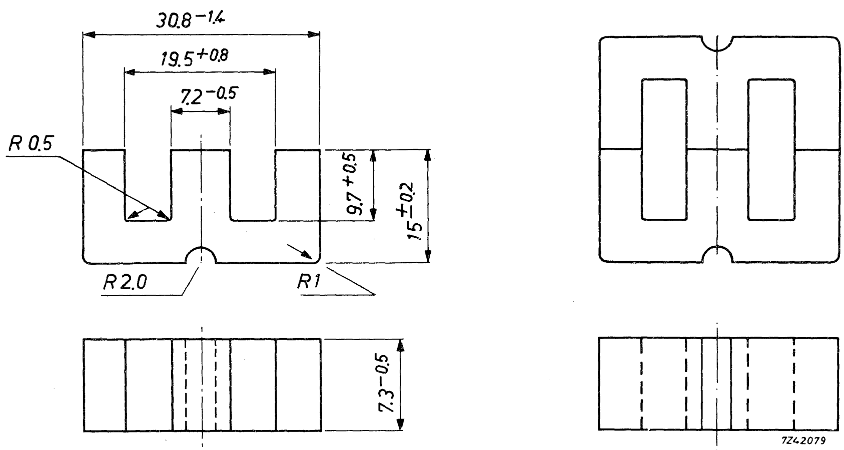
The construction can be used in horizontal and vertical position.
If the construction is used in vertical position, the lips C of the clasp must be bent. The dimensions and mutual distance of these lips are chosen in such a way that they fit printed-wiring boards with a grid of 0.1" as well as those with a grid of 2.50 mm.
If used in a horizontal position the clasp can be earthed by means of a copper wire soldered in hole D.

CHARACTERISTIC CURVES

HANNA CURVES (typical values)
Indicating optimum inductance for a certain airgap and direct current.



E-CORES



The dimensions are according to German specification D.I.N. 41295.

Ferroxcube grade	3E1	improved 3E1
Approximate weight	11 g	11g
Cat. number of E-core	4322 020 34630	4322 020 34840

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer 30/30/7 composed of two cores type E 30/15/7.

shell type transformer 30/30/7

Dimensional quantities:

mean length of lines of force	l_e =	6.69	cm
mean area of lines of force	A_e =	0.597	cm^2
	$\Sigma \frac{l_e}{A_e}$ =	11.2	cm^{-1}
effective volume	V_e =	4.00	cm^3

Electrical properties at 25 ±10 °C		3E1	improved 3E1	
at $\Delta = 0$:	$\mu_e =$	1795-2990		
	$A_L =$	2010-3350	≥ 2640	
	$\alpha \leq$	22.3		
at 4 kHz and $\hat{B}$ between 15 and 30 gauss	$q_{2-24-100} \leq$	7	4	$\Omega/(H^{3/2}.mA)$

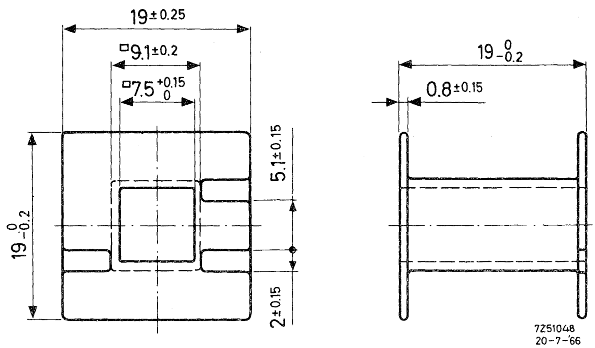
Mechanical force at which the electrical properties are determined is 110 Newton.
Number of turns for L mH $N = \alpha\sqrt{L}$.

The following E-cores with an airgap (ground in each E-core) can be delivered:

catalog number	airgap lenght in mm
4322 020 34650	0.15 ± 0.015
4322 020 34660	0.30 ± 0.015

COIL FORMERS

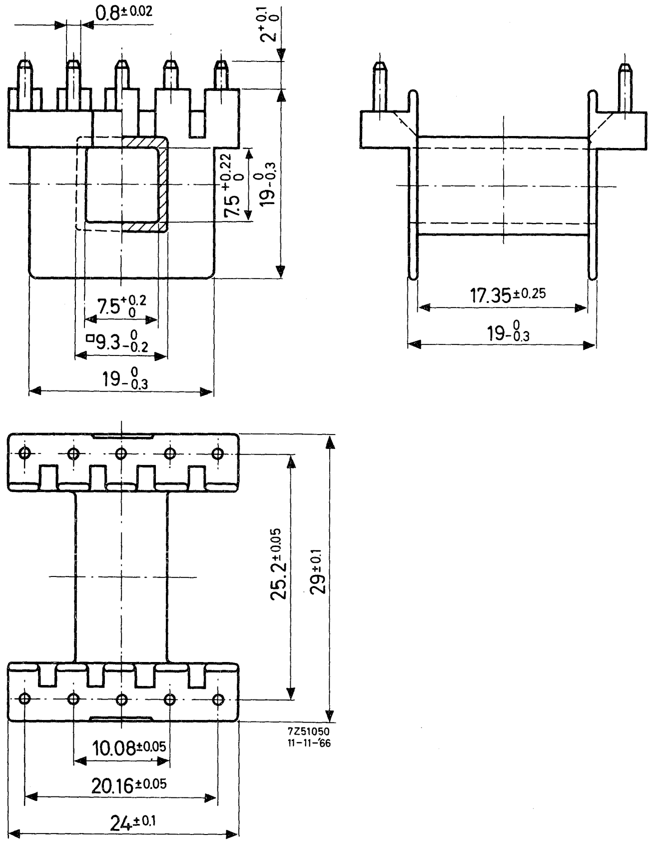
for shell type transformer 30/30/7 (M 30)



catalog number	4312 021 28570
material	polycarbonate
minimum window area in mm^2	80
mean length of turn in cm	5.6
approximate weight in g	1.3
maximum temperature in °C	130

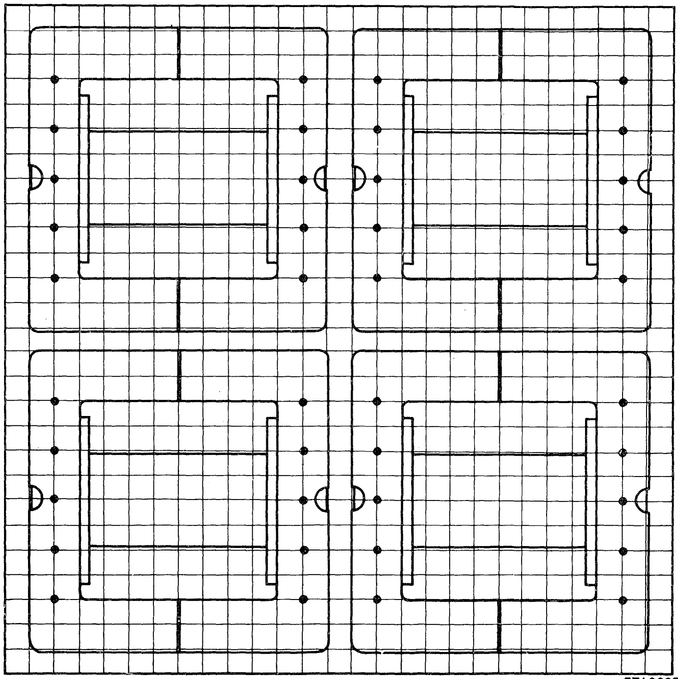
The dimensions are practically according to German specification D.I.N. 41305.

With soldering pins.

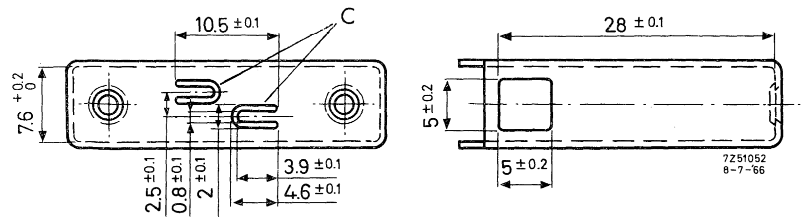


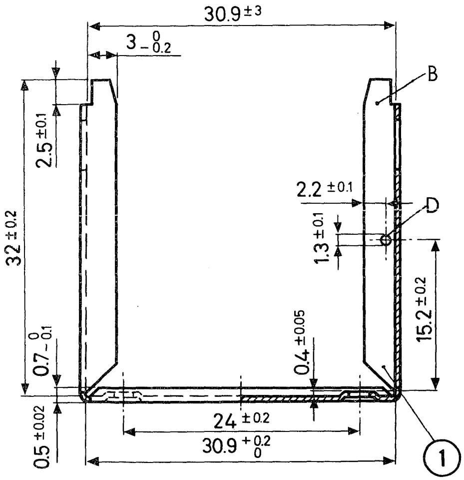
catalog number	4322 021 20250
material minimum window area in mm^2 mean length of turn in cm approximate weight in g maximum temperature for dipsoldering during 5-6 s in °C maximum working temperature in °C	reinforced polyester with brass dipsoldered pins 80 5.6 280 130

The coil former fits a shell type transformer 30/30/7 (M30). The soldering pins are so arranged as to fit a grid of 2.52mm. They will fit printed-wiring boards with 0.1" grid as well as those with a 2.50mm grid. The pin length is sufficient for a board thickness of up to 3mm. The board should be provided with holes of 1.3±0.1mm diameter.

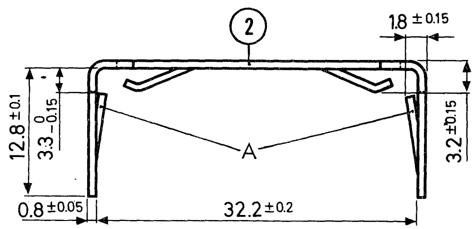


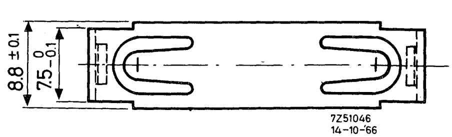
MOUNTING PARTS





(1). Clasp 4322 021 20170
Material: brass, tin-plated





(2). Spring 4322 021 20230
Material: phosphorbronze, tin-plated

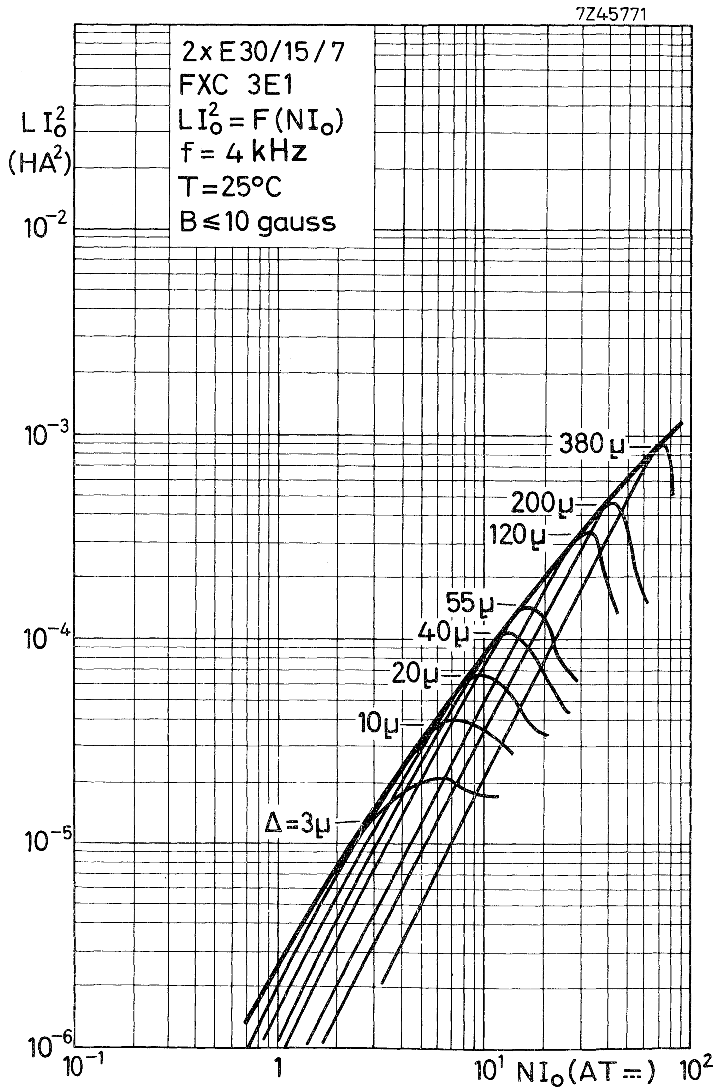
The construction is mounted by pushing the spring over the clasp in such a way that the lips A of the spring catch in the square holes B of the clasp. The mechanical pressure, required to keep the two E-cores together is exercised by means of two lips on top of the spring. No special tool is required for mounting the construction.

The construction can be used in horizontal and vertical position.
If the construction is used in vertical position, the lips C of the clasp must be bent. The dimensions and mutual distance of these lips are chosen in such a way that they fit printed-wiring boards with a grid of 0.1" as well as those with a grid of 2.50 mm.
If used in a horizontal position the clasp can be earthed by means of a copper wire soldered in hole D.

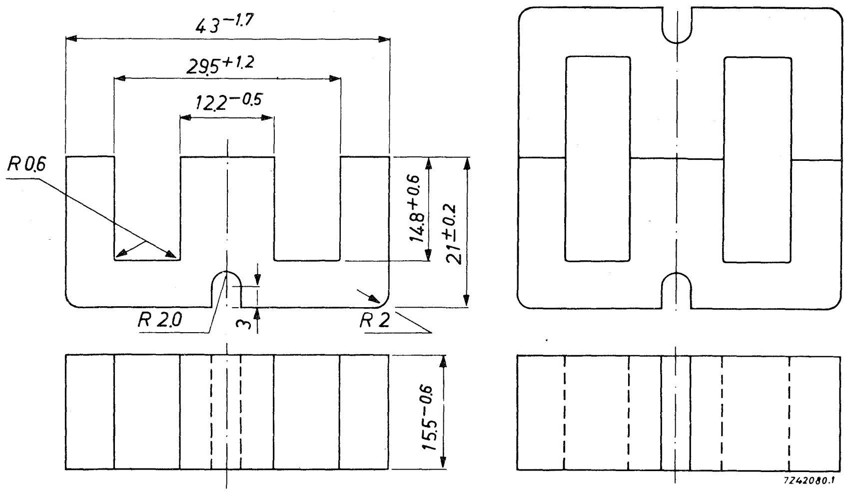
CHARACTERISTIC CURVES

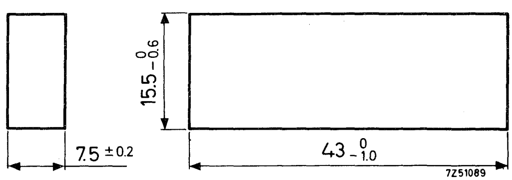
HANNA CURVES

Indicating optimum inductance for a certain airgap and direct current



E- AND I-CORES





The dimensions are according to German specification D.I.N. 41295.

	E42/21/15		I42/7.5/15
Ferroxcube grade	3E1	improved 3E1	3E1
Approximate weight	42g	42g	
Catalog number of E-core	4322 020 34720	4322 020 34850	4322 020 37320

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer 42/42/15 composed of two cores type E 42/21/15 or the E-I combination 42/29/15.

Shell type transformer		42/42/15		42/29/15
Dimensional quantities:				
mean length of lines of force	l_e =	9.70 cm		6.72 cm
mean area of lines of force	A_e =	1.82 cm^2		1.83 cm^2
	$\Sigma \frac{l_e}{A_e}$ =	5.34 cm^{-1}		3.67 cm^{-1}
effective volume	V_e =	17.6 cm^3		12.3 cm^3
Electrical properties at 25 ± 10 °C:		3E1	improved 3E1	3E1
at Δ = 0:	μ_e =	1910-3140		> 1820
	A_L =	4425-7380	≥ 6060	> 6300
	α =	15.0		≤ 12.6
at 4 kHz and $\hat{B}$ between 15 and 30 gauss	$q_{2-24-100}$	≤ 7	4	$\Omega/(H^{3/2}\cdot mA)$

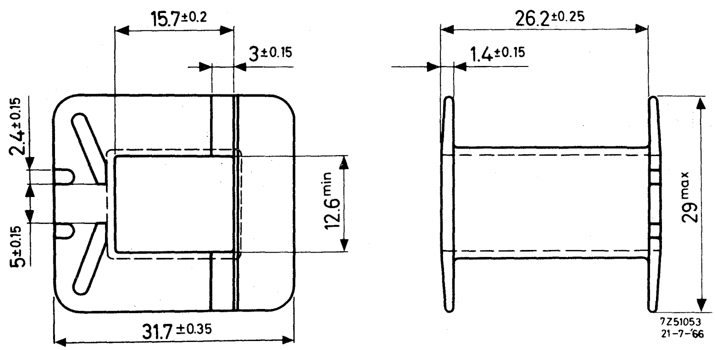
Mechanical force at which the electrical properties are determined is 280 Newton.

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

The following E-cores can be delivered with an airgap (ground in each E-core)

cat.number	airgap length in mm
4322 020 34740	0.25 ± 0.015
4322 020 34750	0.5 ± 0.015

COIL FORMER
for shell type transformer 42/42/15 (M 42)



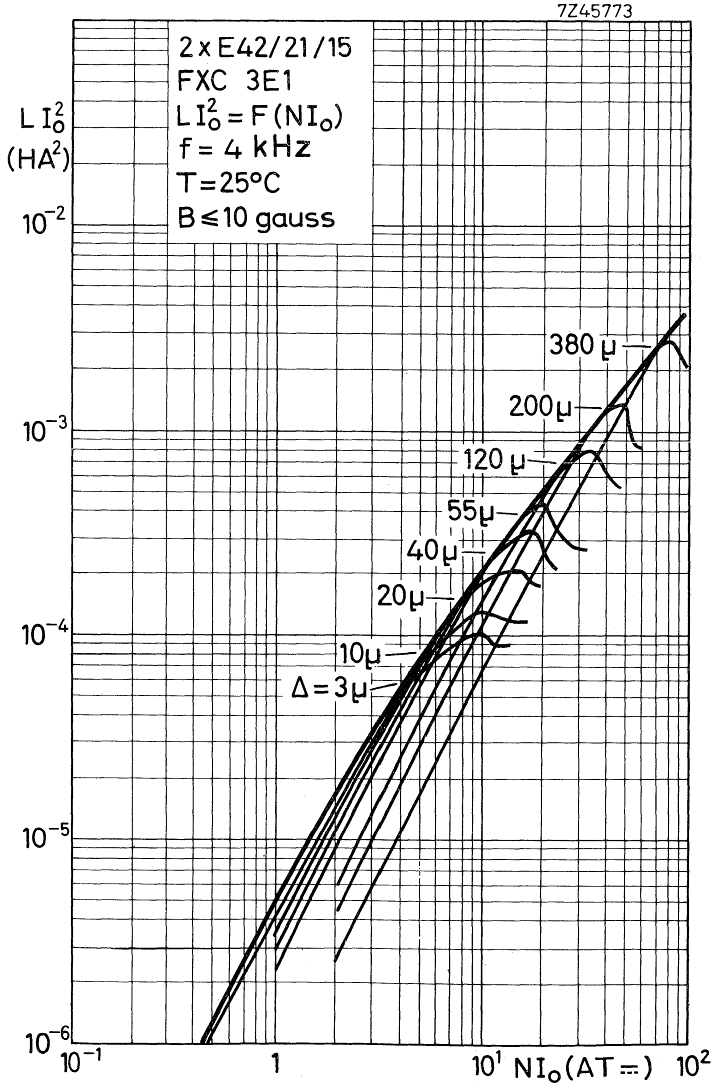
catalog number	4312 021 28672
material	reinforced polyamide
minimum window area in mm^2	178
mean length of turn in cm	9.3
approximate weight in g	4
maximum temperature in ^{o}C	180

The dimensions are practically according to German specification D.I.N. 41305.

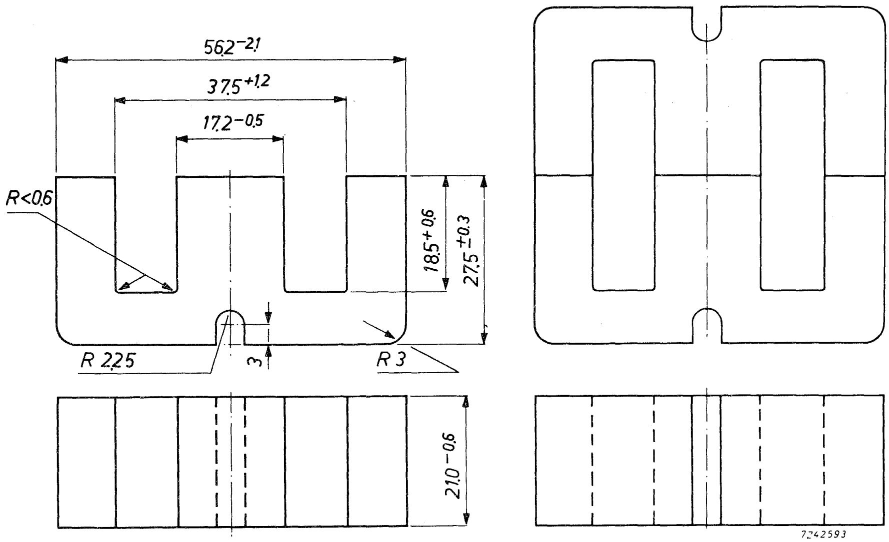
CHARACTERISTIC CURVES

HANNA CURVES

Indicating optimum inductance for a certain airgap and direct current



E-CORE



The dimensions are according to German specification D.I.N. 41295.

Ferroxcube grade	3E1
Approximate weight	115 g
Cat. number of E-core	4322 020 34780

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer 55/55/21 composed of two cores type E 55/28/21.

shell type transformer 55/55/21

Dimensional quantities:

mean length of lines of force	l_e	=	12.3	cm
mean area of lines of force	A_e	=	3.54	cm^2
	$\Sigma \frac{l_e}{A_e}$	=	3.48	cm^{-1}
effective volume	V_e	=	43.7	cm^3

Electrical properties at 25 ±10 °C

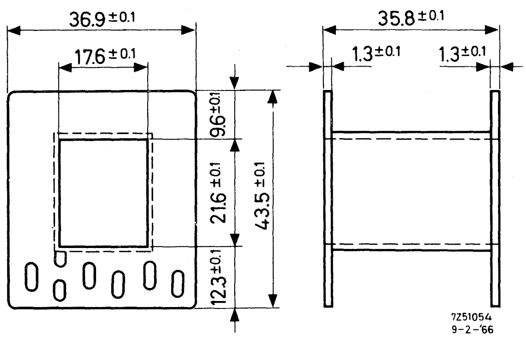
at Δ = 0	μ_e	=	1950 - 3250	
	A_L	=	7050-11700	
at Δ = 0	α	$\leq$	11.9	
at 4 kHz and $\hat{B}$ between 15 and 30 gauss	$q_{2-24-100}$	$\leq$	4	$\Omega/(H^{3/2}\ mA)$

Mechanical force at which the electrical properties are determined is 550 Newton.

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

COIL FORMER

for shell type transformer 55/55/21



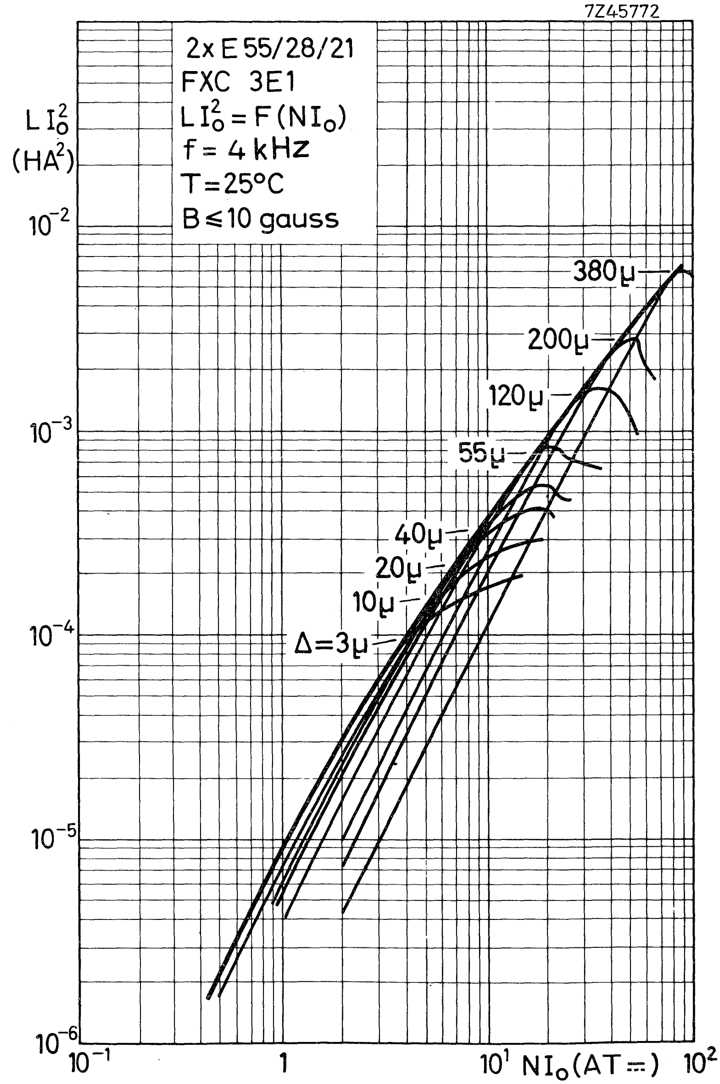
catalog number	4312 021 28700
material	polypropylene
minimum window area in mm^2	250
mean length of turn in cm	11.6
approximate weight in g	9
maximum temperature in °C	100

The dimensions are according to German specification D.I.N. 41305.

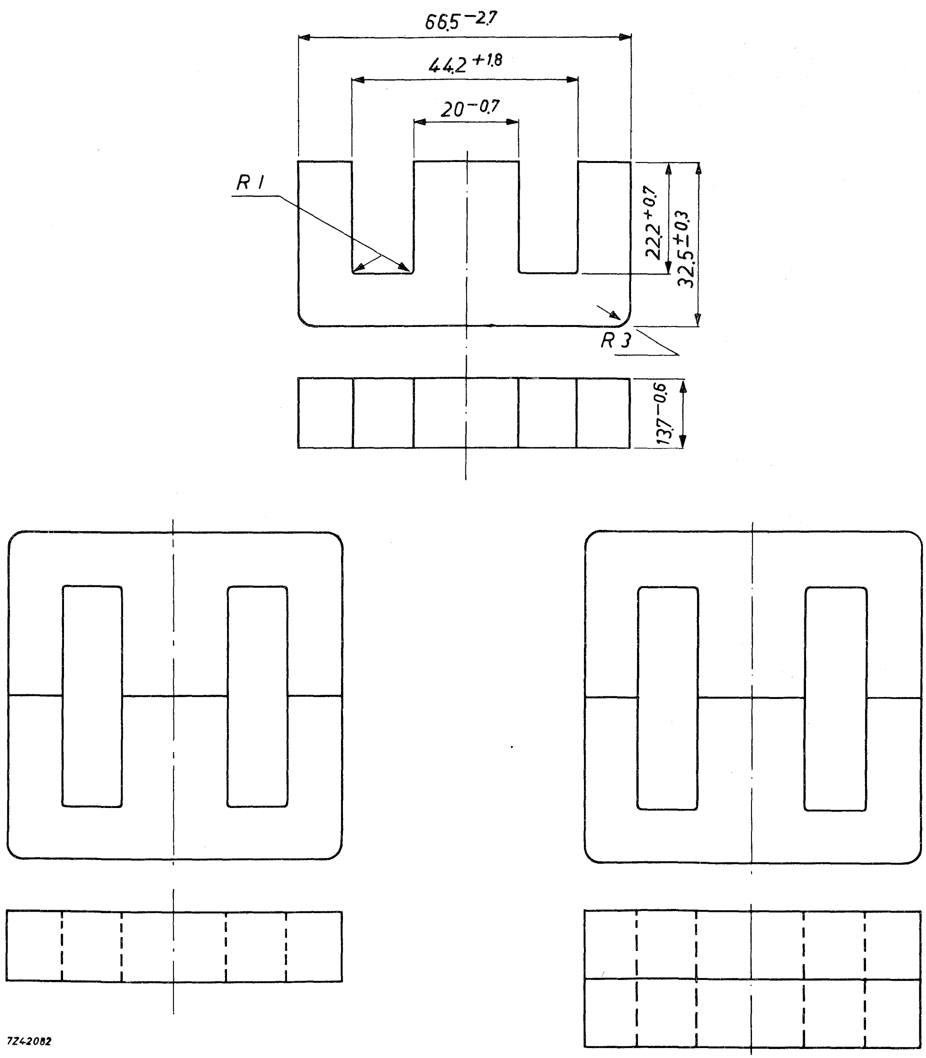
CHARACTERISTIC CURVES

HANNA CURVES

Indicating optimum inductance for a certain airgap and direct current



E-CORE



The dimensions are according to German specification D.I.N. 41295.

Ferroxcube grade 3E1
Approximate weight 76 g
Type number of E-core 4322 020 34820

A transformer core can be built up by combining an even number of E-cores. Shapes that are often chosen are the shell type transformers 65/65/13 composed of two cores type E 65/32/13, and 65/65/27 composed of four cores type E 65/32/13.

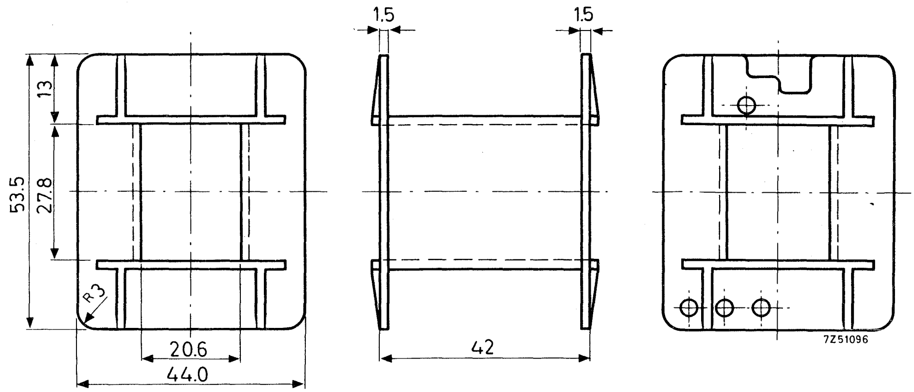
shell type transformer			65/65/13	65/65/27	
Dimensional quantities:					
mean length of lines of force	l_e	=	14.7	14.7	cm
mean area of lines of force	A_e	=	2.66	5.32	cm^2
	$\Sigma' \frac{l_e}{A_e}$	=	5.51	2.75	cm^{-1}
effective volume	V_e	=	39.1	78.2	cm^3
Electrical properties at 25 ± 10 °C					
at $\Delta = 0$:	μ_e	=	1980-3290	1835-3050	
	A_L	=	4500-7500	8400-14000	
	α	$\leq$	14.9	10.9	
at 4 kHz and $\hat{B}$ between 15 and 30 gauss	$q_{2-24-100}$	$\leq$	7		$\Omega/(H^{3/2}\cdot mA)$

Mechanical force at which the electrical properties are determined is 400 Newton

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

COIL FORMER

for shell type transformer 65/65/27 (M 65)



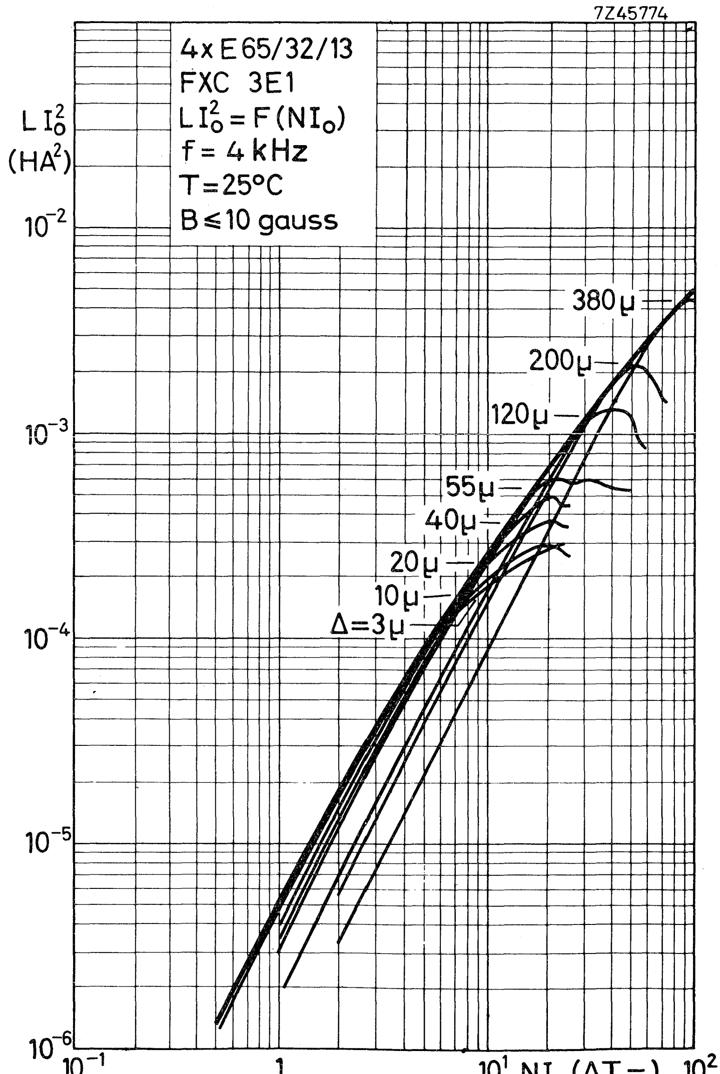
catalog number	4312 021 28690
material	polypropylene
minimum window area in mm^2	394
mean length of turn in cm	15
approximate weight in g	13
maximum temperature in °C	100

The dimensions are according to German specification D.I.N. 41305.

CHARACTERISTIC CURVES

HANNA CURVES

Indicating optimum inductance for a certain airgap and direct current



X-CORES

INTRODUCTION

Ferroxcube cross cores have been especially developed for transformers to be used on printed-wiring boards. To this end these cores have coil formers with soldering pins which are positioned according to a grid. The height of the cores is restricted due to the small available distance between two printed-wiring boards.

The optimal height of the cross cores is approximately 0.8x the side of the square bottom surface. (In some cases a somewhat lower height than the optimal one is chosen to adapt the core to currently used heights in equipment design).

The maximum height of the assembled cross core is given under "Mounting parts".

To save space on the mounting board the connection pins of the coil former have been designed to fit within the waste space enclosed by the outer dimensions of the core (see hatched parts in Fig.2). This could be achieved, without loosing much of the dimensional quantities of the magnetic circuit with respect to potcores, by giving the core the X-shape.

The coilformers of the cross cores have the advantage that the fragile lead-out wires can be soldered to the pins directly after winding and consequent less rejects in production by wire damage.

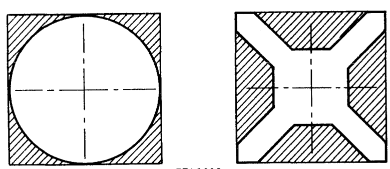


fig.1 7Z43008 fig.2

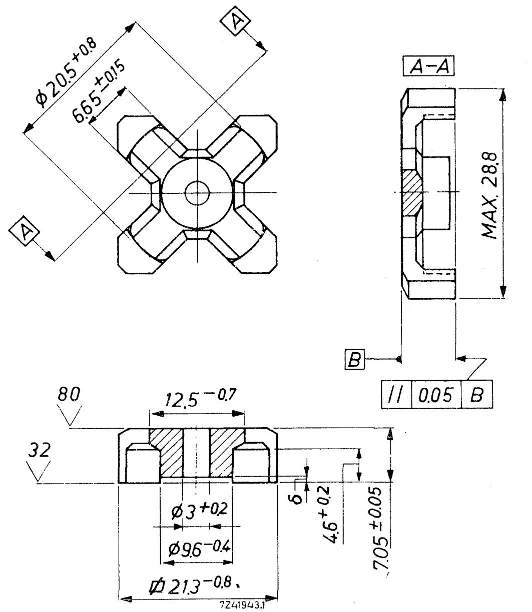
MOUNTING PARTS

Special tools have been designed which first centre the cross core halves and afterwards bend the lips of the containers.
These tools are not supplied, however drawings of the tools are supplied on request. For cat. numbers of these tools, see table below.

core type	catalog number of recommended tool
X 22	4322 058 00080
X 30	4322 058 00090
X 35	4322 058 00100

See also the remarks with regard to the mounting parts of the cross cores.

X-CORE



These cores have been developed especially for transformers to be mounted on printed-wiring boards. Two versions of core halves can be supplied:
(1) without an air-gap, and
(2) with air-gap. Standardised air-gap lengths in each core half are:
0.02, 0.05, 0.15 and 0.25 mm.

The material grades are ferroxcube 3H1, 3E1 and 4C4.

When ordering, the desired core half should be indicated by its catalog number.

The numbers for separate core halves are:

3522 200 03470 for FXC 3E1
4322 020 23510 for FXC 3H1
3522 200 03490 for FXC 4C4

They are supplied without airgap.

For the combination of two cross-core halves, randomly chosen from a lot, the following properties are guaranteed at 25 ± 10 °C.

	$\hat{B}$ gauss	frequency kHz	catalog number 3522 200 03470	4322 020 23510	3522 200 03490
μ_e	≤ 1	4	≥ 1495	≥ 1440	≥ 95
α	≤ 1	4	≤ 17.5	≤ 17.8	≤ 68.0
$\frac{\tan \delta}{\mu_i}$	≤ 1	4		≤ 1.2 × 10^{-6}	
	≤ 1	100		≤ 5 × 10^{-6}	
	≤ 1	2000			≤ 40 × 10^{-6}
	≤ 1	5000			≤ 60 × 10^{-6}
	≤ 1	10,000			≤ 100 × 10^{-6}
$q_{2-24-100}$	15 - 30	4	≤ 6	≤ 1.8	

The mechanical force at which above mentioned values are determined is 120 Newton.

The following X-core halves are available with an airgap:

catalog number	material	air gap length in mm
4322 020 23710	3H1	0.02 ± 0.01
4322 020 23720	3H1	0.05 ± 0.015
4322 020 23730	3H1	0.15 ± 0.015
4322 020 23700	3E1	0.15 ± 0.015
4322 020 23740	3H1	0.25 ± 0.015

Approximate weight of two halves 12 g

Mean length of lines of force l_e = 3.80 cm

A_e = 0.66 cm^2

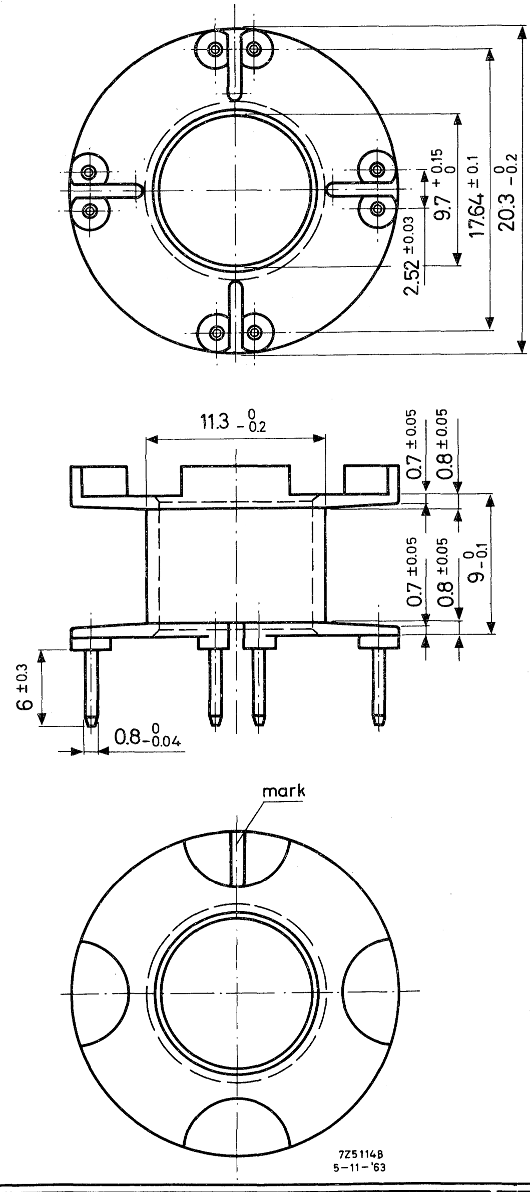
$\Sigma \frac{l_e}{A_e}$ = 5.75 cm^{-1}

V_e = 2.51 cm^3

This X-core meets the following specifications:

International: I.E.C
France : C.C.T.U. 06 - 10
Germany : D.I.N. 41299

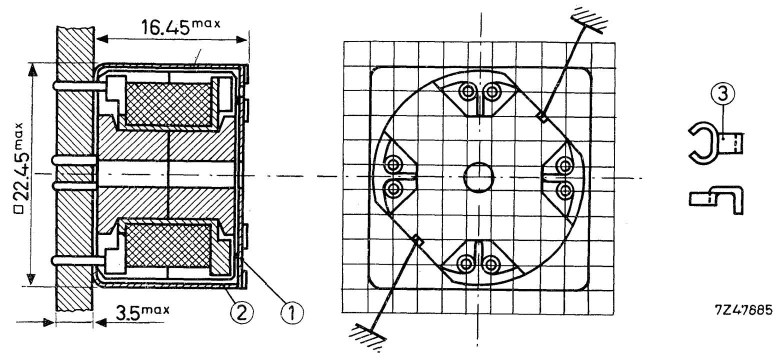
COIL FORMER


9.7 +0.15 0
17.64 ±0.1
20.3 0 −0.2
2.52 ±0.03
11.3 0 −0.2
0.7 ±0.05
0.8 ±0.05
0.7 ±0.05
0.8 ±0.05
9 0 −0.1
6 ±0.3
0.8 0 −0.04
mark
7Z51148
5-11-'63

catalog number	4312 021 28830
Material	reinforced polyester
Window area in mm^2	33.5
Mean length of turn in cm	4.9
Max temperature for dipsoldering for 5-6 s in °C	280
Max. working temperature in °C	130
Force for pulling out pins during 1 min. at 25 °C in N	≥ 15
Max. test voltage (50 Hz) between pins during 2 min in V_{rms}	500

$$\frac{R_o}{L} = \frac{1}{\mu_e} \times \frac{1}{f_{cu}} \times 9.9 \times 10^3 \ \Omega/H$$

MOUNTING PARTS



(1). Cover 4322 021 30230
(2). Container 4322 021 30040
(3). Soldering spring 4322 021 30700.

The cross core has been developed especially for transformers to be mounted on printed-wiring boards.

An advantage of this construction is that the leading-out wires are soldered to the pins which are directly mounted on the coil former.

The eight soldering pins are positioned according to a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for board thicknesses up to 3.5 mm. The printed-wiring board should be provided with holes of 1.3 ± 0.1 mm in diameter.

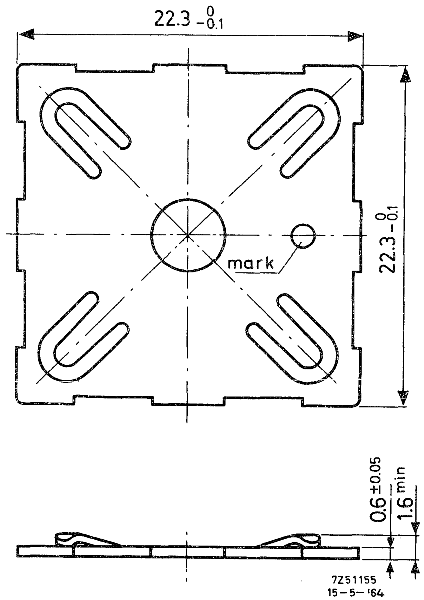
If stranded wire is employed, the use of a soldering spring (pos. 3) is recommended, which facilitates the soldering of the wires to the pins on the coil former. For solid wire the spring is not necessary.

The phosphor-bronze cover has four cut-out lips on the corners, consequently the cover acts as a spring at the same time.

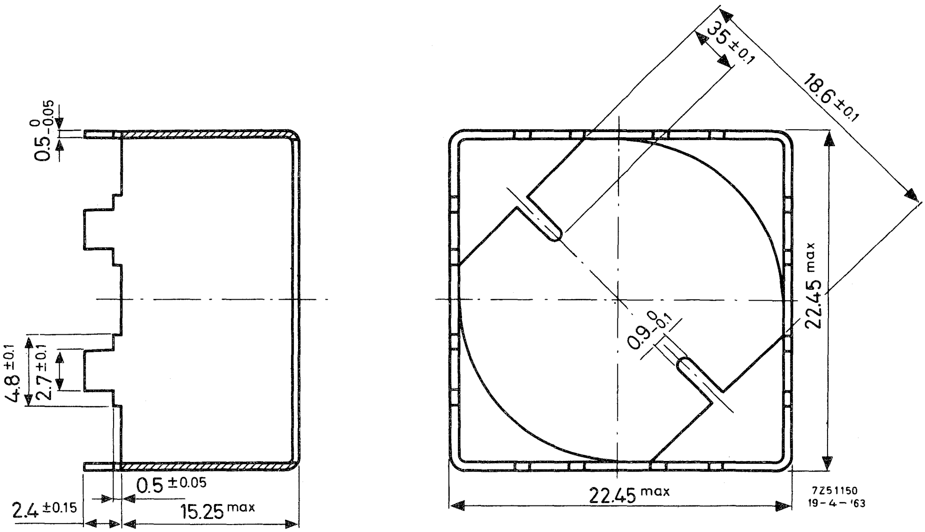
The cover is provided with a marking hole. The mark of the coil former (see the Fig. of coil former) has to be in one line with this hole. These markings facilitate the numbering of the soldering pins and the positioning on the printed-wiring board.

It is recommended to cement the coil former in one of the cross core halves in order to obtain the most possible stable construction.

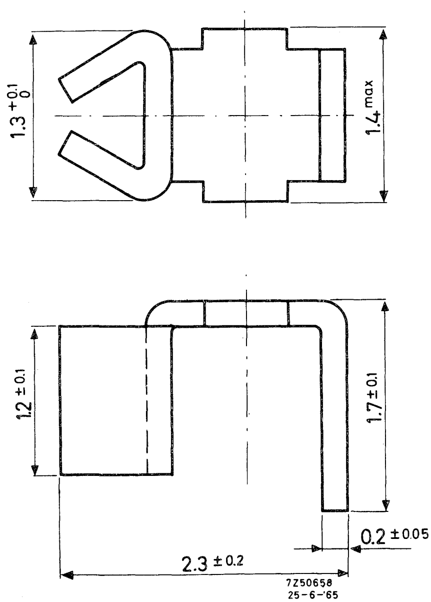
Before bending the lips of the container, pressure should be exercised evenly on the four corners of the cover until the latter meets the container. The required force is approximately 120 Newton. After bending the lips, the core will have the correct tension.



(1) Cover 4322 021 30230
Material: phosphorbronze, nickel plated



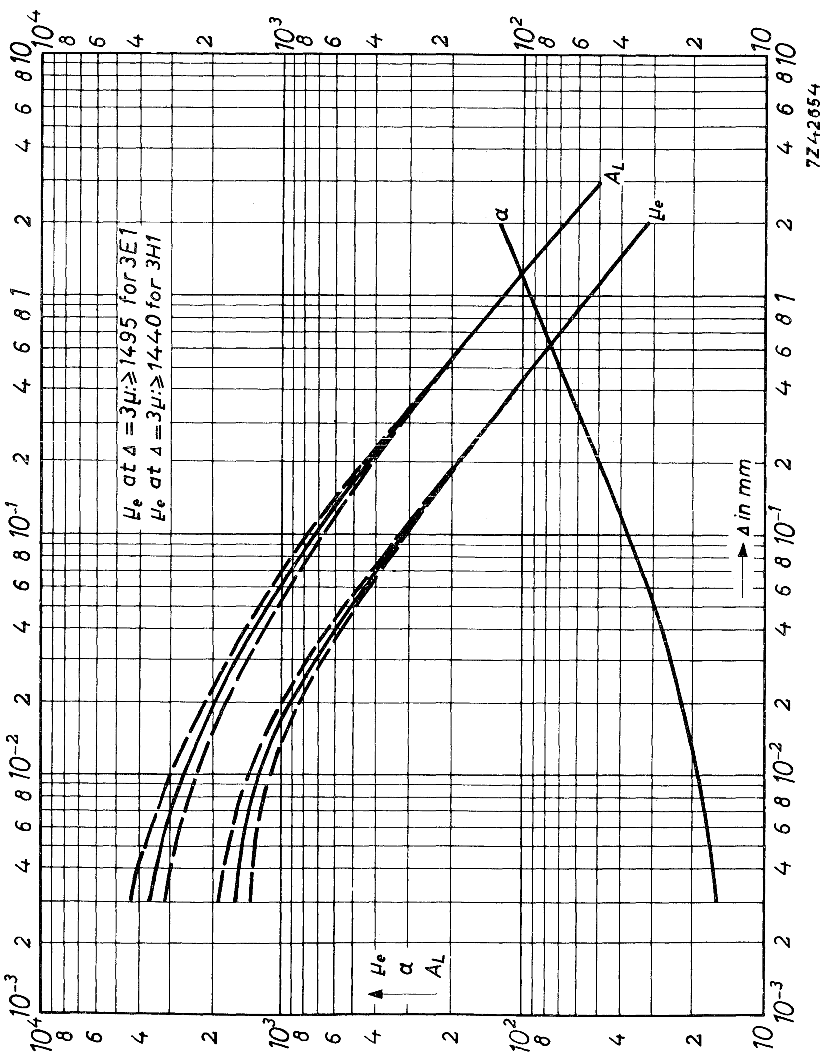
(2) Container 4322 021 30040
Material: brass, nickel plated



(3) Soldering spring 4322 021 30700
Material: brass, dipsoldered

CHARACTERISTIC CURVES

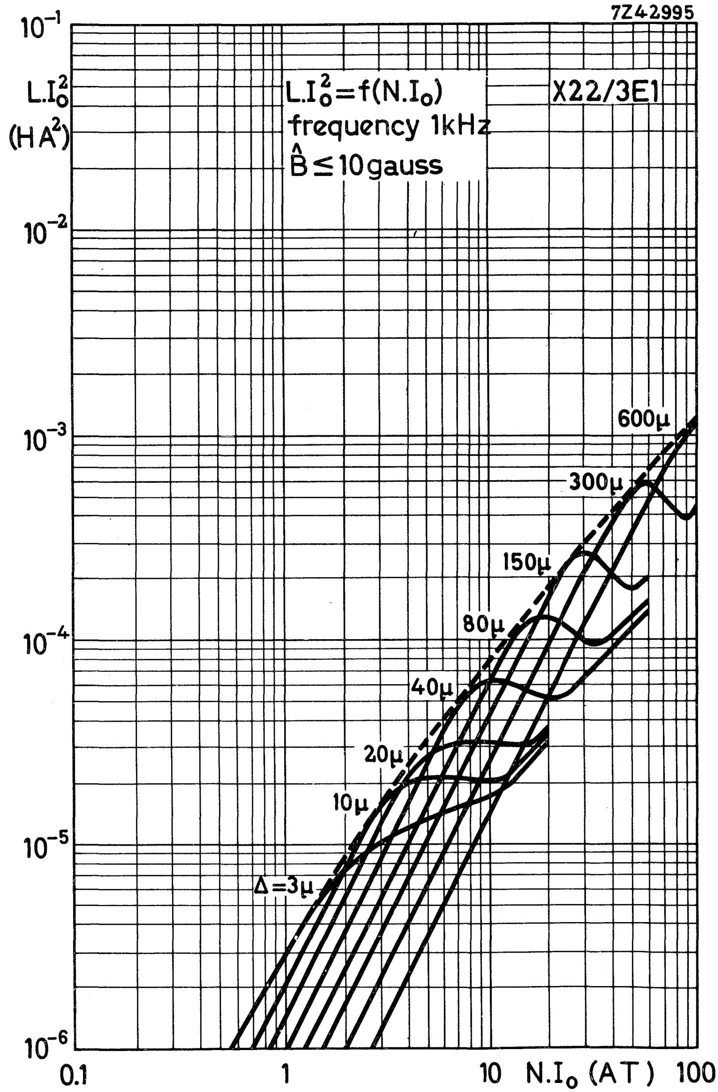
μ_e - α and A_L CURVES.



Effective permeability (μ_e), turn factor for 1 mH (α) and inductance per turn in nanohenrys (A_L) as a function of the airgap length for grades 3E1 and 3H1.

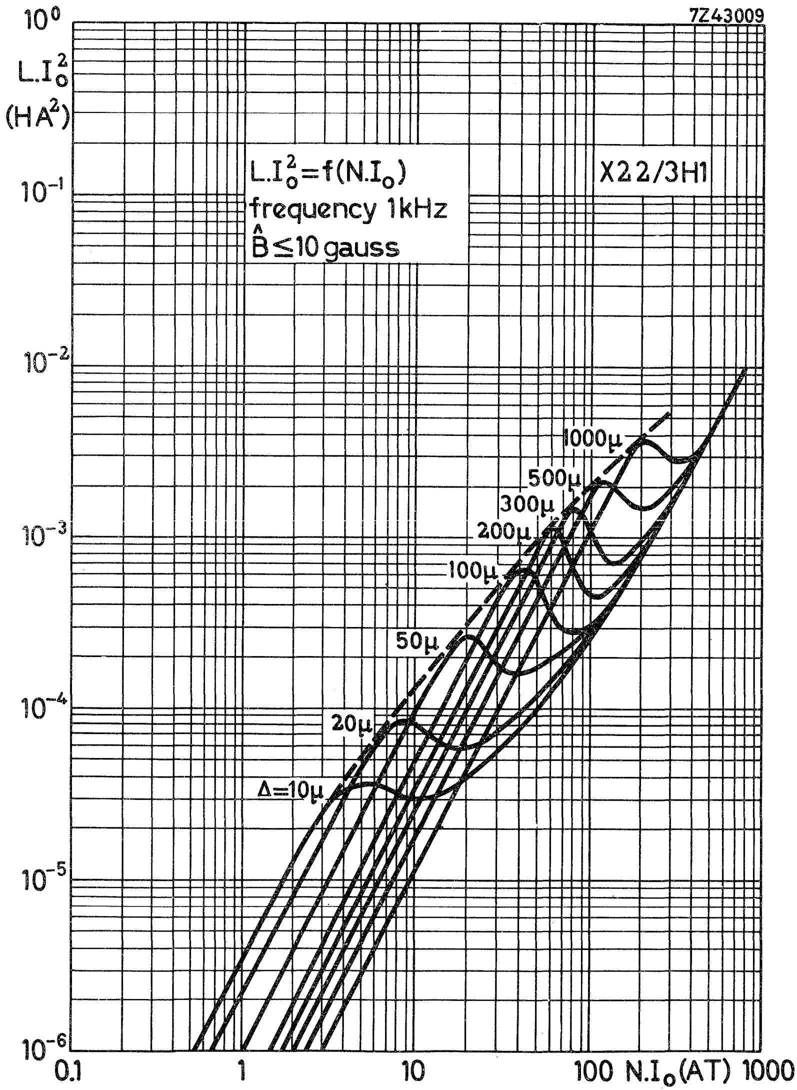
HANNA CURVE

Indicating optimum inductance for a certain airgap and direct current.

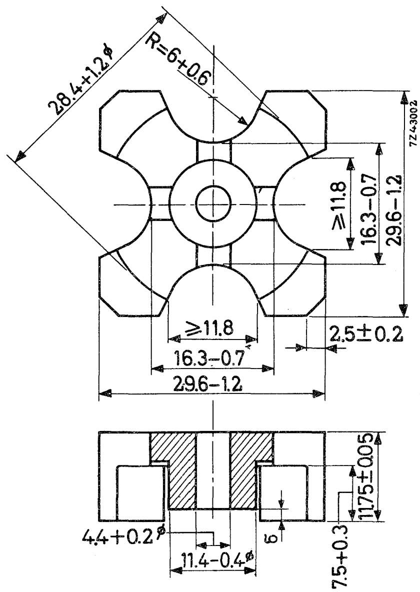


HANNA CURVE

Indicating optimum inductance for a certain airgap and direct current.



X-CORE



These cores have been developed especially for transformers to be mounted on printed-wiring boards. Two versions of core halves can be supplied:

1) without airgap
2) with airgap
   Standardized airgap lengths in each core half are: 0.02, 0.05, 0.15 and 0.25 mm.

The material grade is FXC 3H1.
When ordering, the desired core half should be indicated by its catalog number.
The catalog number for the separate core half without airgap is:

4322 020 23750

For the combination of two cross-core halves, randomly chosen from a lot, the following properties are guaranteed at 25 ± 10 °C.

	$\hat{B}$ gauss	frequency kHz	catalog number 4322 020 23750
μ_e	≤ 1	4	≥ 1525
α	≤ 1	4	≤ 15.9
$\frac{\tan \delta}{\mu_i}$	≤ 1	4	$\leq 1.2 \times 10^{-6}$
	≤ 1	100	$\leq 6 \times 10^{-6}$
$q_{2-24-100}$	15–30	4	≤ 1.8

The mechanical force at which above mentioned values are determined is 250 Newton.

The following X-core halves are available with an airgap:

catalog number	material	airgap length in mm
4322 020 23960	3H1	0.02 ± 0.01
4322 020 23970	3H1	0.05 ± 0.015
4322 020 23980	3H1	0.15 ± 0.015
4322 020 23990	3H1	0.25 ± 0.015

Approximate weight of two halves 38 g

Mean length of lines of force $l_e = 5.58$ cm

$$A_e = 1.14 \text{ cm}^2$$

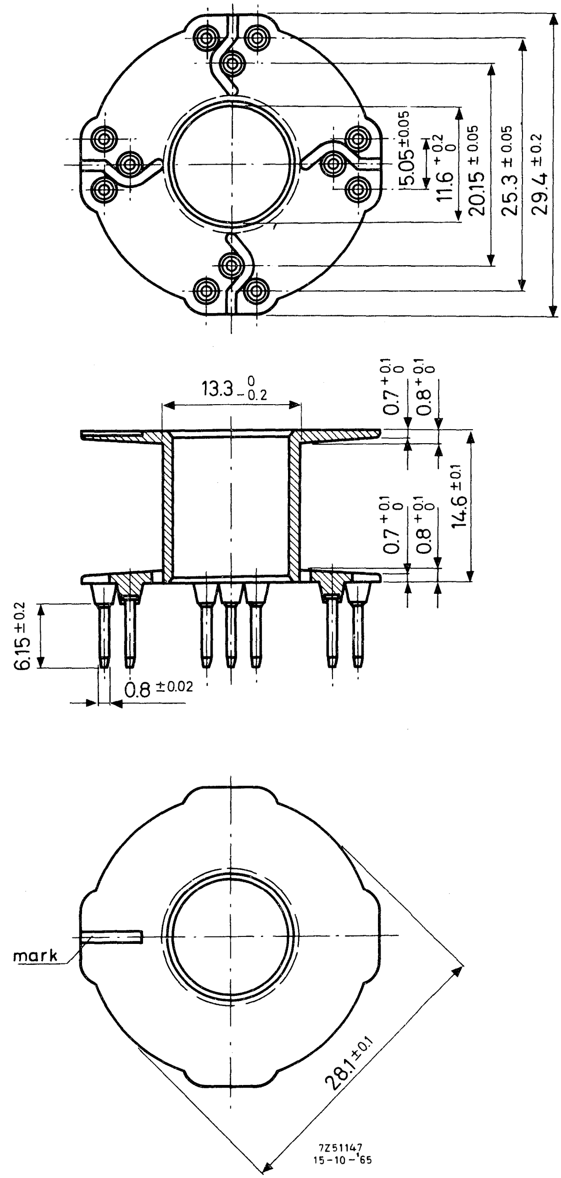
$$\Sigma \frac{l_e}{A_e} = 4.90 \text{ cm}^{-1}$$

$$V_e = 6.36 \text{ cm}^3$$

This X-core meets the following specifications:

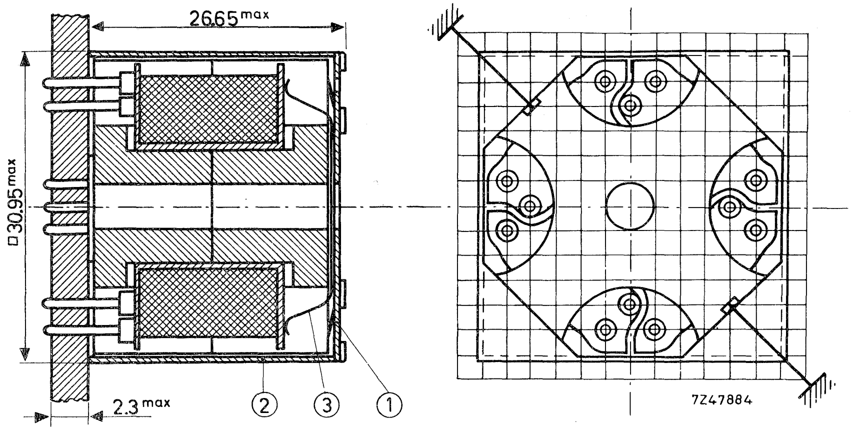
International: I.E.C.
France : C.C.T.U. 06 - 10
Germany : D.I.N. 41299

COIL FORMER


5.05 ±0.05
11.6 +0.2 0
20.15 ± 0.05
25.3 ± 0.05
29.4 ± 0.2
13.3 0 −0.2
0.7 +0.1 0
0.8 +0.1 0
14.6 ±0.1
6.15 ±0.2
0.8 ±0.02
mark
28.1 ±0.1
7Z51147
15-10-'65

catalog number	4322 021 31190
Material	reinforced polyester
Window area in mm^2	97
Mean length of turn in cm	6.5
Max temperature for dipsoldering for 5-6 s in $^{\circ}C$	280
Max. working temperature in $^{\circ}C$	130
Force for pulling out pins during 1 min. in $25^{\circ}C$ in N	≥ 20
Max test voltage (50 Hz) between pins during 2 min in V_{rms}	2000

MOUNTING PARTS



(1) Cover 4322 021 31150
(2) Container 4322 021 31170
(3) Spring 4322 021 30210
(4) Soldering spring 4322 021 30700 (see below)

The cross core has been developed especially for transformers to be mounted on printed-wiring boards.

An advantage of this construction is that the leading-out wires are soldered to the pins which are directly mounted on the coil former.

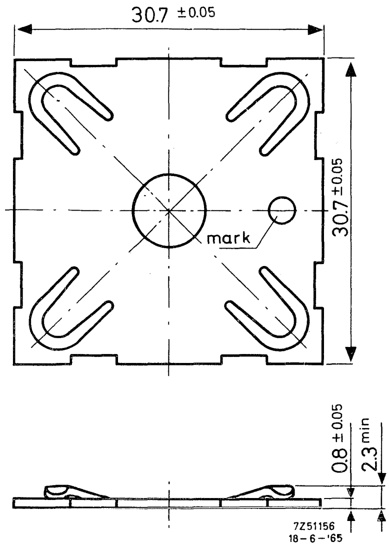
The twelve soldering pins are positioned according to a grid of 2.52mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50mm grid. The pin length is sufficient for board thicknesses up to 2.3mm. The printed-wiring board should be provided with holes of 1.3 ± 0.1 mm in diameter.

The phosphor-bronze cover has four cut-out lips on the corners, consequently the cover acts as a spring at the same time.

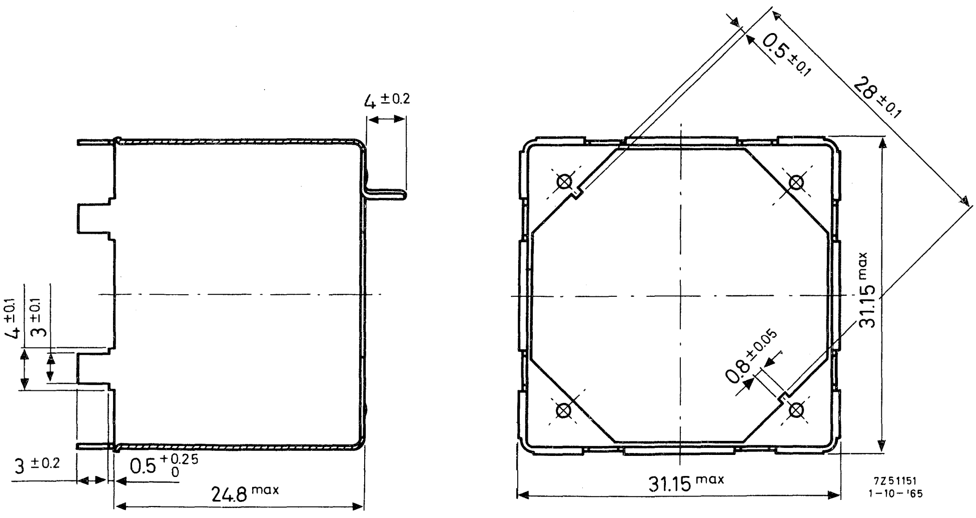
The cover is provided with a marking hole. The mark of the coil former (see the Fig. of coil former) has to be in one line with this hole. These markings facilitate the numbering of the soldering pins and the positioning on the printed-wiring board.

It is recommended to cement the coil former in one of the cross-core halves or to use the spring (pos. 3) in order to obtain the most stable construction.

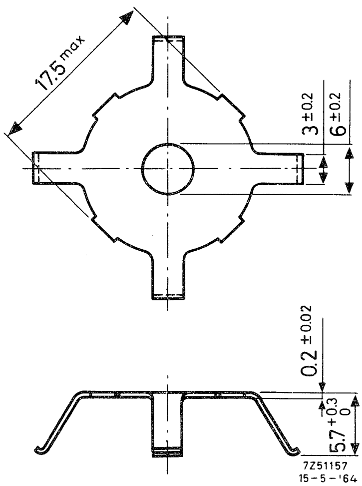
Before bending the lips of the container, pressure should be exercised evenly on the four corners of the cover until the latter meets the container. The required force is approximately 250 Newton. After bending the lips, the core will have the correct tension.



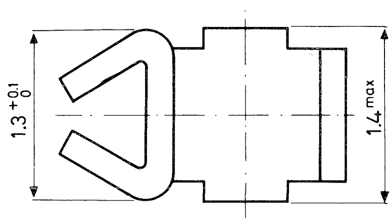
(1) Cover 4322 021 31150
Material: phosphorbronze, nickel plated

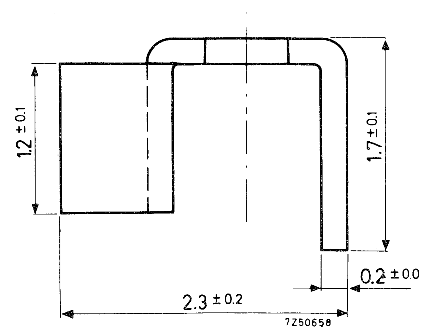


(2) Container 4322 021 31170
Material: brass, nickel plated



(3) Spring 4322 021 30210
Material: phosphorbronze

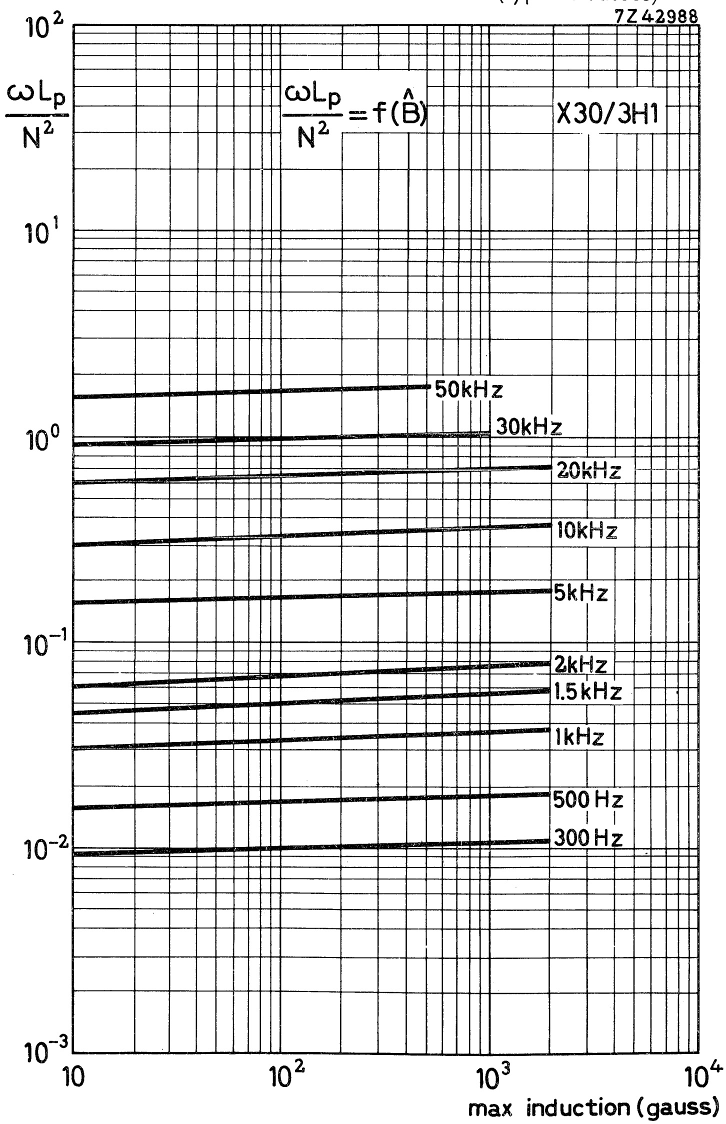




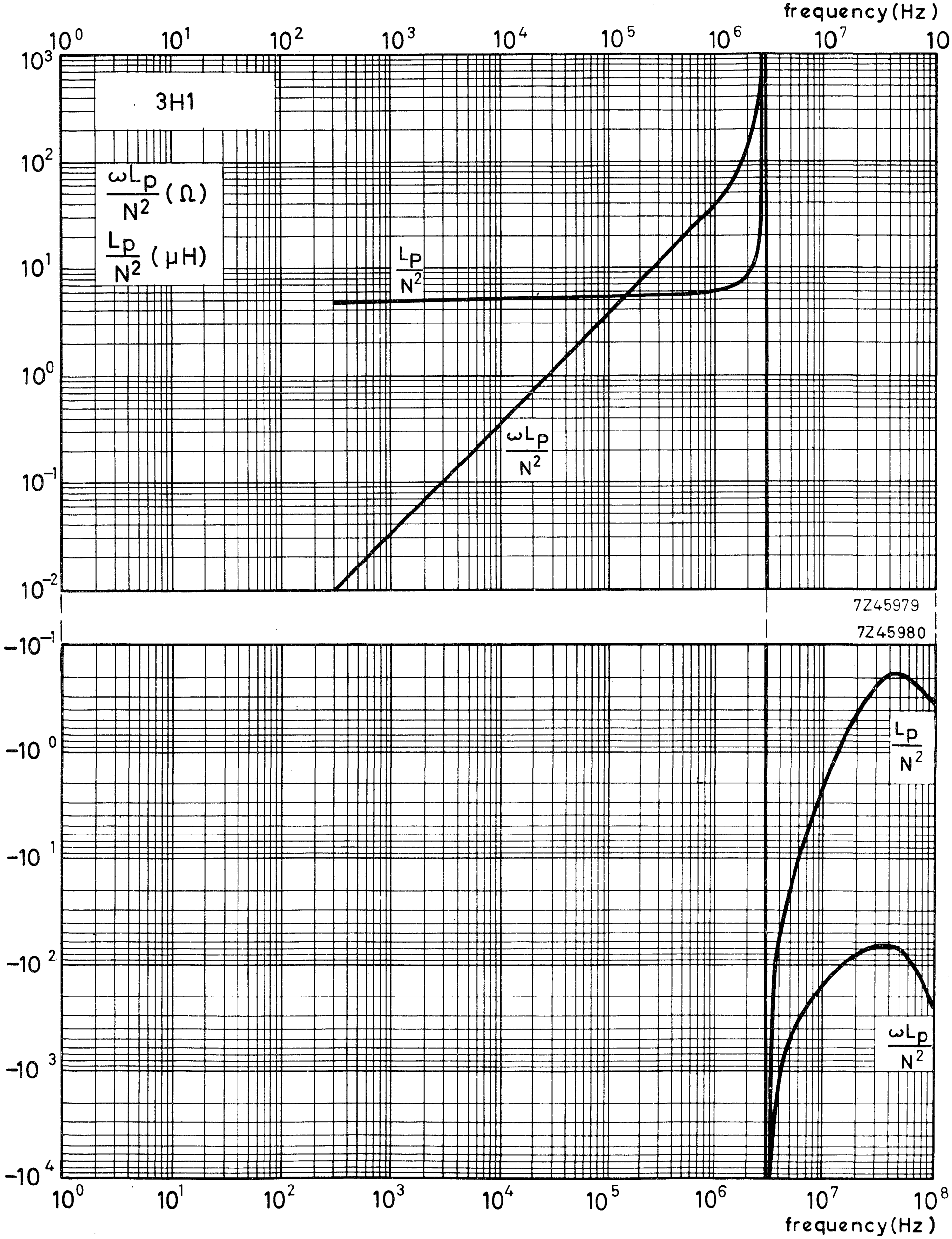
(4) Soldering spring 4322 021 30700
Material: brass, dipsoldered

CHARACTERISTIC CURVES

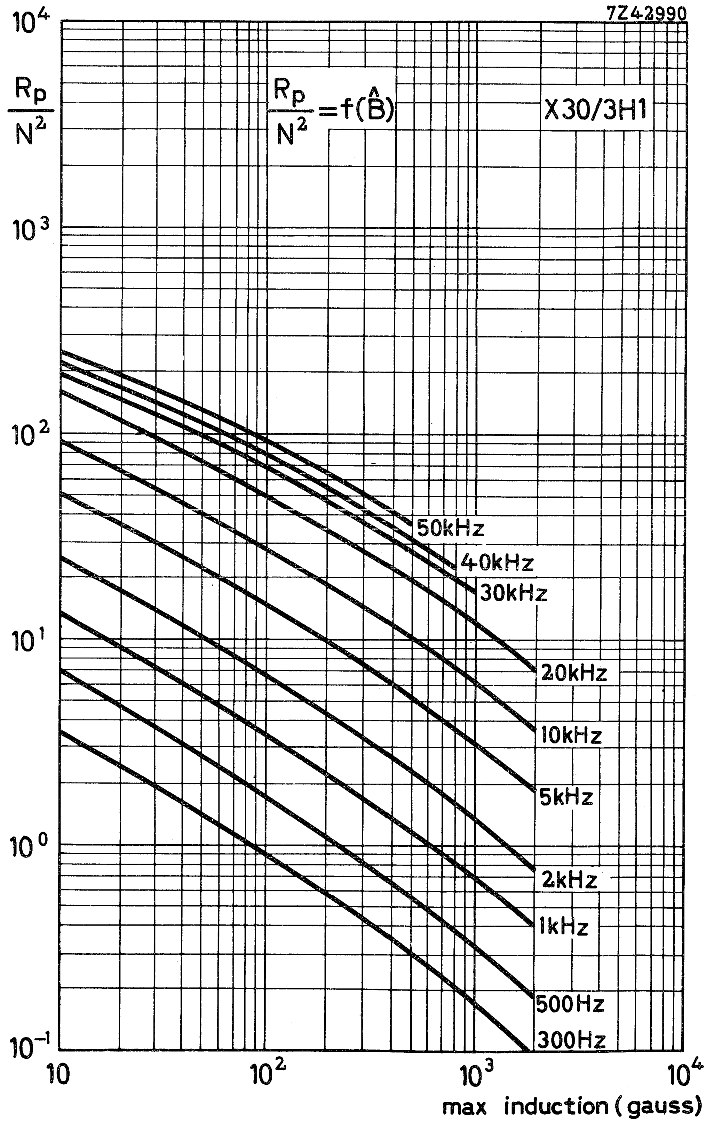
INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)



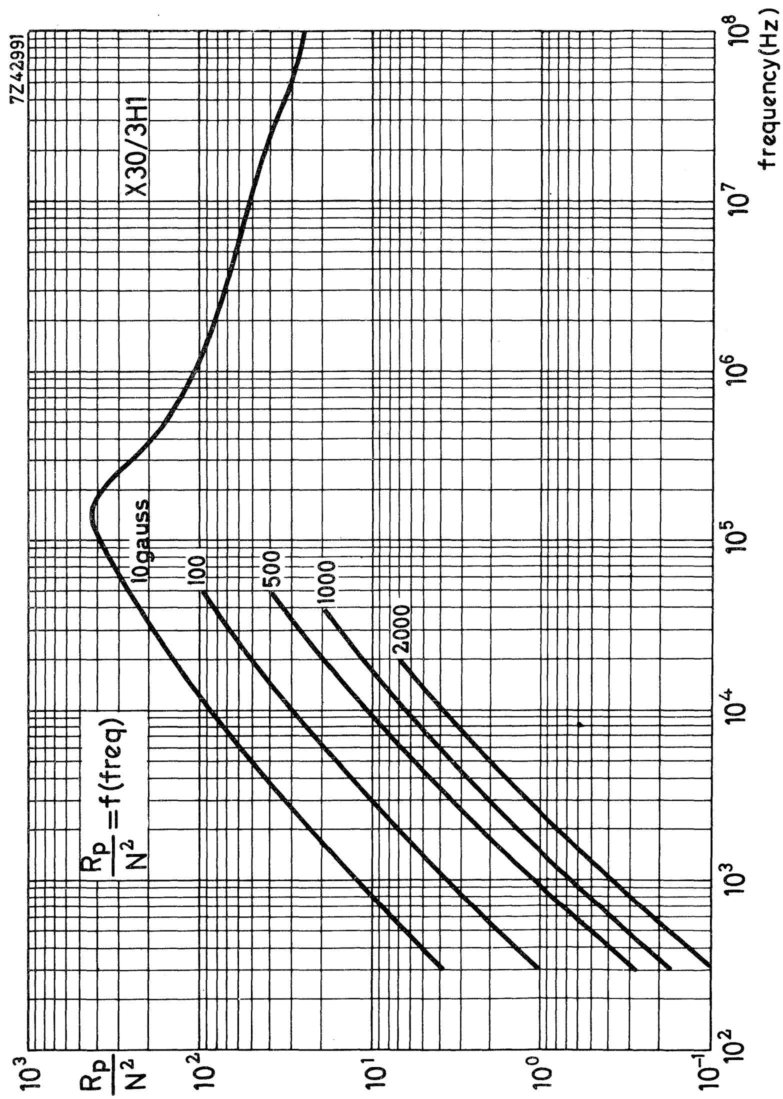
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical curves)



CORE LOSSES AS A FUNCTION OF THE INDUCTION (typical values)

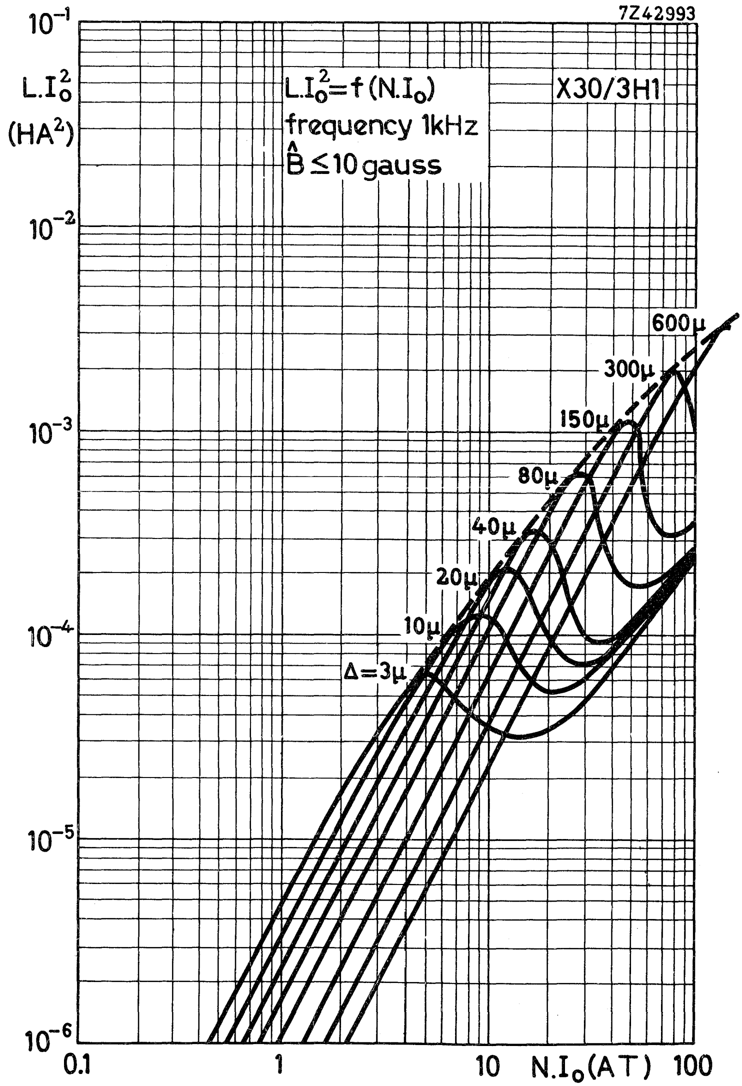


CORE LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)

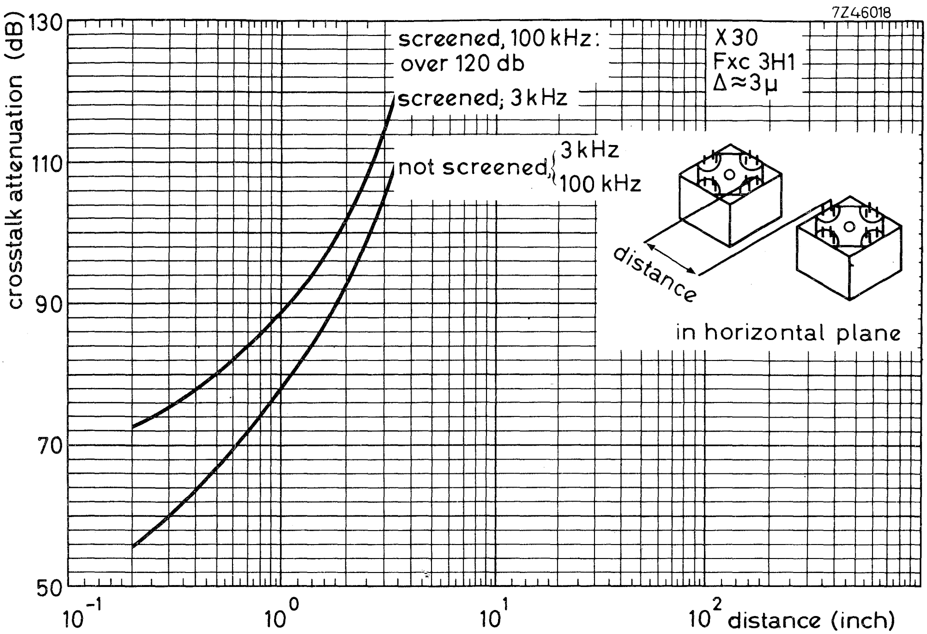


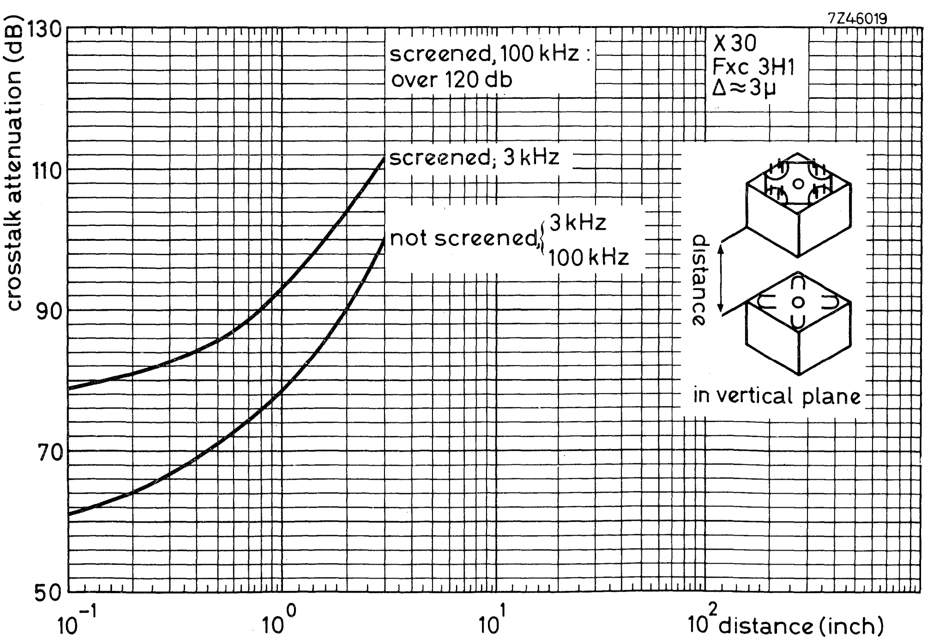
HANNA CURVE (typical values)

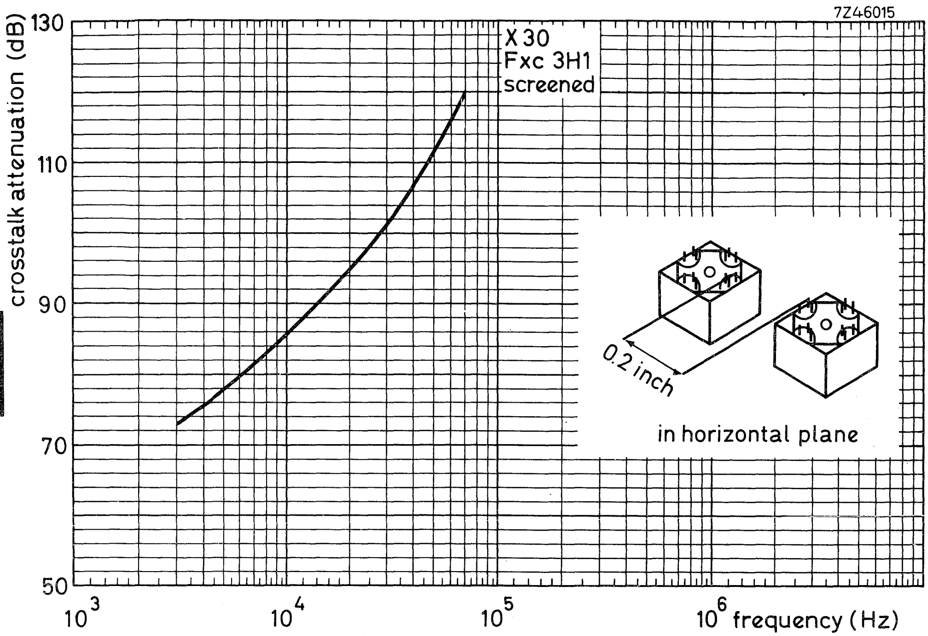
Indicating optimum inductance for a certain airgap and direct current.



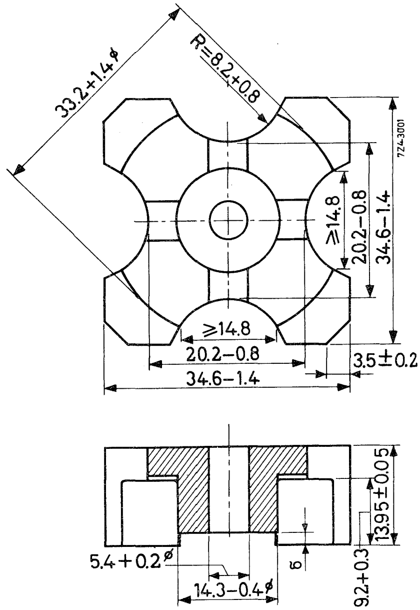
CROSSTALK ATTENUATION






7Z46015
X 30
Fxc 3H1
screened
crosstalk attenuation (dB)
130
110
90
70
50
10^3
10^4
10^5
10^6
frequency (Hz)
0.2 inch
in horizontal plane

X-CORE



These cores have been developed especially for transformers to be mounted on printed-wiring boards. Two versions of core halves can be supplied:

1) without airgap
2) with airgap
   Standardized airgap lengths in each core half are: 0.02, 0.05, 0.15, 0.25, 0.5 and 1.0 mm.

The material grade is FXC 3H1 or 3C5.

When ordering, the desired core half should be indicated by its catalog number.

The catalog number for the separate core halves without airgap is:

4322 020 24000 for FXC 3H1
4322 020 24010 for FXC 3C5

For the combination of two cross-core halves, randomly chosen from a lot, the following properties are guaranteed.

	$\hat{B}$ gauss	frequency kHz	catalog number 4322 020	
			24000	24010
μ_e	≤ 1	4	≥ 1580	
α	≤ 1	4	≤ 14.4	
$\frac{\tan \delta}{\mu_i}$	≤ 1	4	$\leq 1.2 \times 10^{-6}$	
	≤ 1	100	$\leq 7 \times 10^{-6}$	
$q_{2-24-100}$	15-30	4	≤ 1.8	

The mechanical force at which above mentioned values are determined is 330 Newton.

The following X-core halves are available with an airgap:

catalog number	material	air gap length in mm
4322 020 24210	3H1	0.02 ± 0.01
4322 020 24220	3H1	0.05 ± 0.015
4322 020 24230	3H1	0.15 ± 0.015
4322 020 24240	3H1	0.25 ± 0.015
4322 020 24190	3C5	0.5 ± 0.015
4322 020 24200	3C5	1.0 ± 0.015

Approximate weight of two halves 58 g

Mean length of lines of force $l_e = 6.73$ cm

$A_e = 1.64\ cm^2$

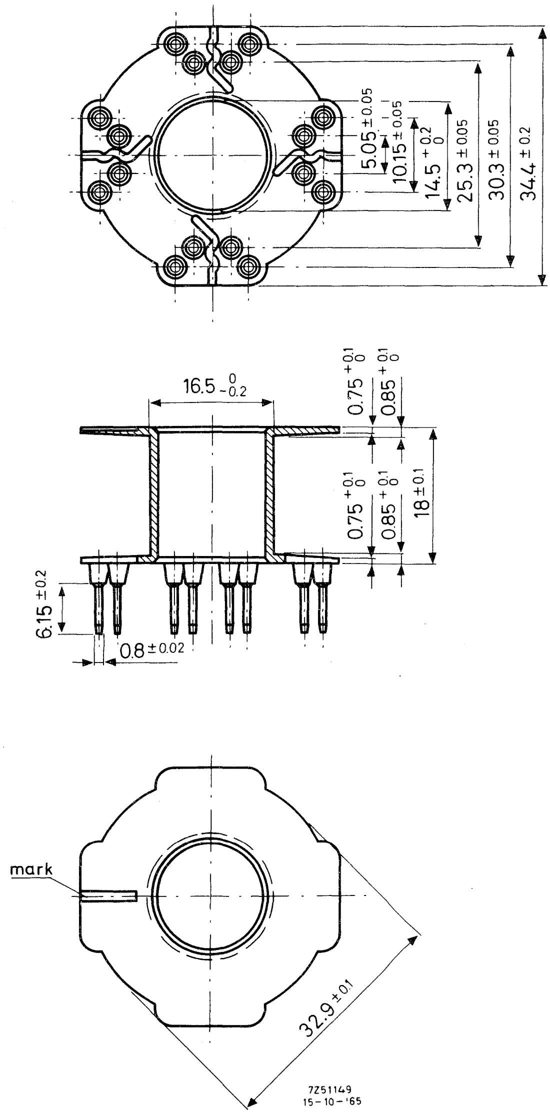
$\Sigma \frac{l_e}{A_e} = 4.10\ cm^{-1}$

$V_e = 11.0\ cm^3$

This X-core meets the following specifications:

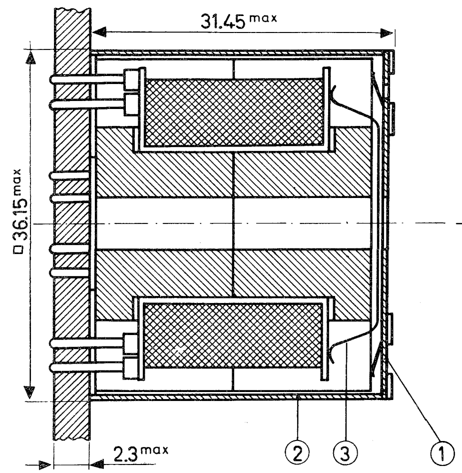
International: I.E.C
France : C.C.T.U. 06 - 10
Germany : D.I.N. 41299

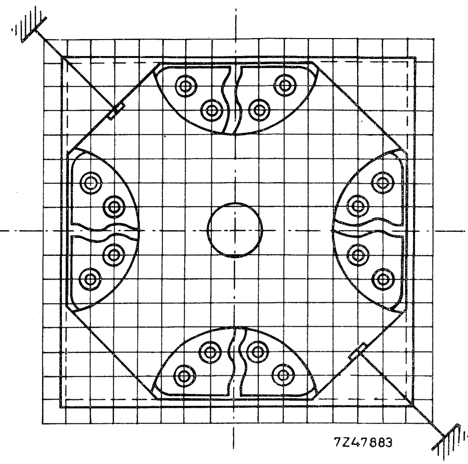
COIL FORMER


5.05 ±0.05
10.15 ±0.05
14.5 +0.2 0
25.3 ±0.05
30.3 ±0.05
34.4 ±0.2
16.5 0 -0.2
0.75 +0.1 0
0.85 +0.1 0
0.75 +0.1 0
0.85 +0.1 0
18 ±0.1
6.15 ±0.2
0.8 ±0.02
mark
32.9 ±0.1
7Z51149
15-10-'65

catalog number	4322 021 31200
Material	reinforced polyester
Window area in mm^2	134
Mean length of turn in cm	7.75
Max temperature for dipsoldering for 5-6 s in °C	280
Max working temperature in °C	130
Force for pulling out pins during 1 min. in 25 °C in N	≥20
Max. test voltage (50 Hz) between pins during 2 min in V_{rms}	2000

MOUNTING PARTS





(1) Cover 4322 021 31160
(2) Container 4322 021 31180
(3) Spring 4322 021 30220
(4) Soldering spring 4322 021 30700 (see below)

The cross core has been developed especially for transformers to be mounted on printed-wiring boards.

An advantage of this construction is that the leading-out wires are soldered to the pins, which are directly mounted on the coil former.

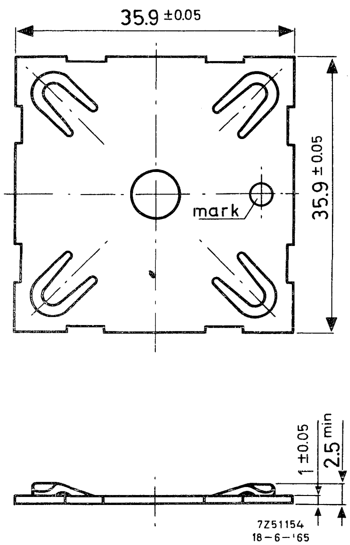
The sixteen soldering pins are positioned according to a grid of 2.52 mm. They will fit printed-wiring boards with a 0.1" grid as well as those with a 2.50 mm grid. The pin length is sufficient for board thicknesses up to 2.3 mm. The printed-wiring board should be provided with holes of 1.3 ± 0.1 mm in diameter.

The phosphor-bronze cover has four cut-out lips on the corners, consequently the cover acts as a spring at the same time.

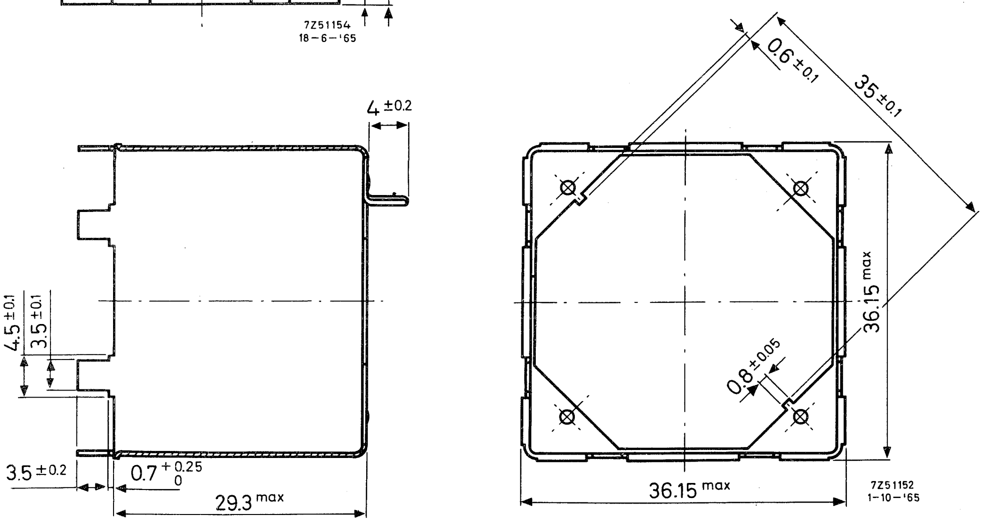
The cover is provided with a marking hole. The mark of the coil former (see the Fig. of coil former) has to be in one line with this hole. These markings facilitate the numbering of the soldering pins and the positioning on the printed-wiring board.

It is recommended to cement the coil former in one of the cross-core halves or to use the spring (pos. 3) in order to obtain the most stable construction.

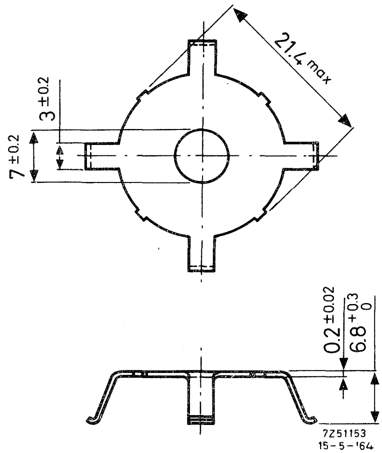
Before bending the lips of the container, pressure should be exercised evenly on the four corners of the cover until the latter meets the container. The required force is approximately 330 Newton. After bending the lips, the core will have the correct tension.



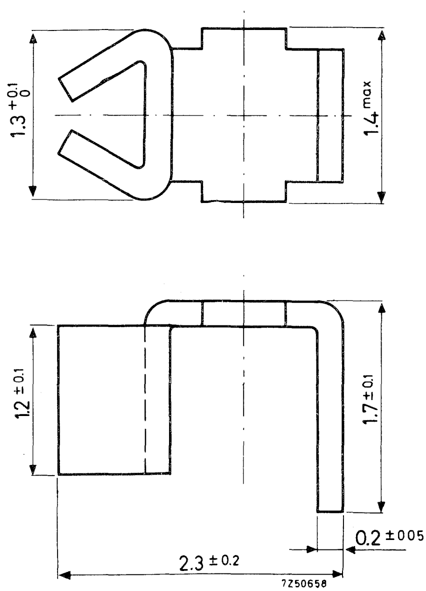
(1) Cover 4322 021 31160
Material: phosphorbronze, nickel plated



(2) Container 4322 021 31180
Material: brass, nickel plated



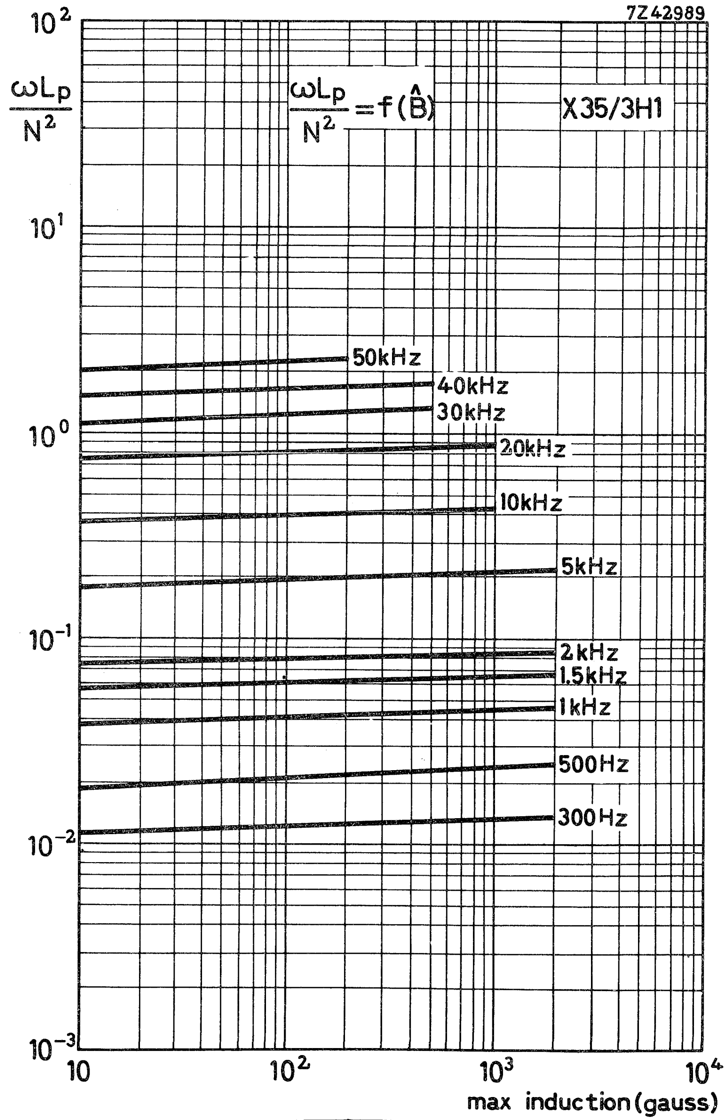
(3) Spring 4322 021 30220
Material: phosphorbronze



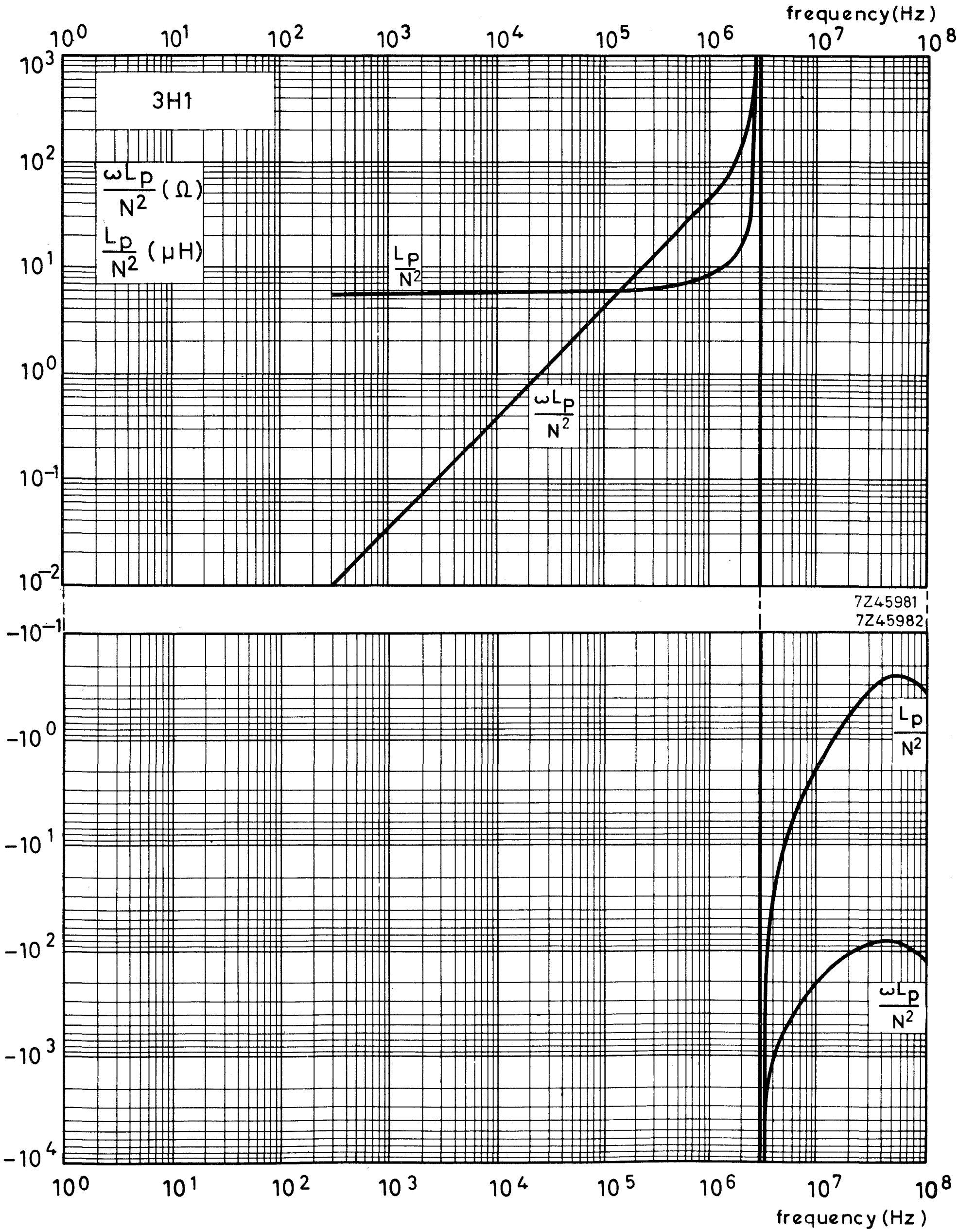
(4) Soldering spring 4322 021 30700
Material: brass, dipsoldered

CHARACTERISTIC CURVES

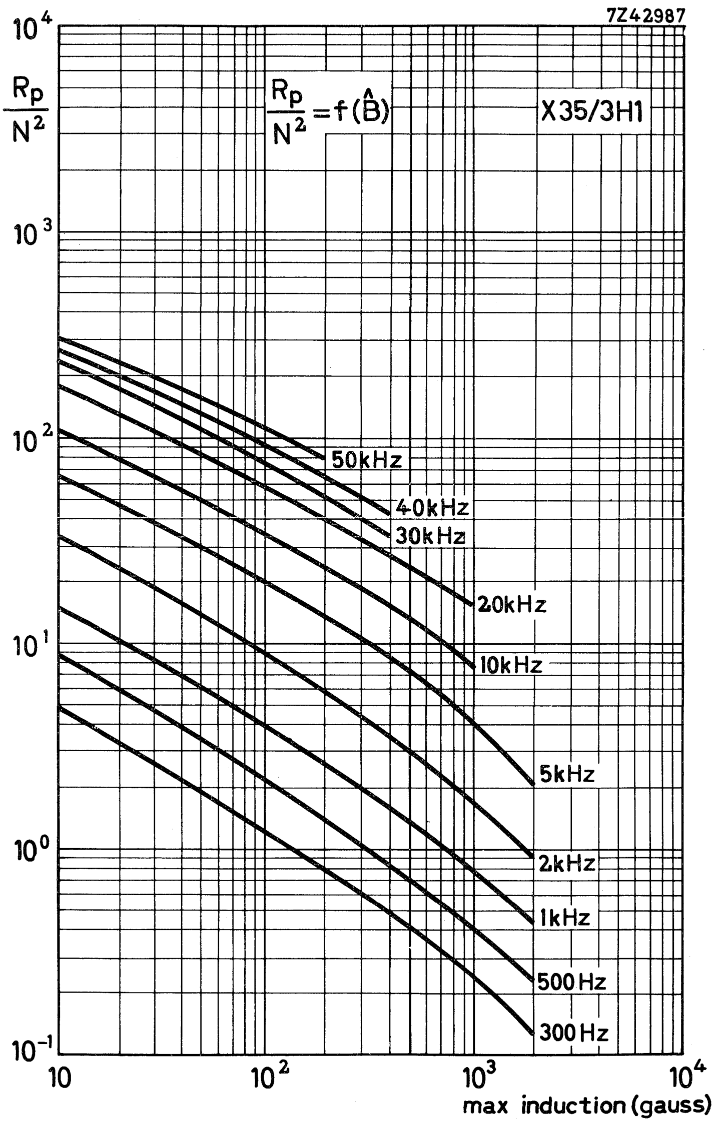
INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)



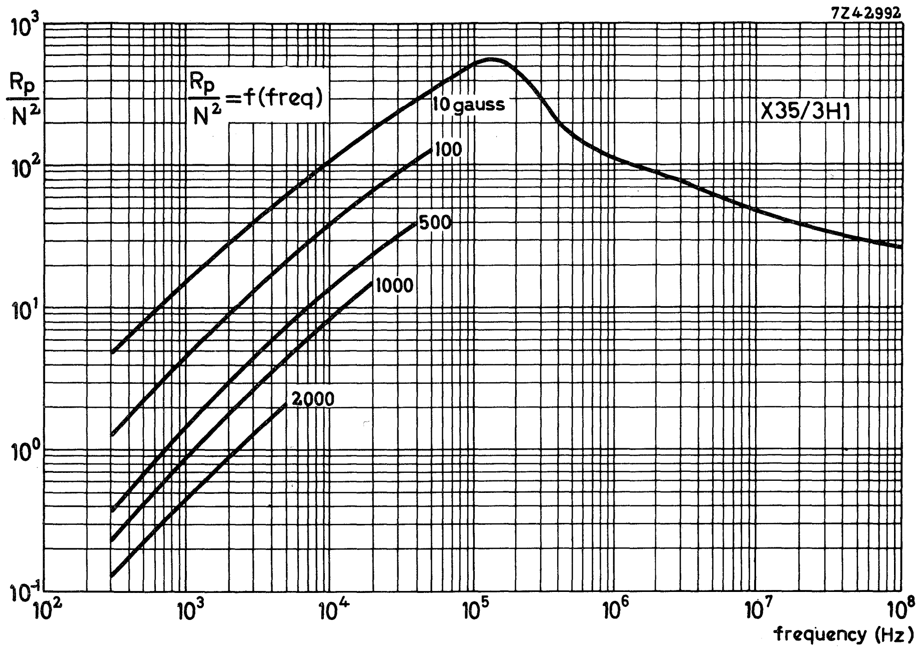
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical curves)



CORE LOSSES AS A FUNCTION OF THE INDUCTION (typical values)

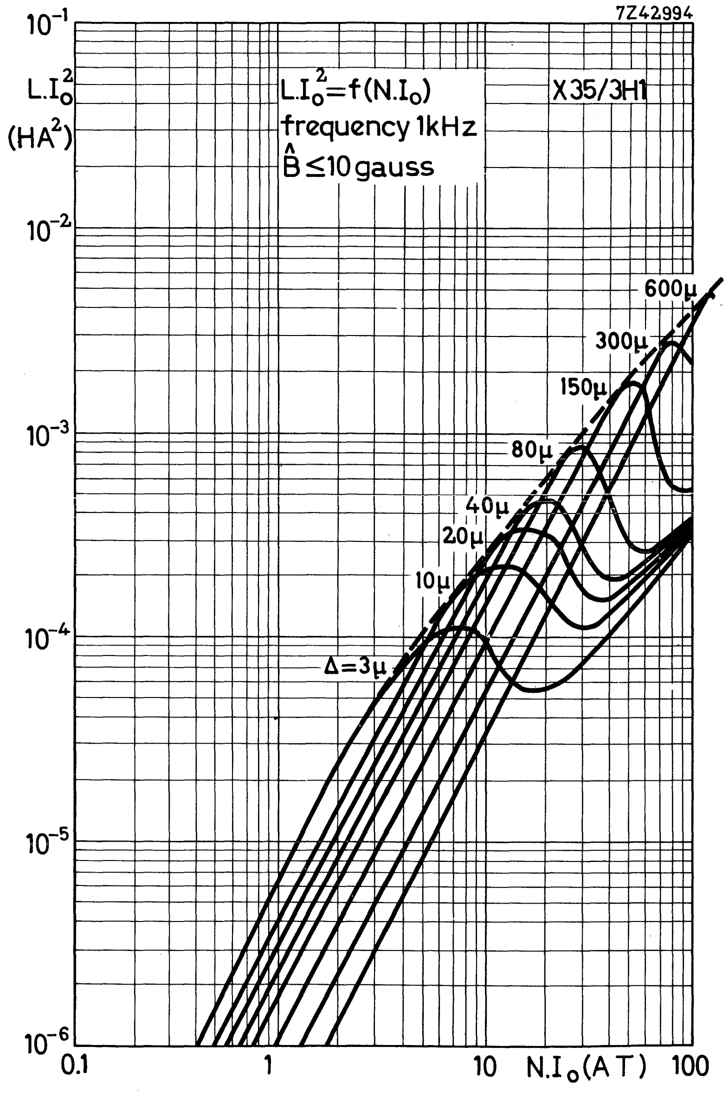


CORE LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)

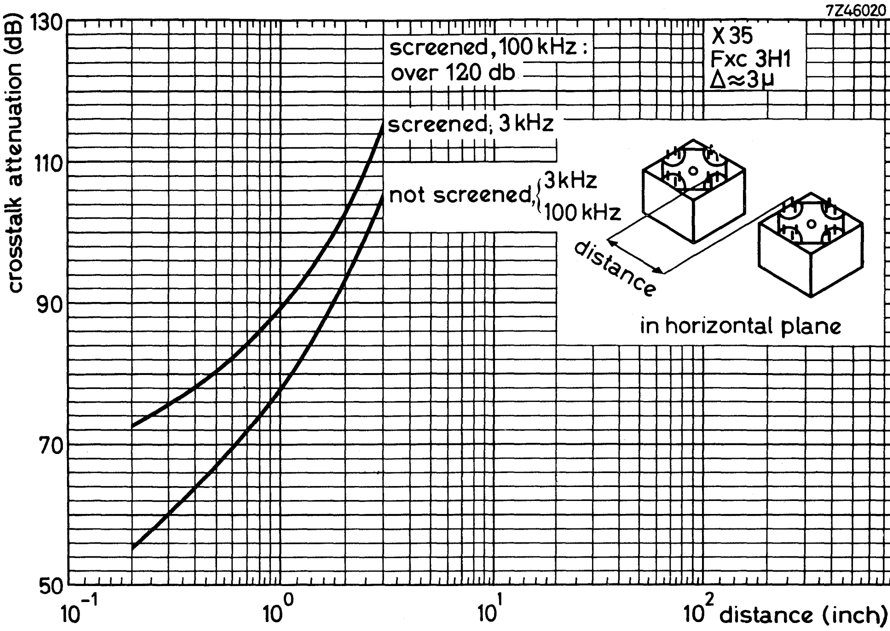


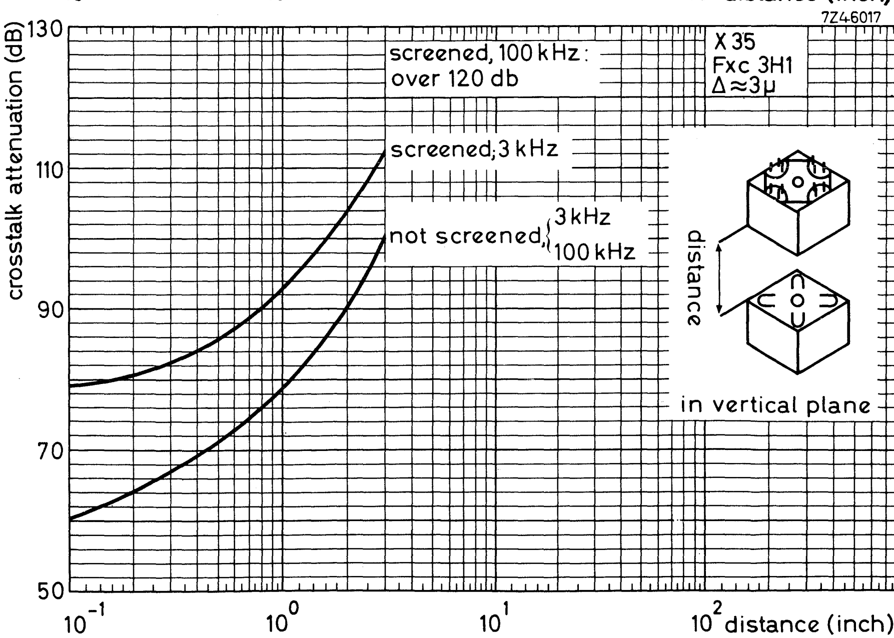
HANNA CURVE (typical values)

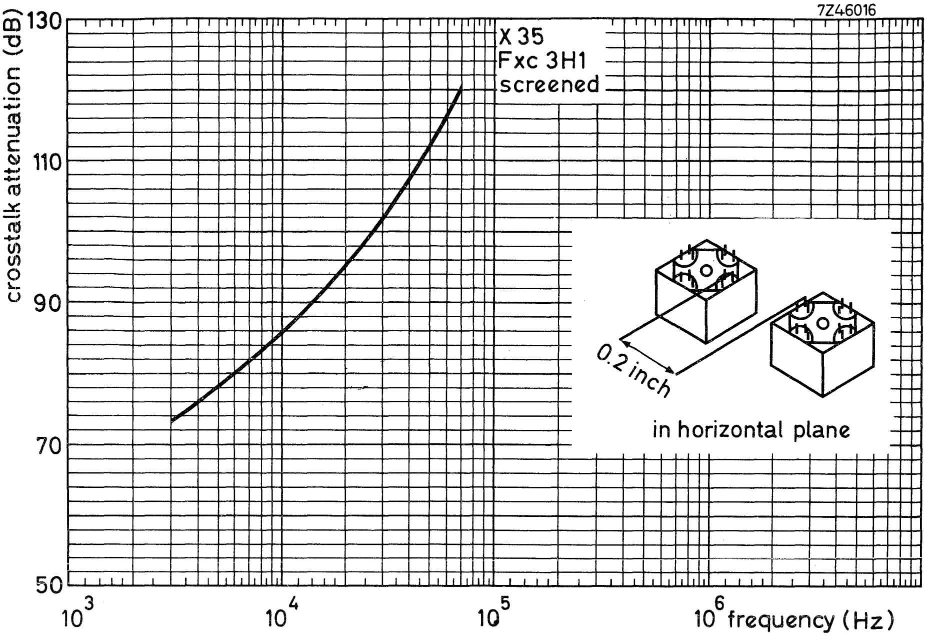
Indicating optimum inductance for a certain airgap and direct current.



CROSSTALK ATTENUATION






7Z46016
crosstalk attenuation (dB)
130
110
90
70
50
X 35
Fxc 3H1
screened
0.2 inch
in horizontal plane
10^3
10^4
10^5
10^6 frequency (Hz)

H-CORES

INTRODUCTION

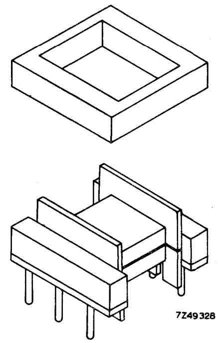
The development of magnetic core materials with high initial permeability for series production opened the way for the construction of transformer cores of very small dimensions without the loss of transformer performance.
One of the problems immediately arising when miniaturizing magnetic cores is that the high initial material permeability practically always is reduced considerably by an unavoidable airgap except when the toroid shape is used. However, for application in transformers the toroid has the disadvantage of being difficult to wind and time consuming in assembly.
The H-core transformer shape overcomes the above mentioned disadvantages with a minimum of component parts and has moreover the advantage that it may be wound on simple conventional winding machines.
The magnetic circuit is closed by a core in the shape of a rectangular window or of a U. The two parts are sufficient to construct a complete transformer suitable for mounting on a printed wiring board, since the coil former, which forms one piece with the H-core, is provided with soldering pins on grid module distances.

Four sets of transformer components of different size are available. Their type designation is H7, H10, H16 and H20. The material grade used is FXC 3E2.

In addition to the well-known applications of ferroxcube cores in transformers in communication systems, an important part of the field of applications of metal laminations in the audio frequency range can be covered with these H-cores.

The high A_L values realised with these small cores combined with the proper winding technique lead to small stray capacitances and small stray inductances, in this way permitting the design of wide band transformers in a small volume.

H-CORE



The H 7-core consists of a ferroxcube H-shape with coil former, a ferroxcube window, a brass container and a silicon rubber washer.
All these components are adapted to each other.

The H 7-core can only be supplied as a complete assembly.
Cat. number of the assembly : 4322 020 33020
Approximate weight of the assembly : 0.8 g

The applied ferroxcube material is the high permeable 3E2 grade.

The jointing surfaces are very flat and smoothly lapped.

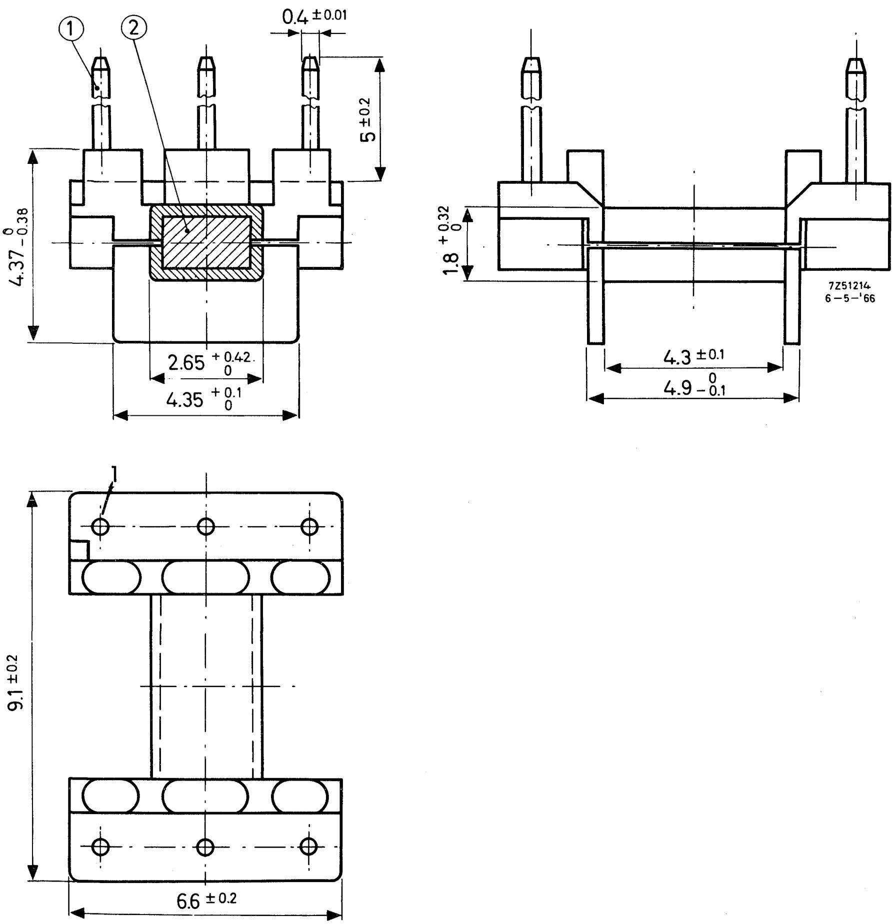
Dimensional quantities

Mean length of lines of force l_e = 1.75 cm
Mean area of lines of force A_e = 0.0325 cm^2
$\Sigma \frac{l_e}{A_e}$ = 54 cm^{-1}
Effective volume V_e = 0.0571 cm^3

Electrical requirements measured with 25 windings of 0.15 mm wire, at $\hat{B} \leq 1$ gauss,

f = 4 kHz and a mechanical force of 1.5 Newton in the temperature range from +23 till +70 °C.
$\mu_e \geq 3000$
$\alpha \leq 37.8$
$A_L \geq 700$ nH/N^2
The six soldering pins are arranged so as to fit printed-wiring boards with 0.1" grid as well as those with a 2.50 mm grid. The board should be provided with holes of max. 0.8 + 0.1 mm ϕ.

COIL FORMER



Coil former 4322 020 33300
(1) Pins: phosphorbronze, dipsoldered
(2) H-core: ferroxcube

The coil former and the ferroxcube H-shape are combined to one part.

Material coil former	reinforced polyester with phosphor-bronze dipsoldered pins
Window area in mm^2	4.2
Mean length of turn in cm	1.34
Max. temperature for dipsoldering	
for 5-6 s in °C	280
for 1-2 s in °C	380-400
Max. working temperature in °C	130

For speeding up the soldering operation of the winding wire to the pins, the use of self fluxing wire is advised. In case a terminal of the winding must be connected to the container, it should be soldered to pin 1 (see figure above).
The side of the coil former where the soldering pins protrude is asymmetrical providing a means for numbering the connections.

In order to avoid damage of the ferroxcube H-shape, care should be taken that during winding the turning couple exercised on this ferroxcube part is not too high.

MOUNTING PARTS

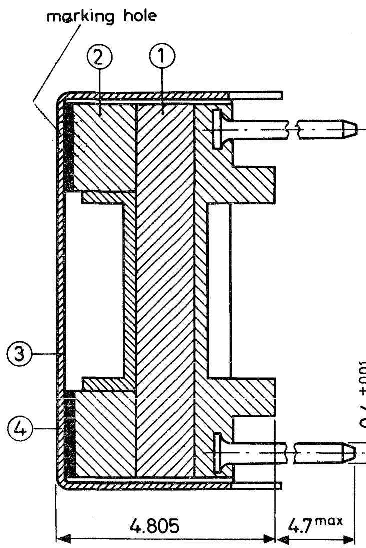


Fig. 1

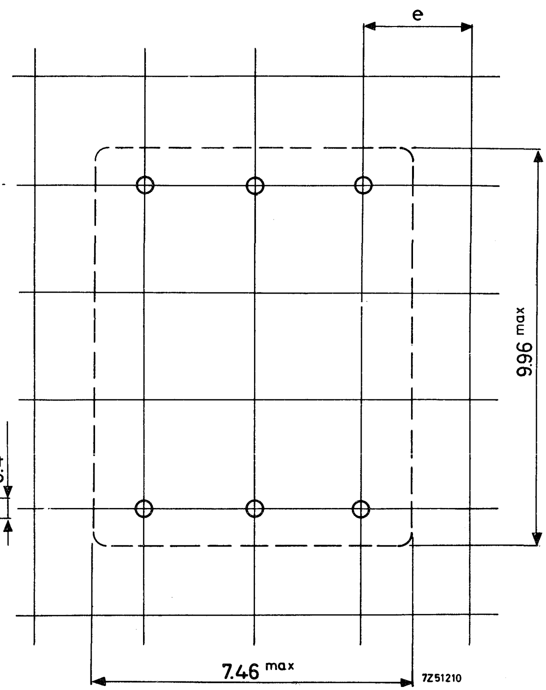


Fig. 2. Hole pattern.
e = 0.1" or 2.50 mm.

The H 7-core is only applied as a complete assembly.
Cat. number of the assembly: 4322 020 33020.

Components according to Fig. 1:
(1) Ferroxcube H-shape with reinforced polyester coil former
(2) Ferroxcube window
(3) Brass container 4322 021 20100
(4) Silicon rubber washer 4322 021 20110

Take care that the jointing surfaces of the two core parts are very clean.

On one side of the H-shape and on one side of the window is a mark. These marks must be in one line.

When glueing is desired, apply a suitable adhesive around the jointing surfaces of the H-shape and the window (see Fig. 3). The area where the adhesive is to be applied should first be degreased thoroughly. A suitable adhesive is e.g. Araldite type D, with Versamite 140, mixing ratio is 70:30: curing time at least 24 hours at room temperature. There is a marking hole on the top side of the container (see Fig. 1). This hole must be in one line with soldering pin 1. This pin can easily be recognised by the asymmetrical shape of the coil former under side.

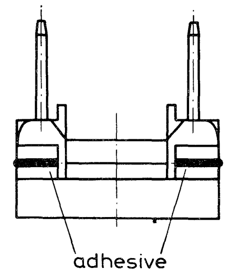
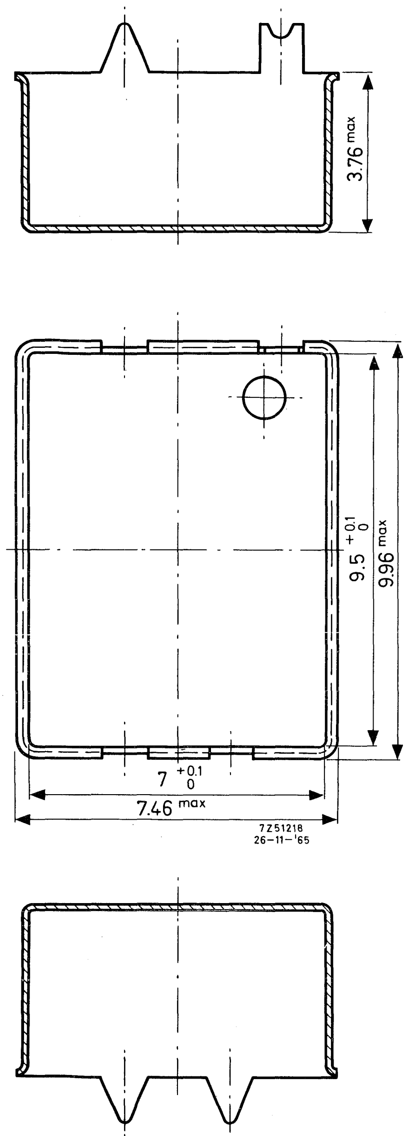
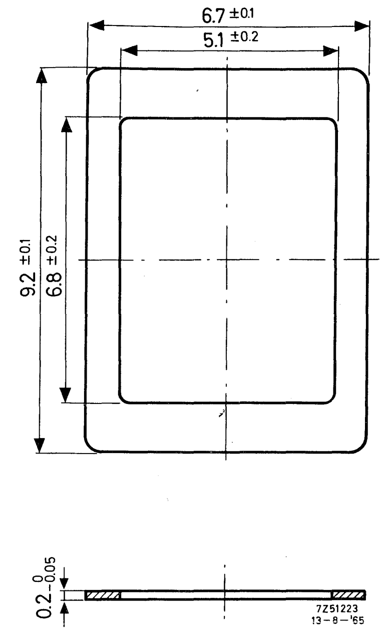


Fig. 3

If the brass container must be earthed, the longer (tin-plated) lip must be soldered to pin 1 after bending the lips.
For bending the container lips a simple tool (placed in a press with cranked levers) has been developed.
This tool can not be supplied, however drawings of this tool are supplied on request under catalog number 4322 058 00110.



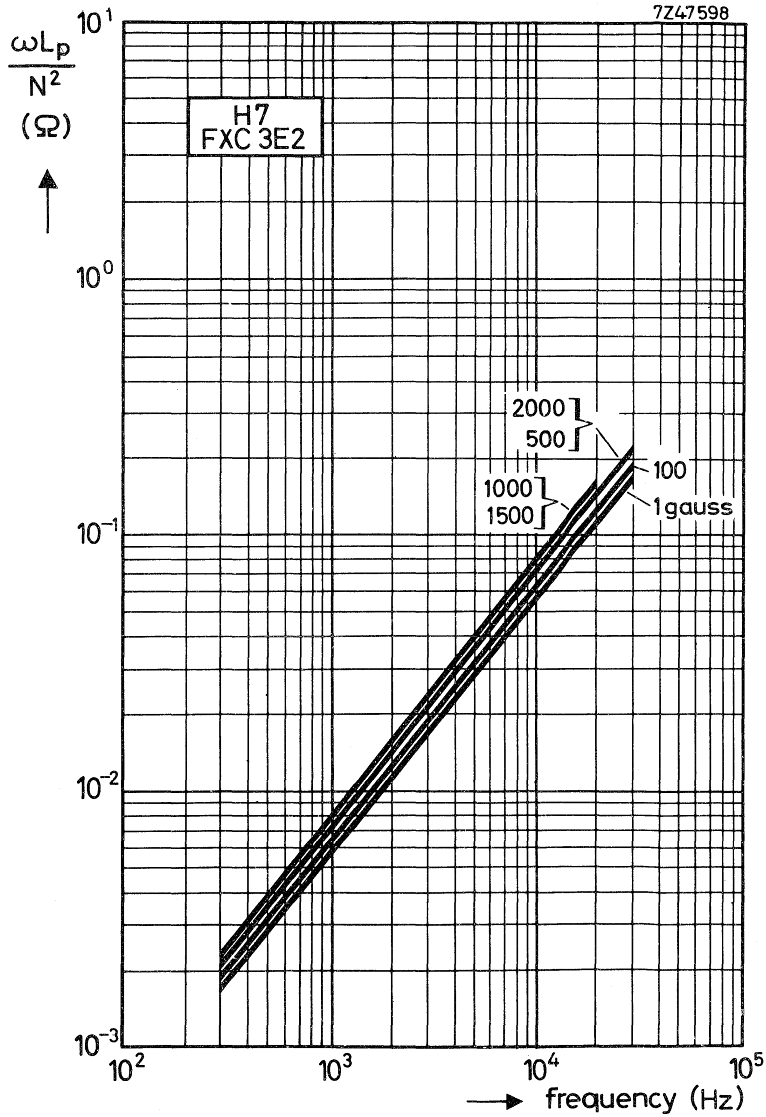
(3) Container 4322 021 20100
Material: brass, nickel-plated

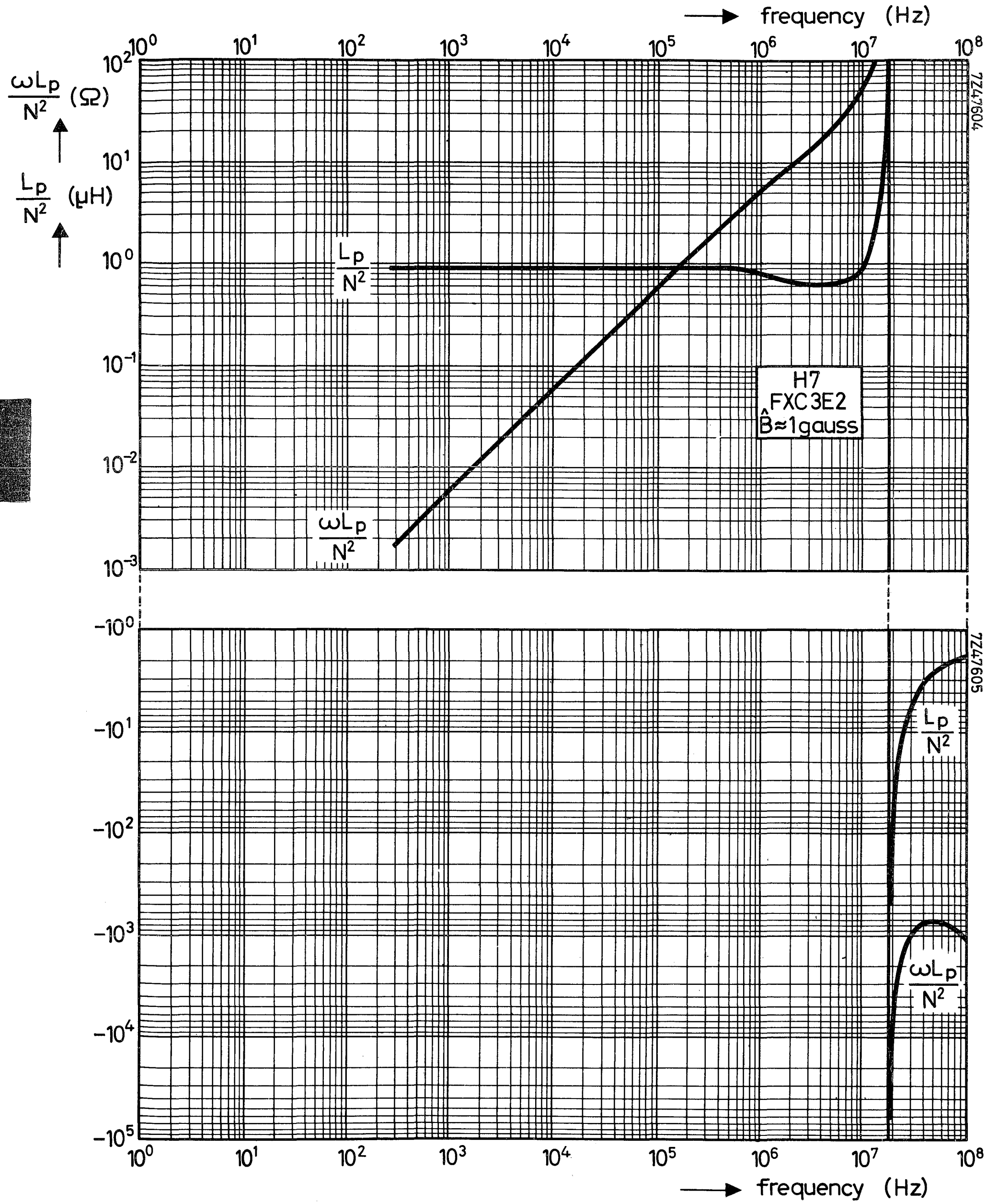


(4) Washer 4322 021 20110
Material: silicon rubber

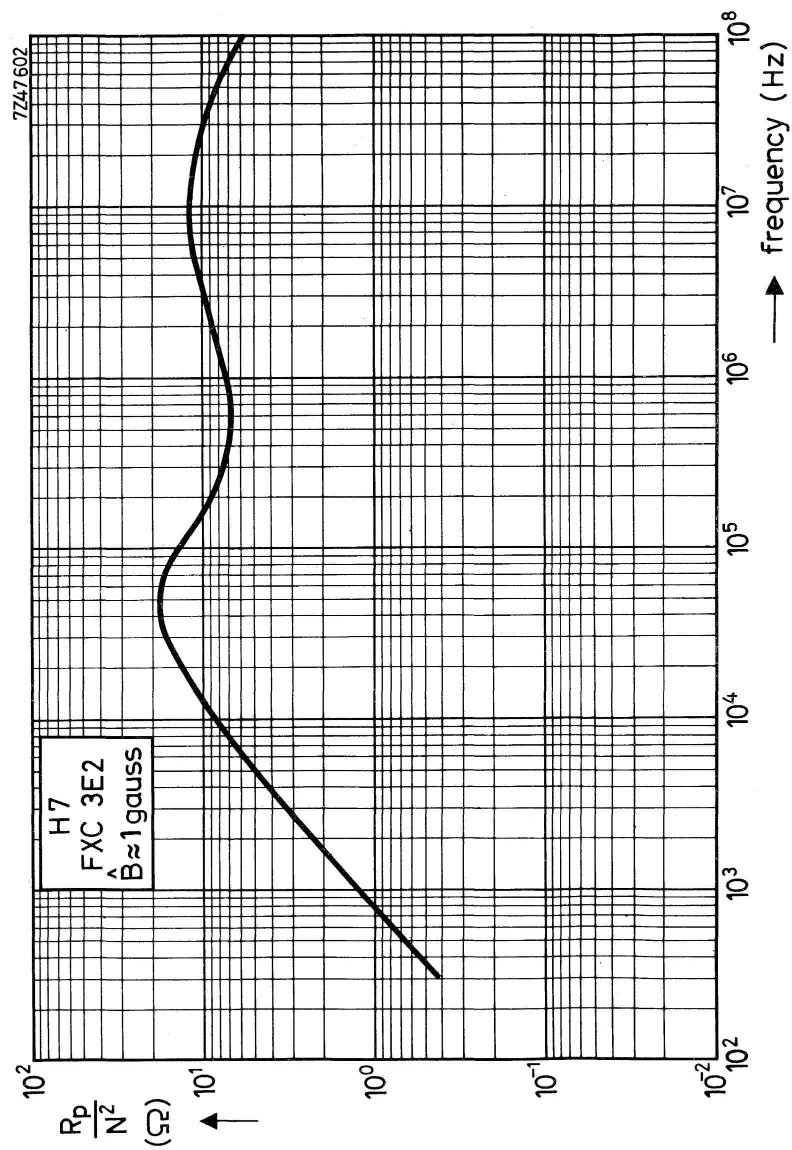
CHARACTERISTIC CURVES

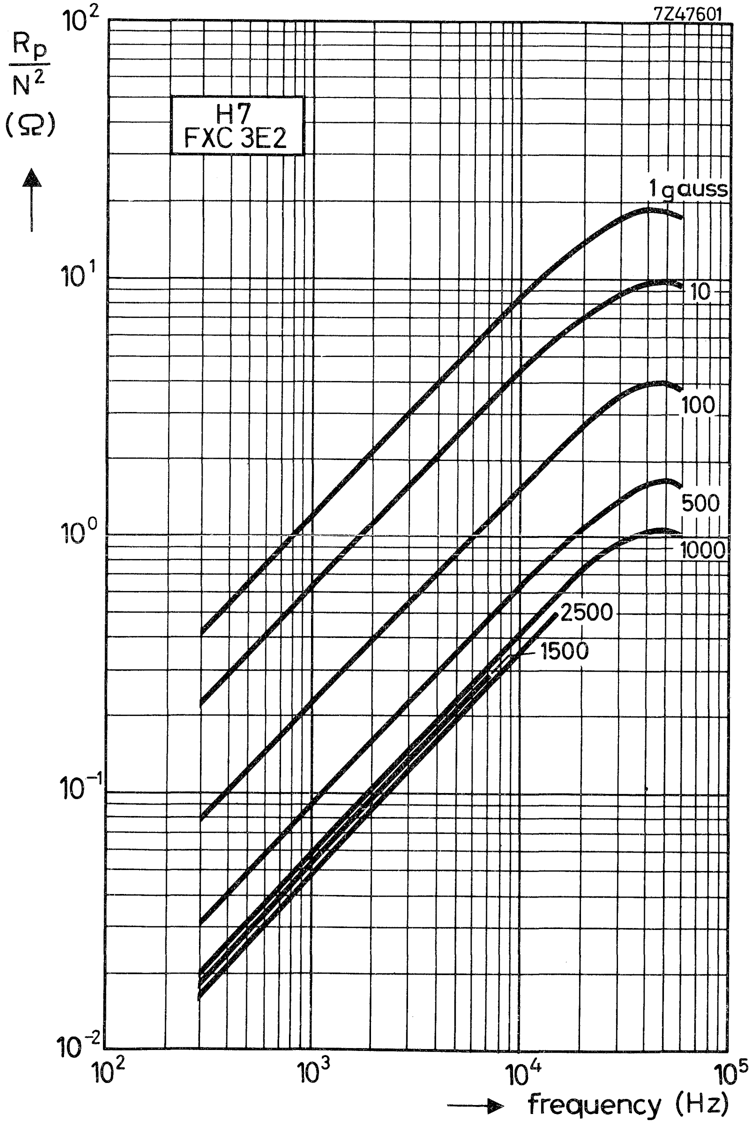
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical values)

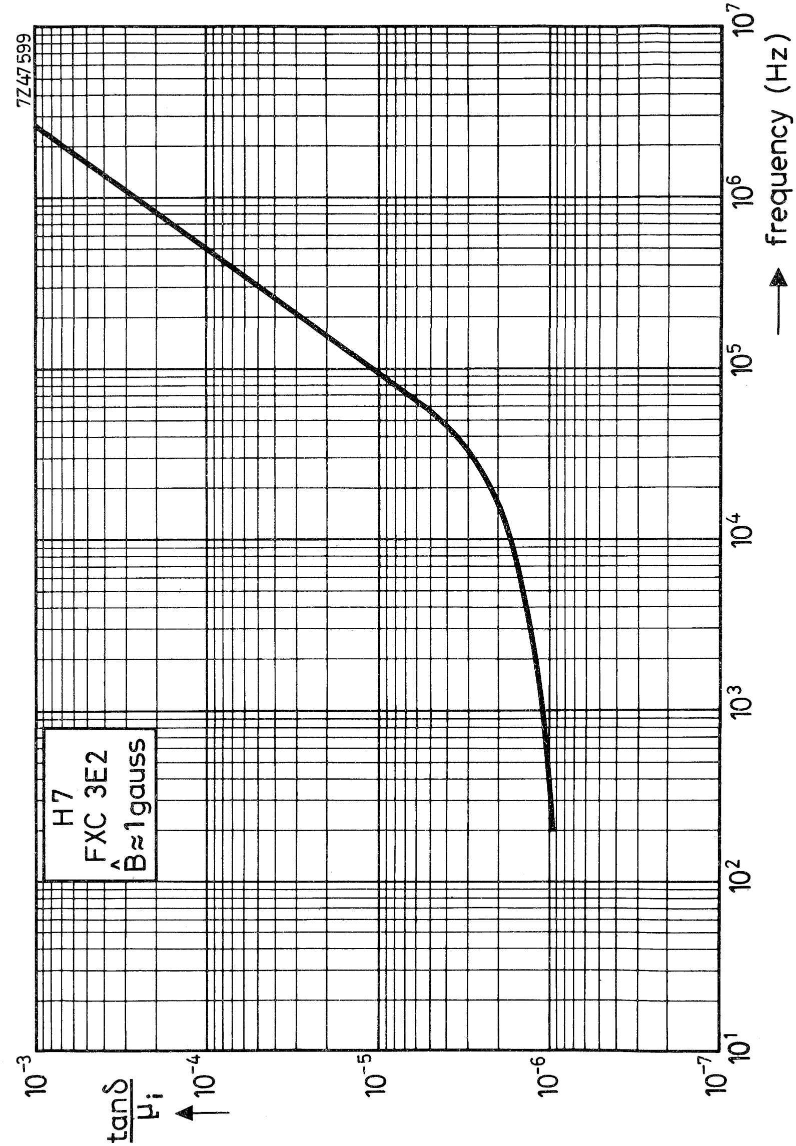



frequency (Hz)
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
$\frac{\omega L_p}{N^2}$ (Ω)
$\frac{L_p}{N^2}$ (μH)
10^2 10^1 10^0 10^{-1} 10^{-2} 10^{-3}
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
H7
FXC 3E2
$\hat{B}$≈1gauss
7Z47604
-10^0 -10^1 -10^2 -10^3 -10^4 -10^5
7Z47605
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
frequency (Hz)

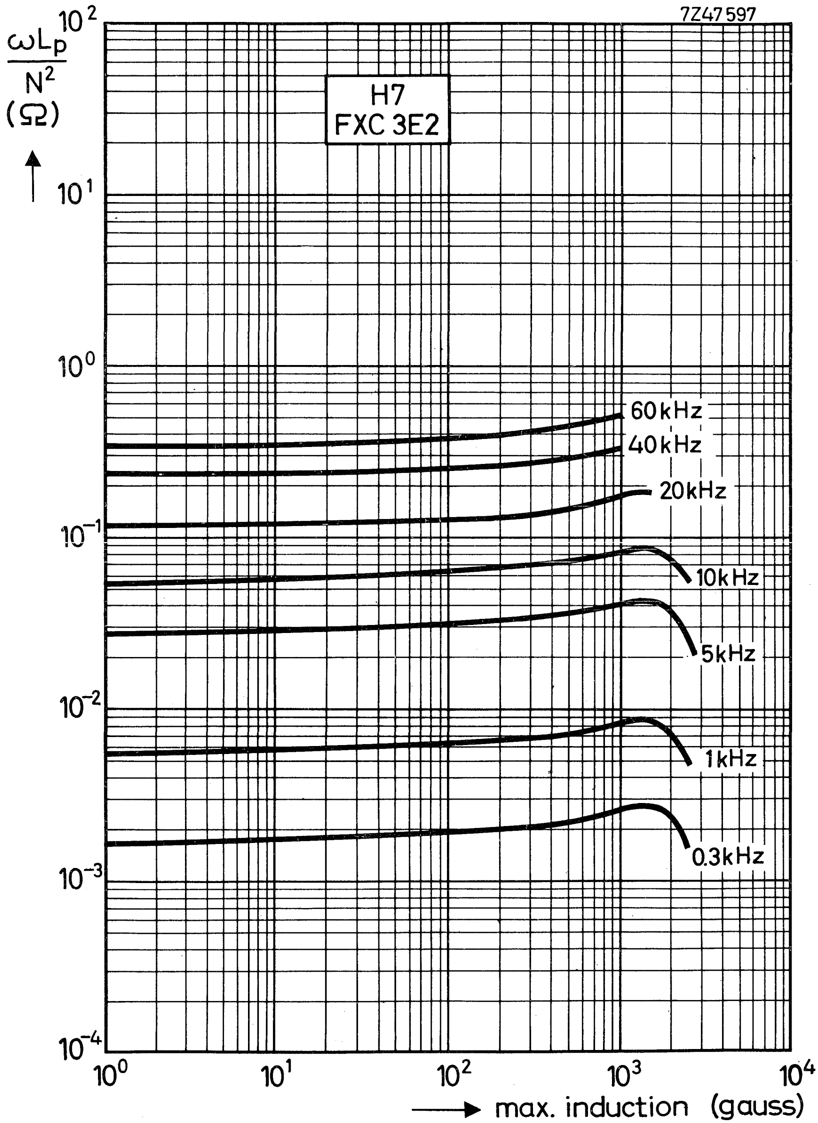
LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)



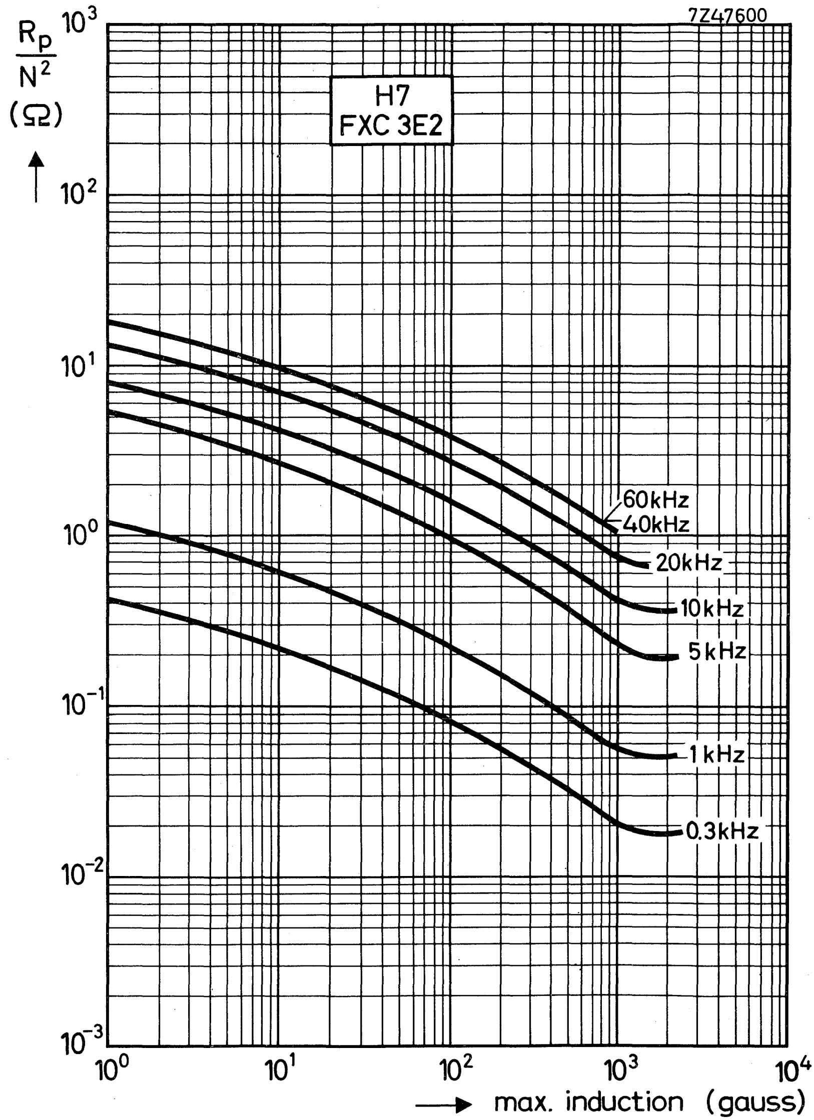

7Z47601
$\frac{R_p}{N^2}$ (Ω)
H7
FXC 3E2
1 gauss
10
100
500
1000
2500
1500
10^2
10^1
10^0
10^{-1}
10^{-2}
10^2
10^3
10^4
10^5
frequency (Hz)


7Z47599
H7
FXC 3E2
B̂≈1gauss
$\frac{\tan\delta}{\mu_i}$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
frequency (Hz)

INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)

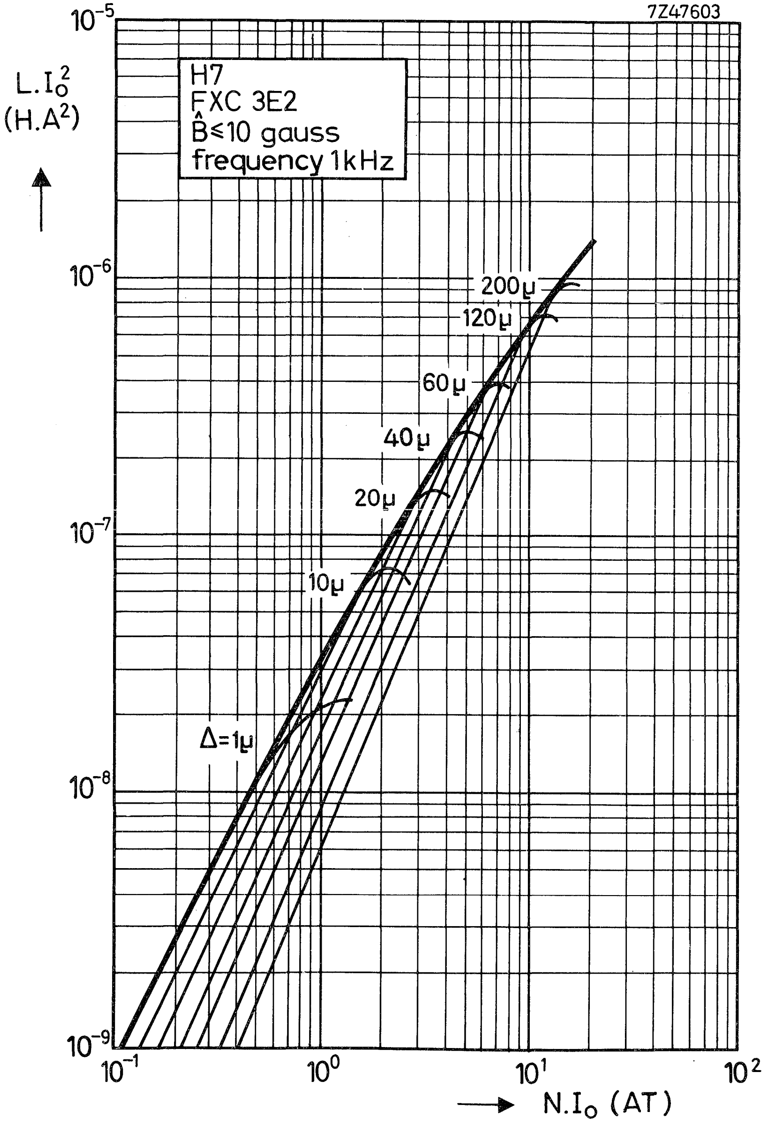


LOSSES AS A FUNCTION OF THE INDUCTION (typical values)

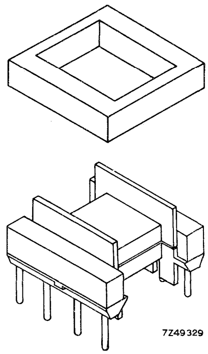


HANNA CURVE (typical values)

Indicating optimum inductance for a certain airgap and direct current.



H-CORE


7Z49329

The H 10-core consists of a ferroxcube H-shape with coil former, a ferroxcube window, a brass container and a silicon rubber washer.
All these components are adapted to each other.

The H 10-core can only be supplied as a complete assembly.
Cat. number of the assembly : 4322 020 33010
Approximate weight of the assembly : 2.0 g

The applied ferroxcube material is the high permeable 3E2 grade.

The jointing surfaces are very flat and smoothly lapped.

Dimensional quantities

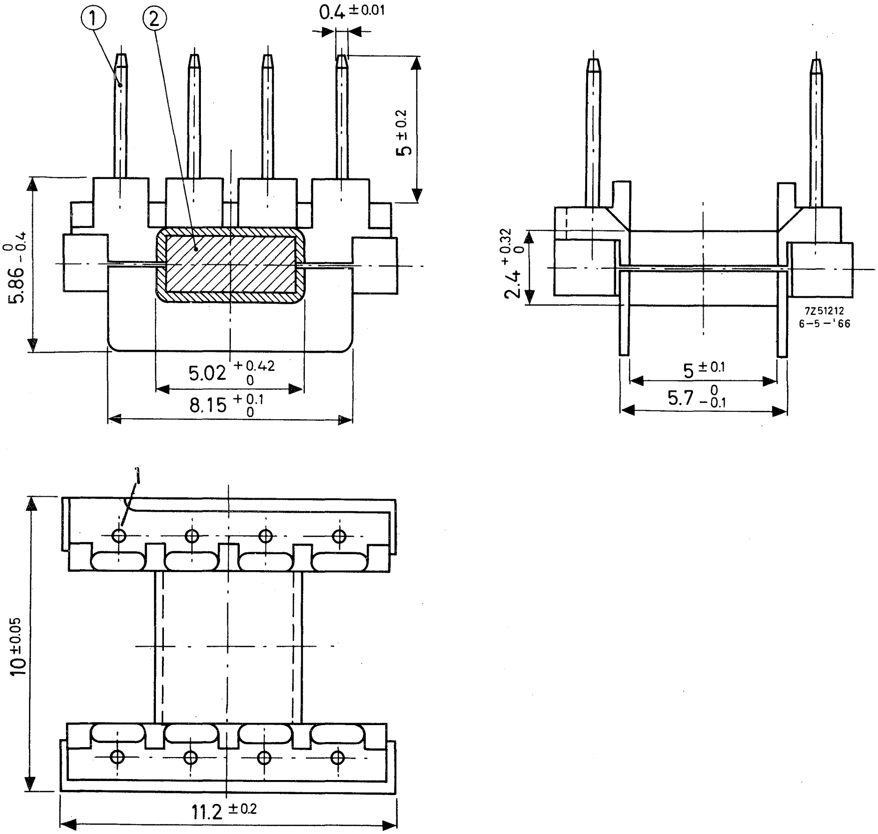
Mean length of lines of force $l_e = 2.25$ cm
Mean area of lines of force $A_e = 0.075$ cm^2
$\Sigma \frac{l_e}{A_e} = 30$ cm^{-1}
Effective volume $V_e = 0.17$ cm^3

Electrical requirements, measured with 20 windings of 0.20 mm wire, at $\hat{B} \leq 1$ gauss,

f = 4kHz and a mechanical force of 1.5 Newton in the temperature range from +23 till +70 °C
$\mu_e \geq 3820$
$\alpha \leq 25.0$
$A_L \geq 1600$ nH/N^2

The eight soldering pins are arranged so as to fit printed-wiring boards with 0.1" grid as well as those with a 2.50 mm grid. The board should be provided with holes of max. 0.8 + 0.1 mm ϕ.

COIL FORMER



Coil former 4322 020 33280
(1) Pins: phosphorbronze, dipsoldered
(2) H-core: ferroxcube

The coil former and the ferroxcube H-shape are combined to one part.

Material of coil former	reinforced polyester with phosphor-bronze dipsoldered pins
Window area in mm^2	7.6
Mean length of turn in cm	2.17
Max. temperature for dipsoldering	
for 5-6 s in ^{o}C	280
for 1-2 s in ^{o}C	380 - 400
Max. working temperature in ^{o}C	130

For speeding up the soldering operation of the winding wire to the pins, the use of self fluxing wire is advised. In case a terminal of the winding must be connected to the container, it should be soldered to pin 1 (see figure above).
The side of the coil former where the soldering pins protrude is asymmetrical providing a means for numbering the connections.

In order to avoid damage of the ferroxcube H-shape, care should be taken that during winding the turning couple exercised on this ferroxcube part is not too high.

MOUNTING PARTS

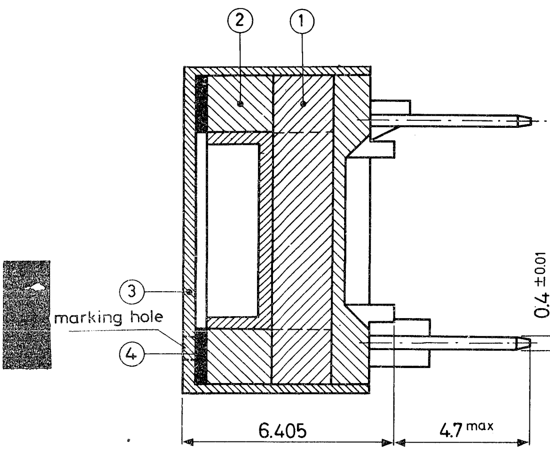


Fig. 1

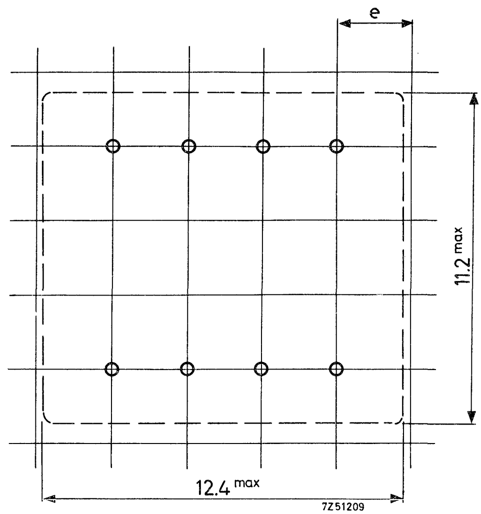


Fig.2. Hole pattern.
e = 0.1" or 2.50 mm.

The H 10-core is only applied as a complete assembly.
Cat. number of the assembly: 4322 020 33010

Components according to Fig. 1:
(1) Ferroxcube H-shape with reinforced polyester coil former
(2) Ferroxcube window
(3) Brass container 4322 021 20020
(4) Silicon rubber washer 4322 021 20030

Take care that the jointing surfaces of the two core parts are very clean.

On one side of the H-shape and on one side of the window is a mark. These marks must be in one line.

When glueing is desired, apply a suitable adhesive around the jointing surfaces of the H-shape and the window (see Fig. 3). The spots where the adhesive is to be applied should first be degreased thoroughly. A suitable adhesive is e.g. Araldite type D, with Versamite 140, mixing ratio is 70 : 30; curing time at at least 24 hours at room temperature.
There is a marking hole on the top side of the container (see Fig. 1). This hole must be in one line with soldering pin 1. This pin can easely be recognised by the asymmetrical shape of the coil former under side.

If the brass container must be earthed, the longer (tin-plated) lip must be soldered to pin 1 after bending the lips.
For bending the container lips, a simple tool (placed in a press with cranked levers) has been developed.
This tool can not be supplied, however drawings of this tool are supplied on request under cat. number 4322 058 00120.

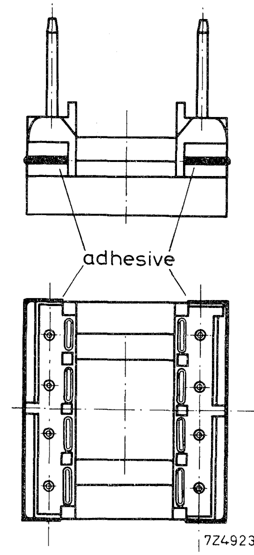
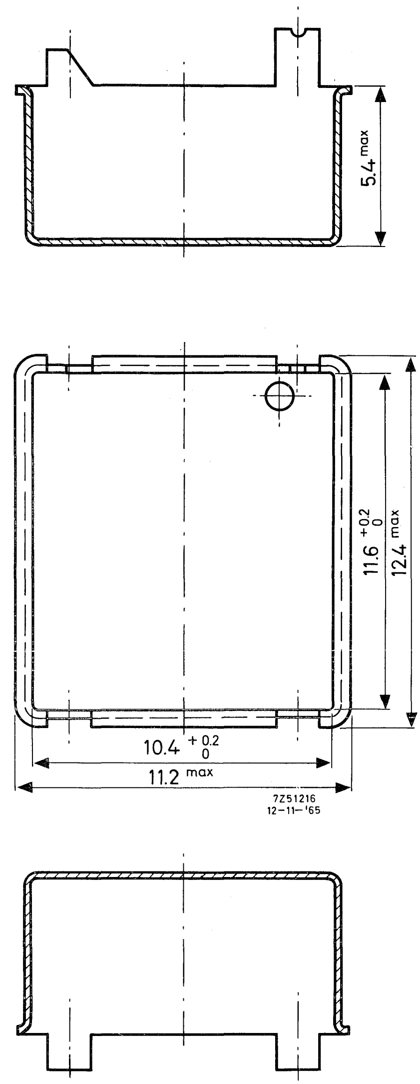
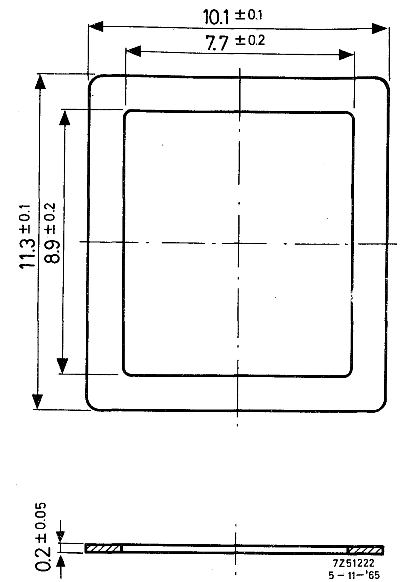


Fig. 3



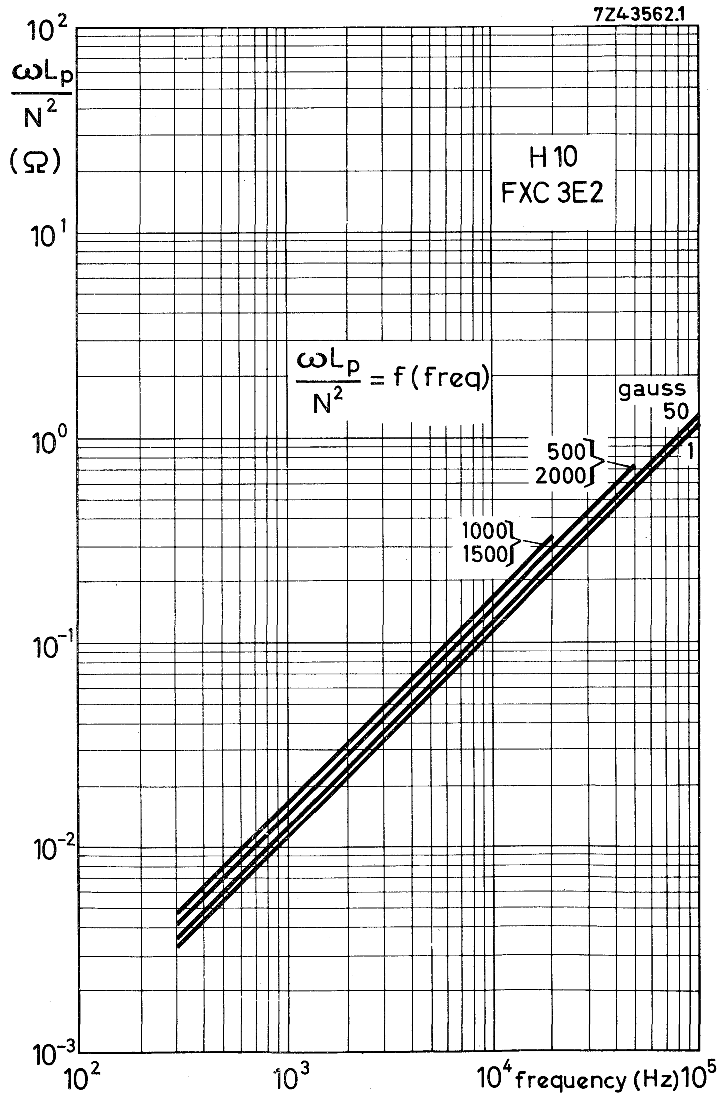
(3) Container 4322 021 20020
Material: brass, nickel-plated

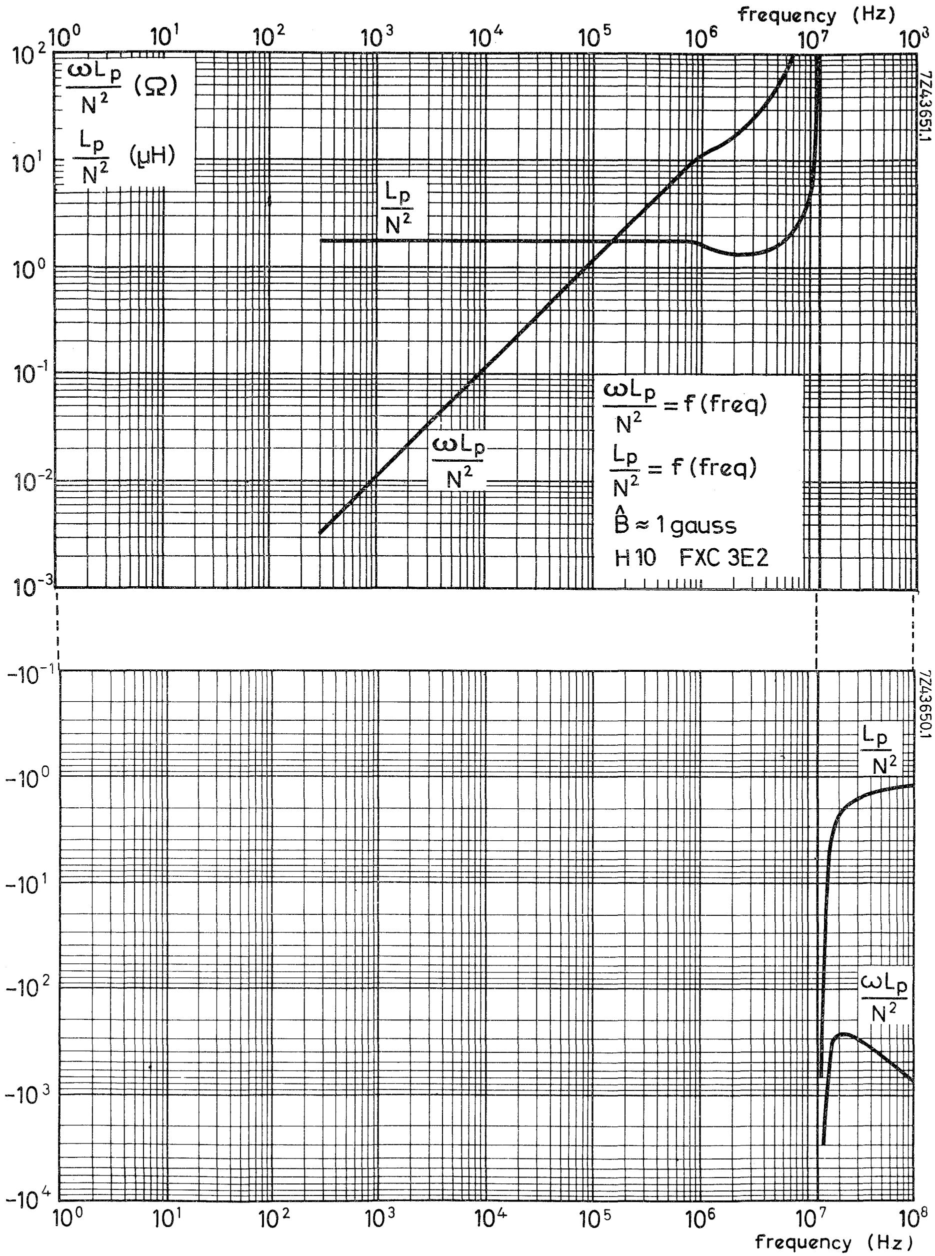


(4) Washer 4322 021 20030
Material: silicon rubber

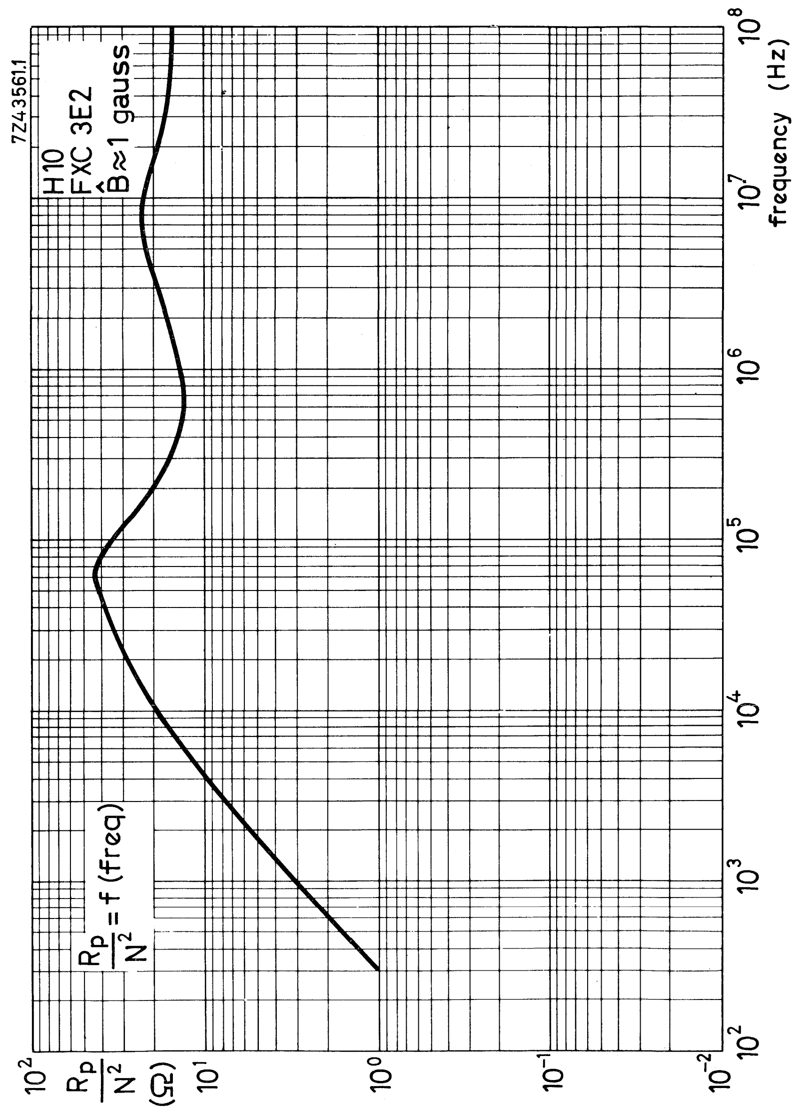
CHARACTERISTIC CURVES

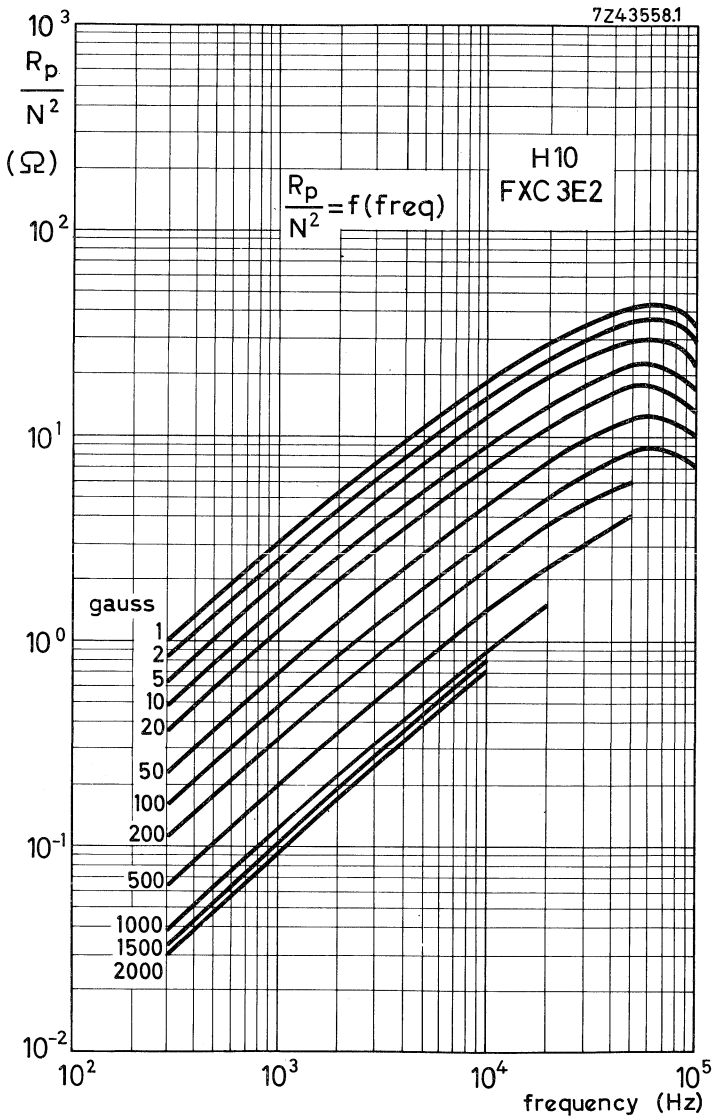
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical values)

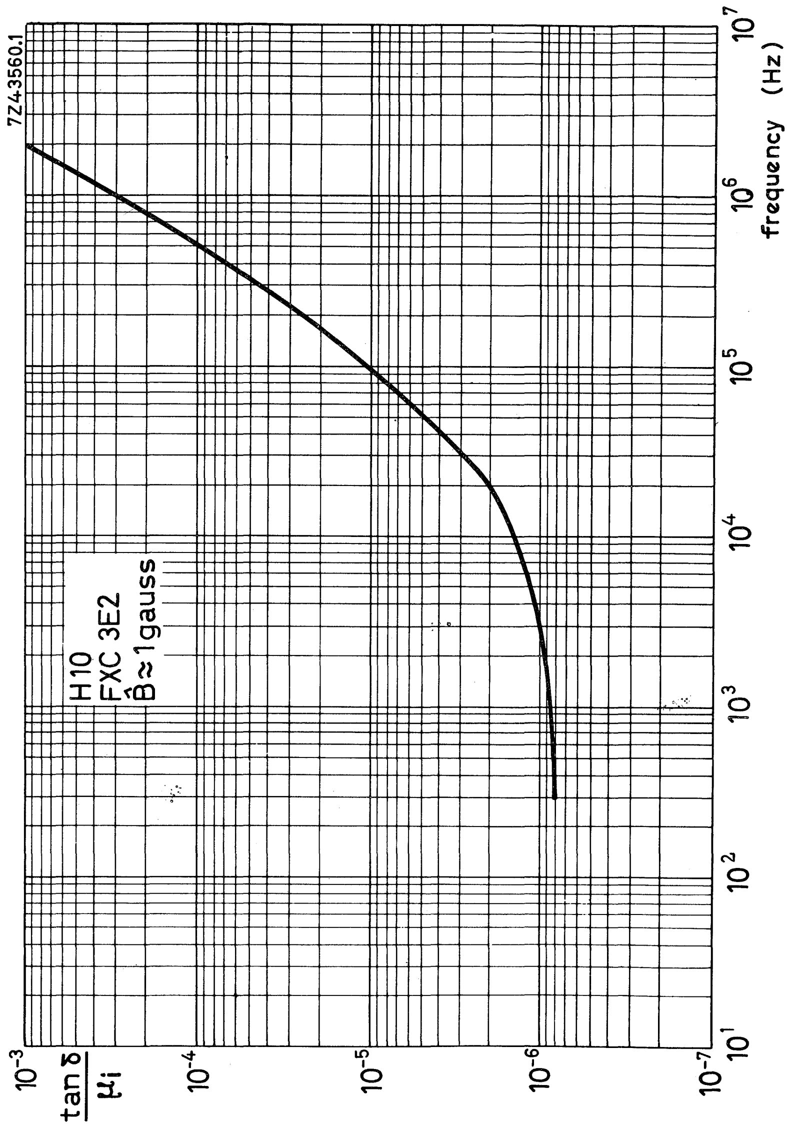



frequency (Hz)
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
10^2 10^1 10^0 10^{-1} 10^{-2} 10^{-3}
$\frac{\omega L_p}{N^2}$ (Ω)
$\frac{L_p}{N^2}$ (μH)
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
$\frac{\omega L_p}{N^2} = f(\text{freq})$
$\frac{L_p}{N^2} = f(\text{freq})$
$\hat{B} \approx 1$ gauss
H 10 FXC 3E2
7Z43651.1
-10^{-1} -10^0 -10^1 -10^2 -10^3 -10^4
7Z43650.1
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
frequency (Hz)

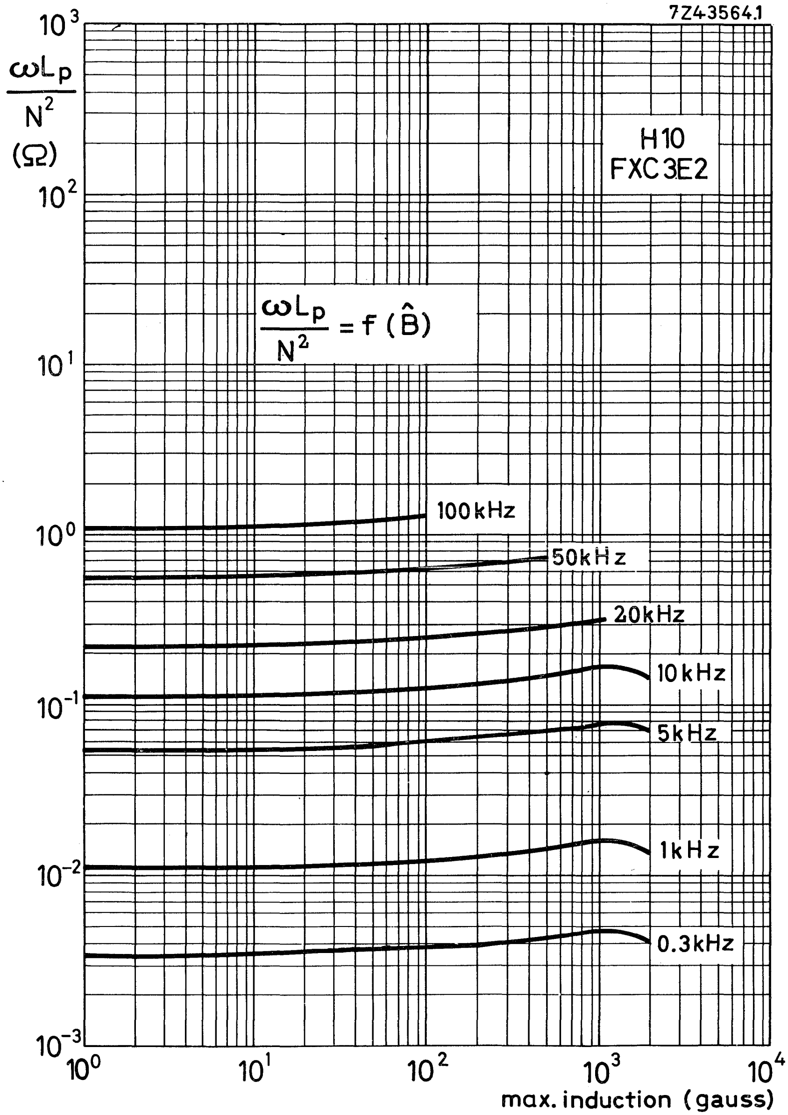
LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)



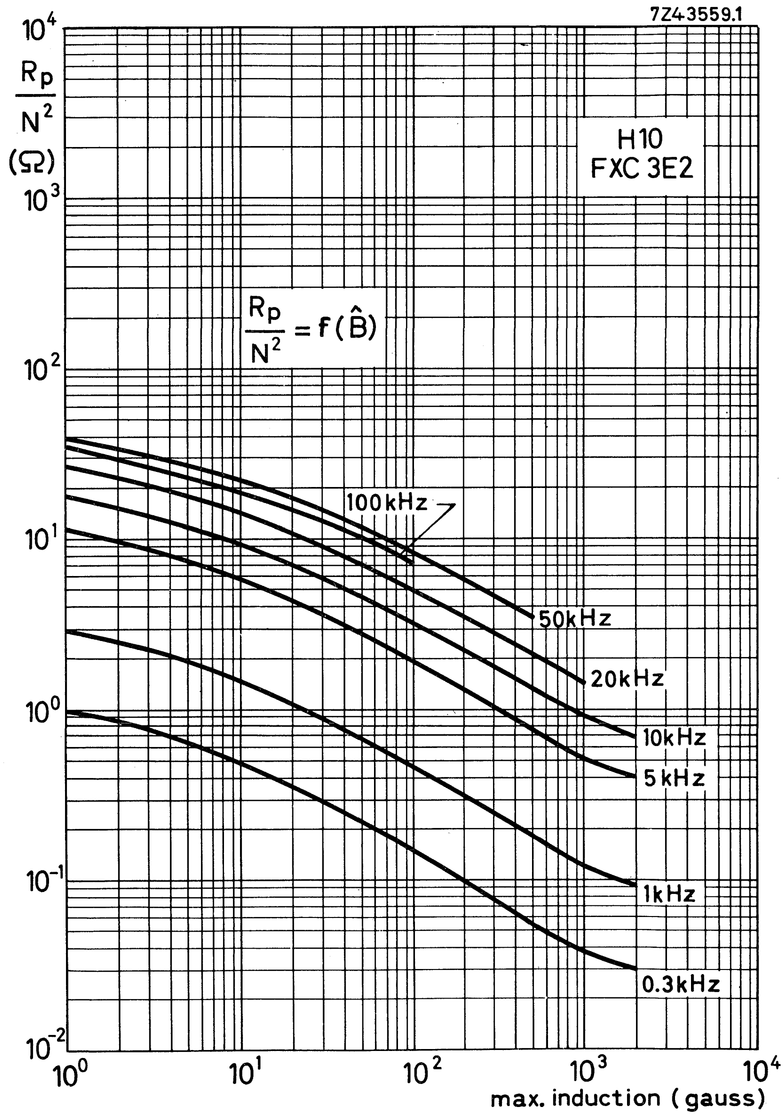

7Z43558.1
10^3
$\frac{R_p}{N^2}$
(Ω)
10^2
10^1
10^0
10^{-1}
10^{-2}
$\frac{R_p}{N^2} = f(freq)$
H 10
FXC 3E2
gauss
1
2
5
10
20
50
100
200
500
1000
1500
2000
10^2
10^3
10^4
10^5
frequency (Hz)


7Z43560.1
H10
FXC 3E2
B̂ ≈ 1gauss
tan δ / μi
10^-3
10^-4
10^-5
10^-6
10^-7
10^1
10^2
10^3
10^4
10^5
10^6
10^7
frequency (Hz)

INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)

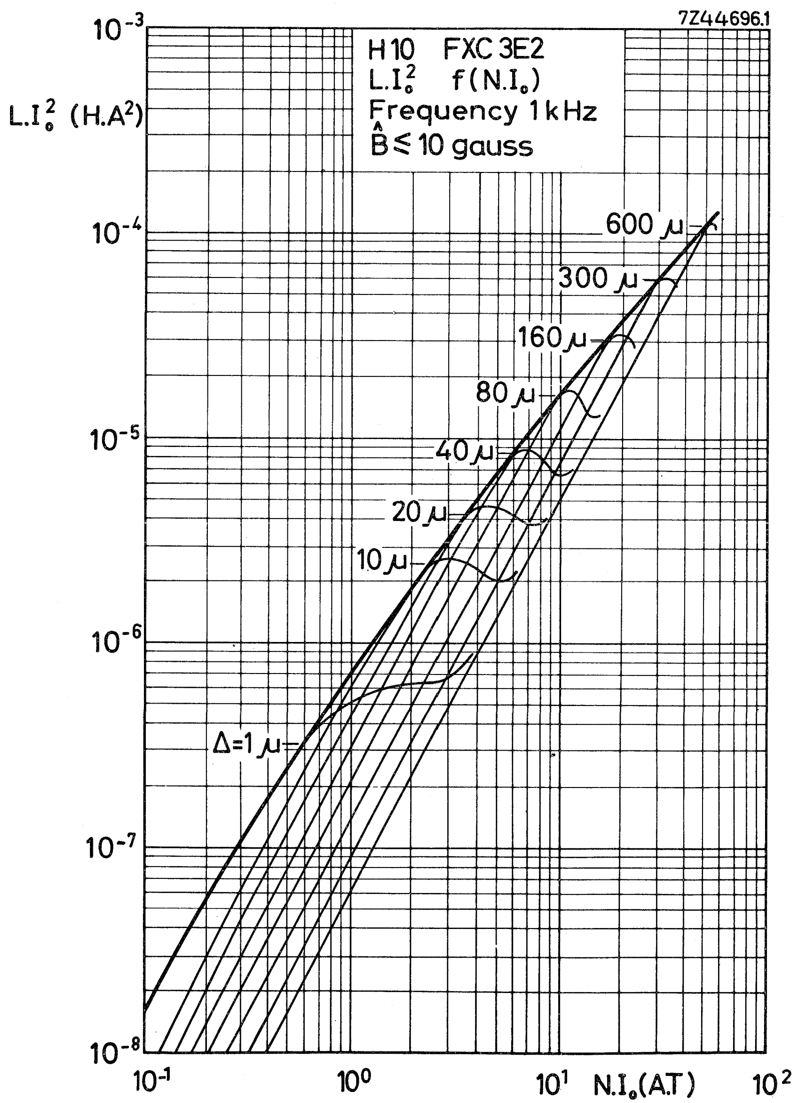


LOSSES AS A FUNCTION OF THE INDUCTION (typical values)

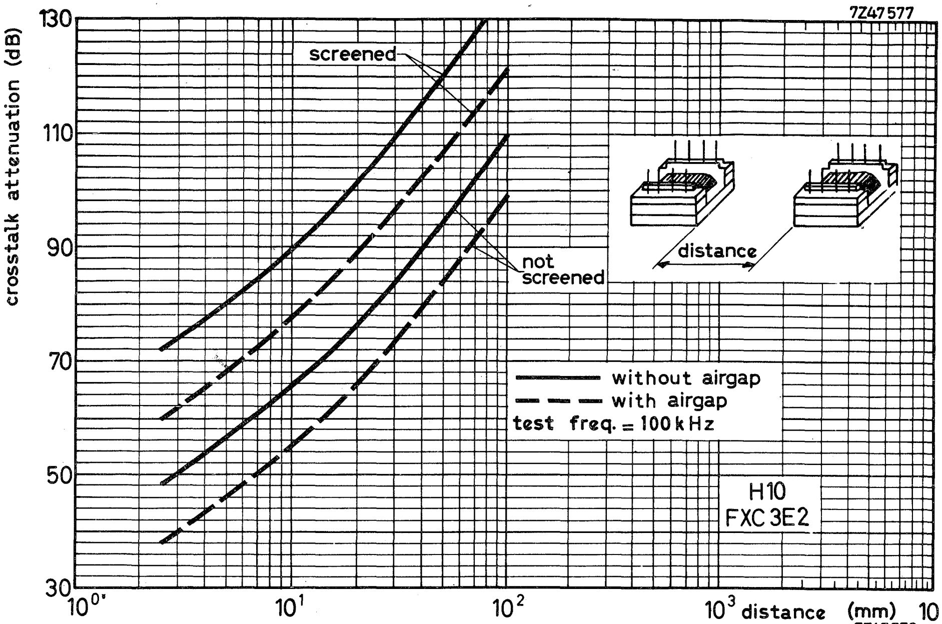


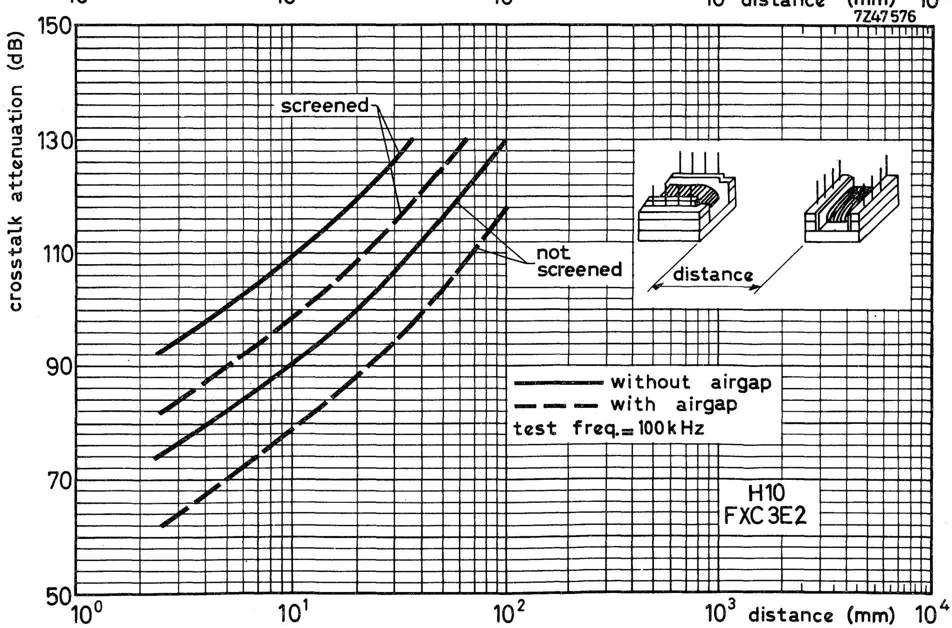
HANNA CURVE (typical values)

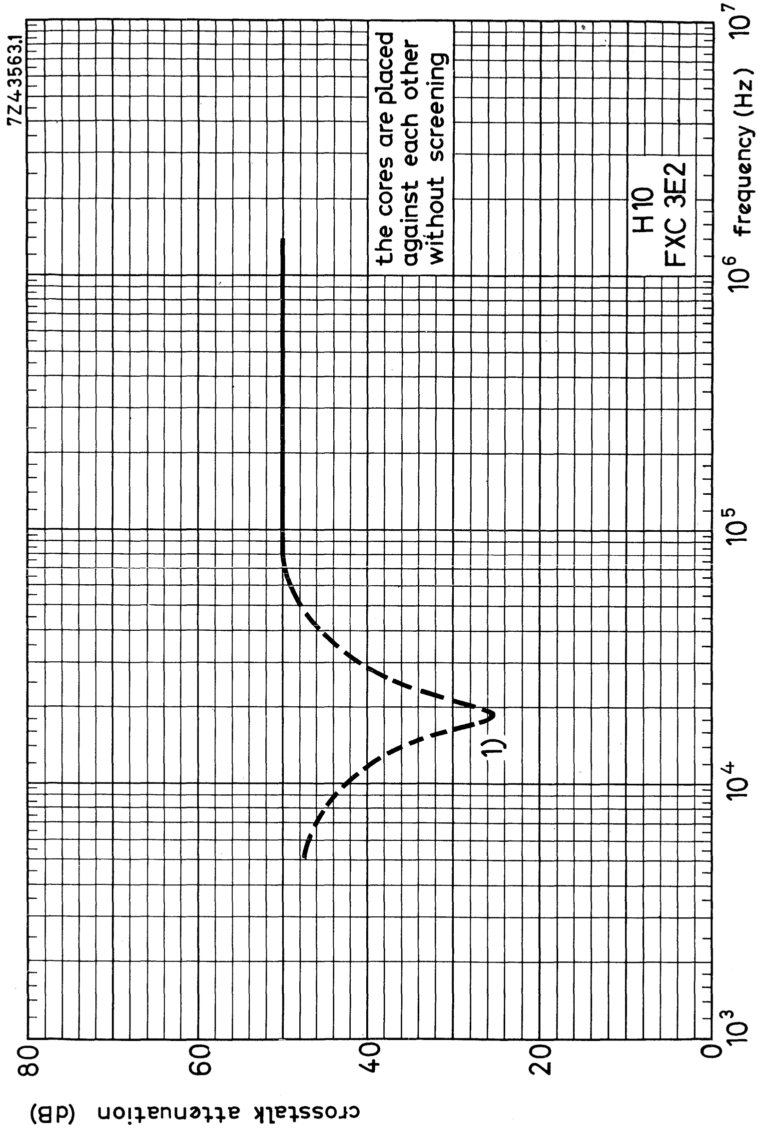
Indicating optimum inductance for a certain airgap and direct current



CROSS TALK ATTENUATION (typical values)

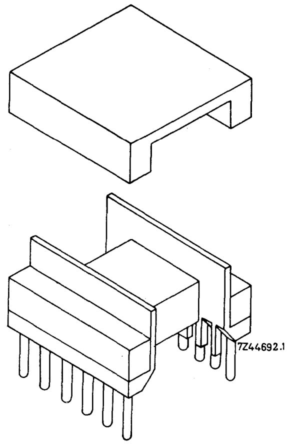






1) This dip does not depend on the magnetic circuit. It is caused by resonances of the inductance and stray capacitance of the two components in the test circuit.

H-CORE



The H 16-core consists of a ferroxcube H-shape with coil former, a ferroxcube U-shape, a brass container and a silicon rubber washer.
All these components are adapted to each other.

The H 16-core can only be supplied as a complete assembly.

Cat. number of the assembly : 4322 020 33030
Approximate weight of the assembly:

The applied ferroxcube material is the high permeable 3E2 grade.

The jointing surfaces are very flat and smoothly lapped.

Dimensional quantities

Mean length of lines of force l_e = cm
Mean area of lines of force A_e = cm^2

$\Sigma \frac{l_e}{A_e} = 0.63\ cm^{-1}$

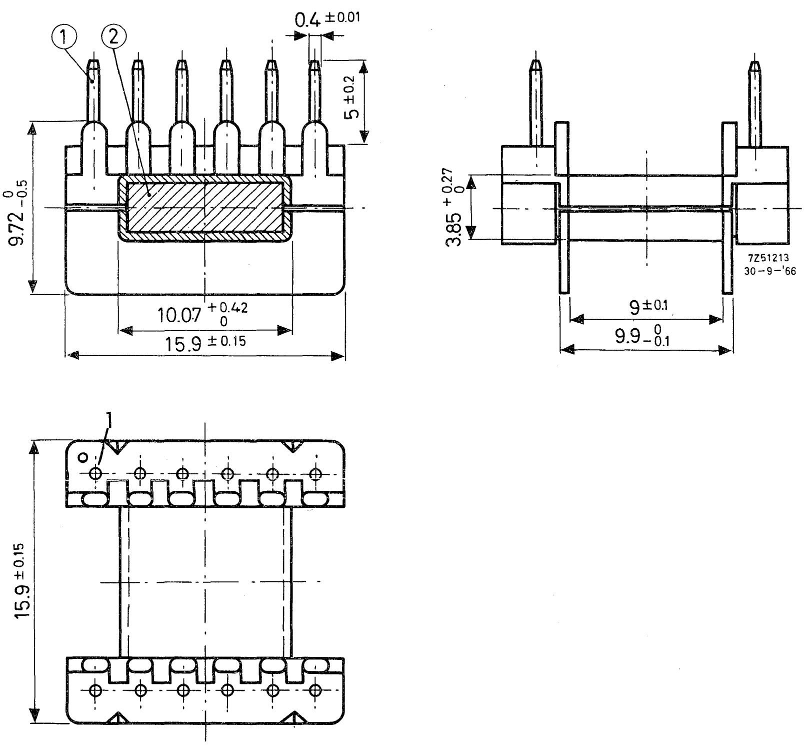
Effective volume V_e = cm^3

Electrical requirements, measured with 30 windings of 0.30mm wire, at $\hat{B} < 1$ gauss, f = 4kHz and a mechanical force of 1.5 Newton in the temperature range from +23 till +70 °C

$\mu_e >$
$\alpha <$
$A_L > 4500\ nH/N^2$

The eight soldering pins are arranged so as to fit printed-wiring boards with 0.1" grid as well as those with a 2.50mm grid. The board should be provided with holes of max. 0.8+0.1 mm ϕ

COIL FORMER



Coil former 4322 020 33310
(1) Pins: phosphorbronze, dipsoldered
(2) H-core: ferroxcube

The coil former and the ferroxcube H-shape are combined to one part.

Material of coil former	reinforced polyester with phosphorbronze dipsoldered pins
Window in mm^2	
Mean length of turn in cm	3.96
Max. temperature for dipsoldering	
for 5-6 s in °C	
for 1-2 s in °C	
Max. working temperature in °C	

For speeding up the soldering operation of the winding wire to the pins, the use of self fluxing wire is advised. In case a terminal of the winding must be connected to the container, it should be soldered to pin 1 (see figure above).

In order to avoid damage of the ferroxcube H-shape, care should be taken that during winding the turning couple exercised on this ferroxcube part is not too high.

MOUNTING PARTS

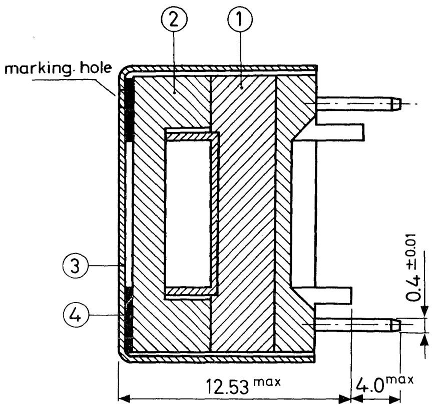


Fig. 1

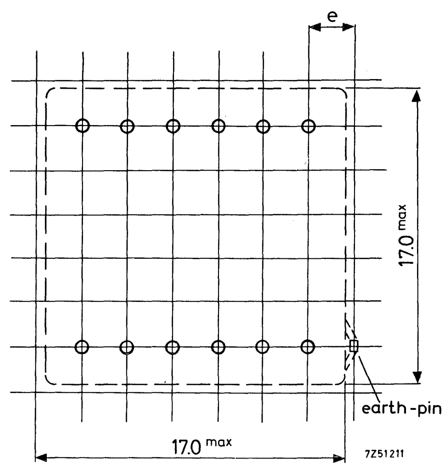


Fig. 2. Hole pattern.
e = 0.1" or 2.50 mm.

The H 16-core is only applied as a complete assembly.
Catalog number of the assembly: 4322 020 33030

Components according to Fig. 1.
(1) Ferroxcube H-shape with reinforced polyester coil former
(2) Ferroxcube U-shape
(3) Brass container 4322 021 20180
(4) Silicon rubber washer 4322 021 20210

Take care that the jointing surfaces of the two core parts are very clean.

On one side of the H-shape and on one side of the U-shape is a mark. These marks must be in one line.

When glueing is desired, apply a suitable adhesive around the jointing surfaces of the H-shape and the U-shape (see Fig. 3). The spots where the adhesive is to be applied should first be degreased thoroughly. A suitable adhesive is e.g. Araldite type D, with Versamite 140, mixing ratio 70 : 30; curing time at least 24 hours at room temperature.
Each pin is marked with a figure. There is also a marking hole on the top side of the container. This marking hole must be in one line with soldering pin 1.

If wanted the brass container can be earthed by means of the earth pin (see Fig. 2).

For closing the container, a simple tool (placed in a press with cranked levers) has been developed. This tool can not be supplied, however drawings of this tool are supplied on request under code number 4E 40202.

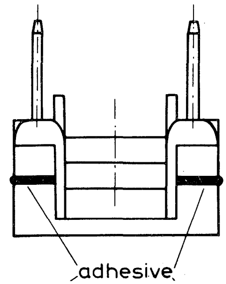
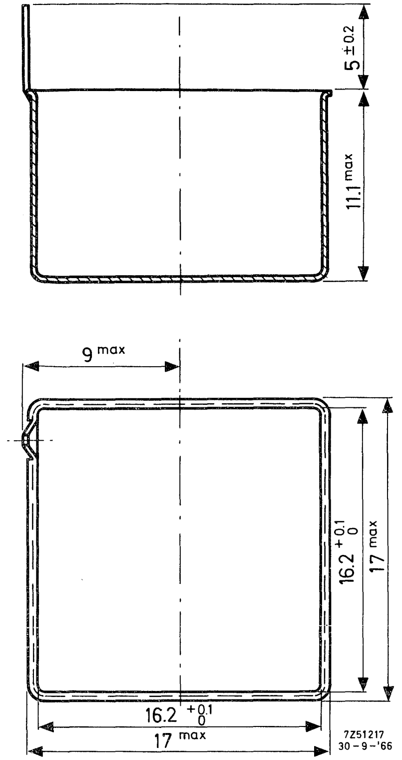
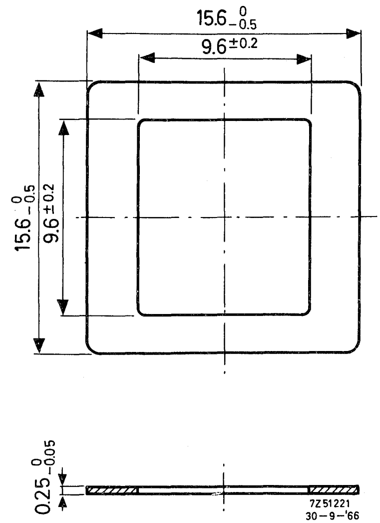


Fig. 3



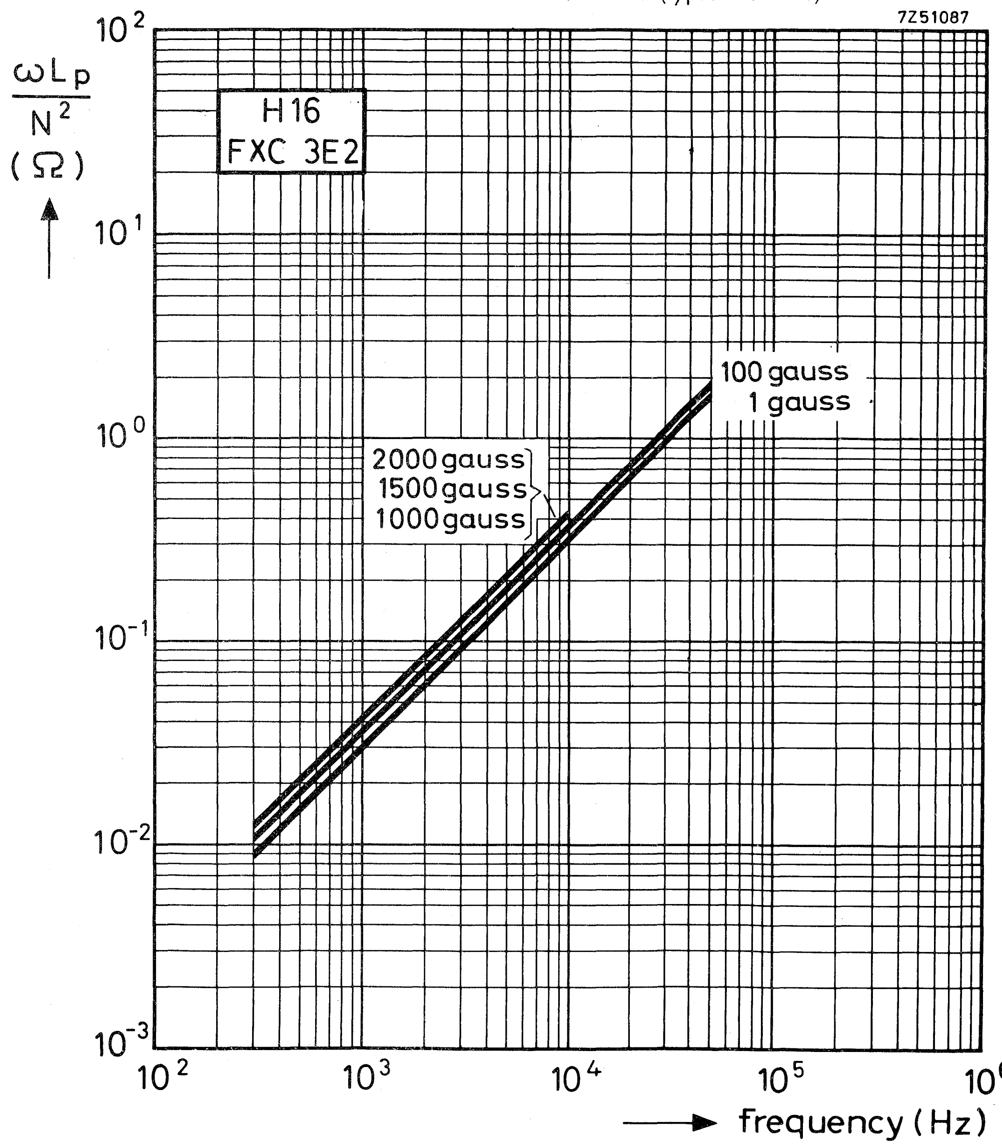
(3) Container 4322 021 20180
Material: brass, nickel-plated

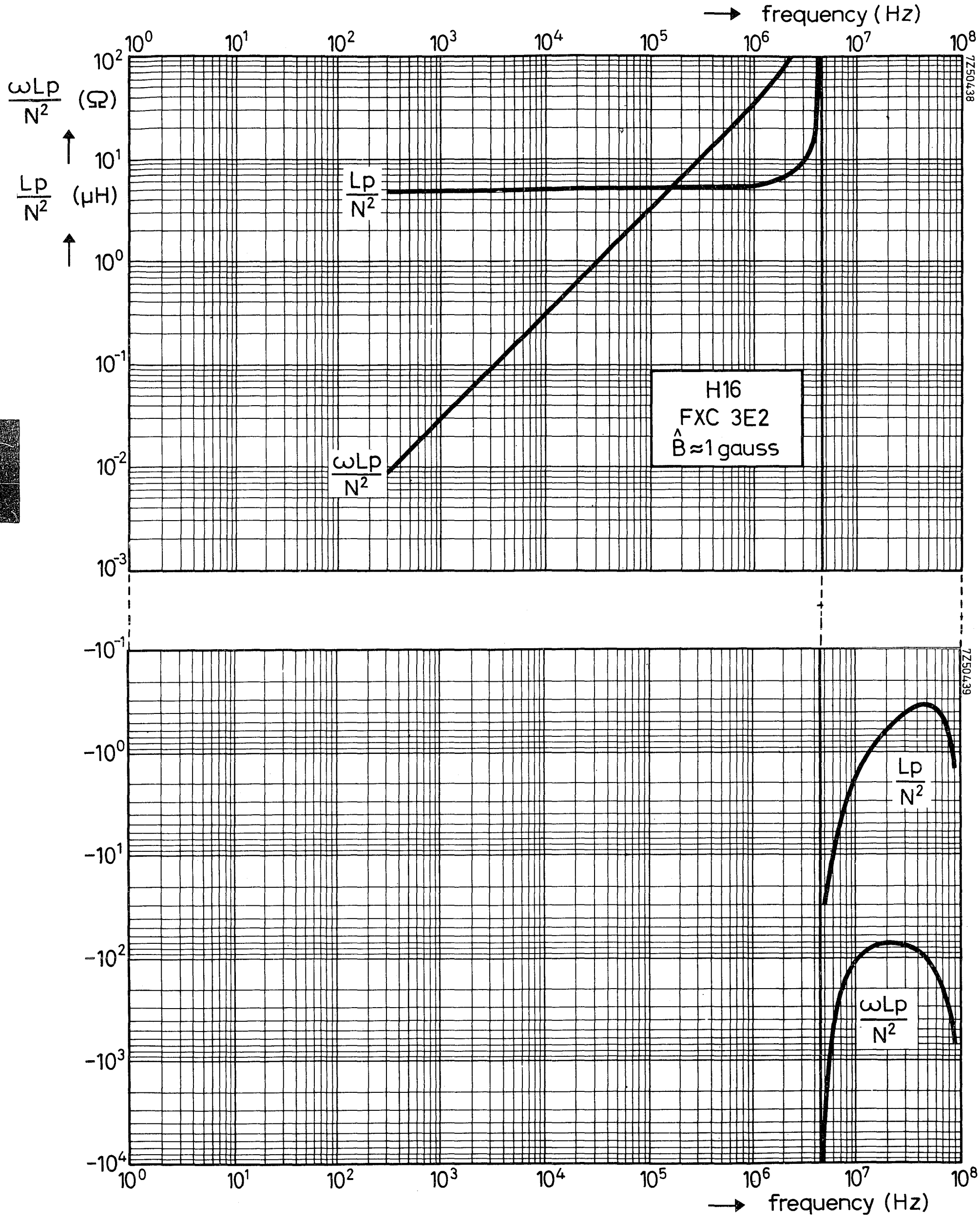


(4) Washer 4322 021 20210
Material: silicon rubber

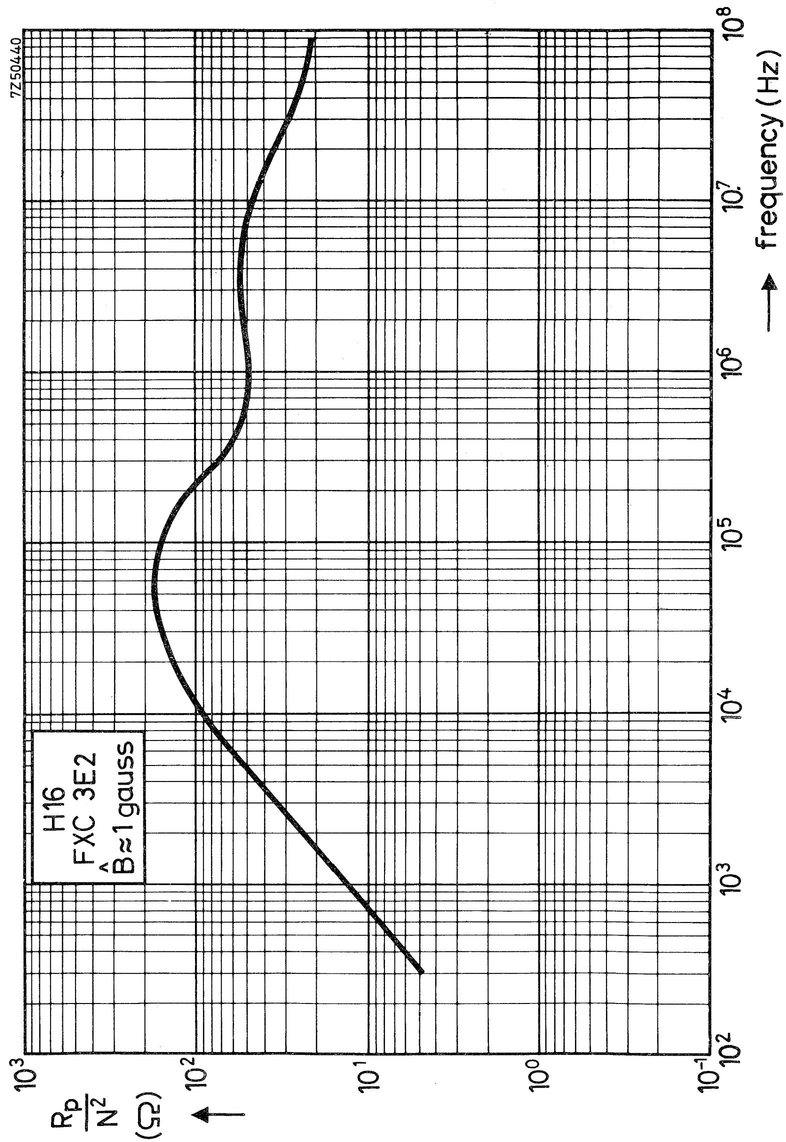
CHARACTERISTIC CURVES

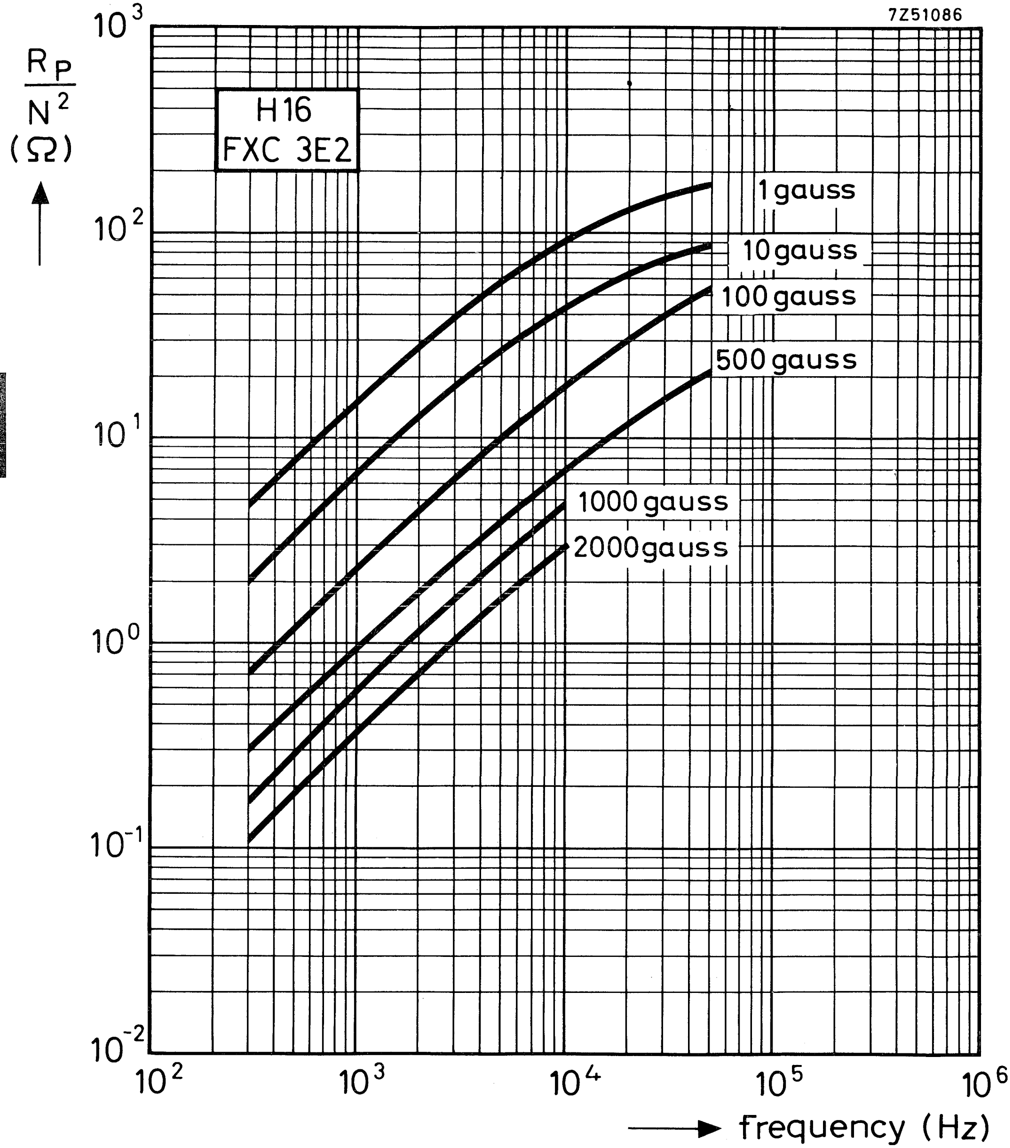
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical values)

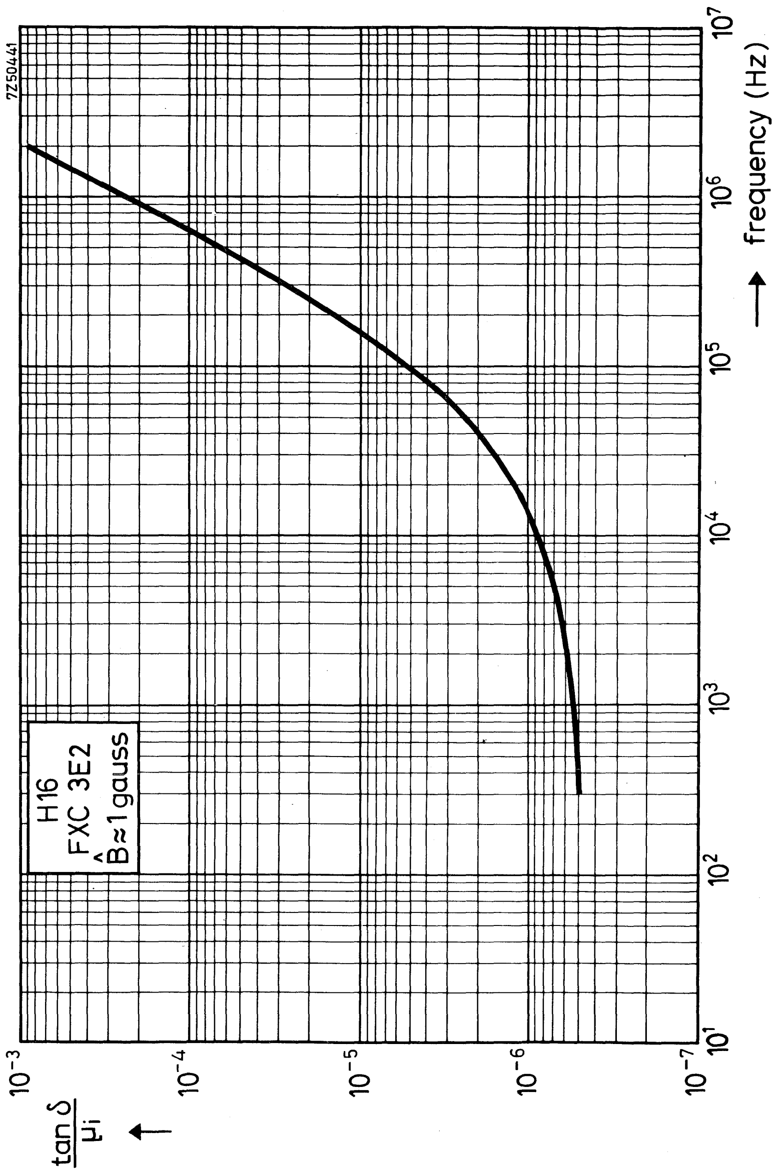



→ frequency (Hz)
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
$\frac{\omega Lp}{N^2}$ (Ω)
$\frac{Lp}{N^2}$ (μH)
10^2 10^1 10^0 10^{-1} 10^{-2} 10^{-3}
$\frac{Lp}{N^2}$
$\frac{\omega Lp}{N^2}$
H16
FXC 3E2
$\hat{B}\approx 1$ gauss
7Z50438
-10^{-1} -10^0 -10^1 -10^2 -10^3 -10^4
$\frac{Lp}{N^2}$
$\frac{\omega Lp}{N^2}$
7Z50439
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8
→ frequency (Hz)

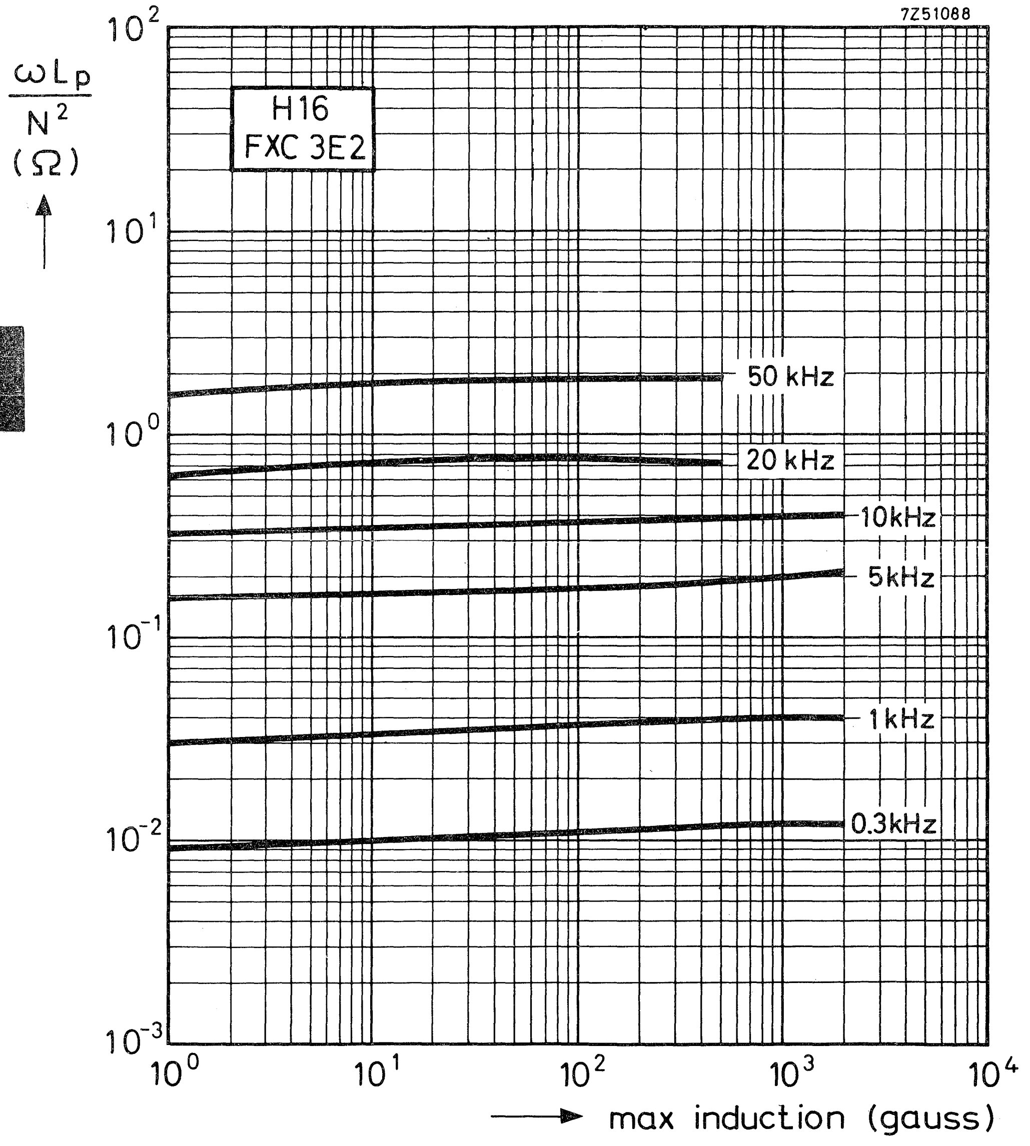
LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)



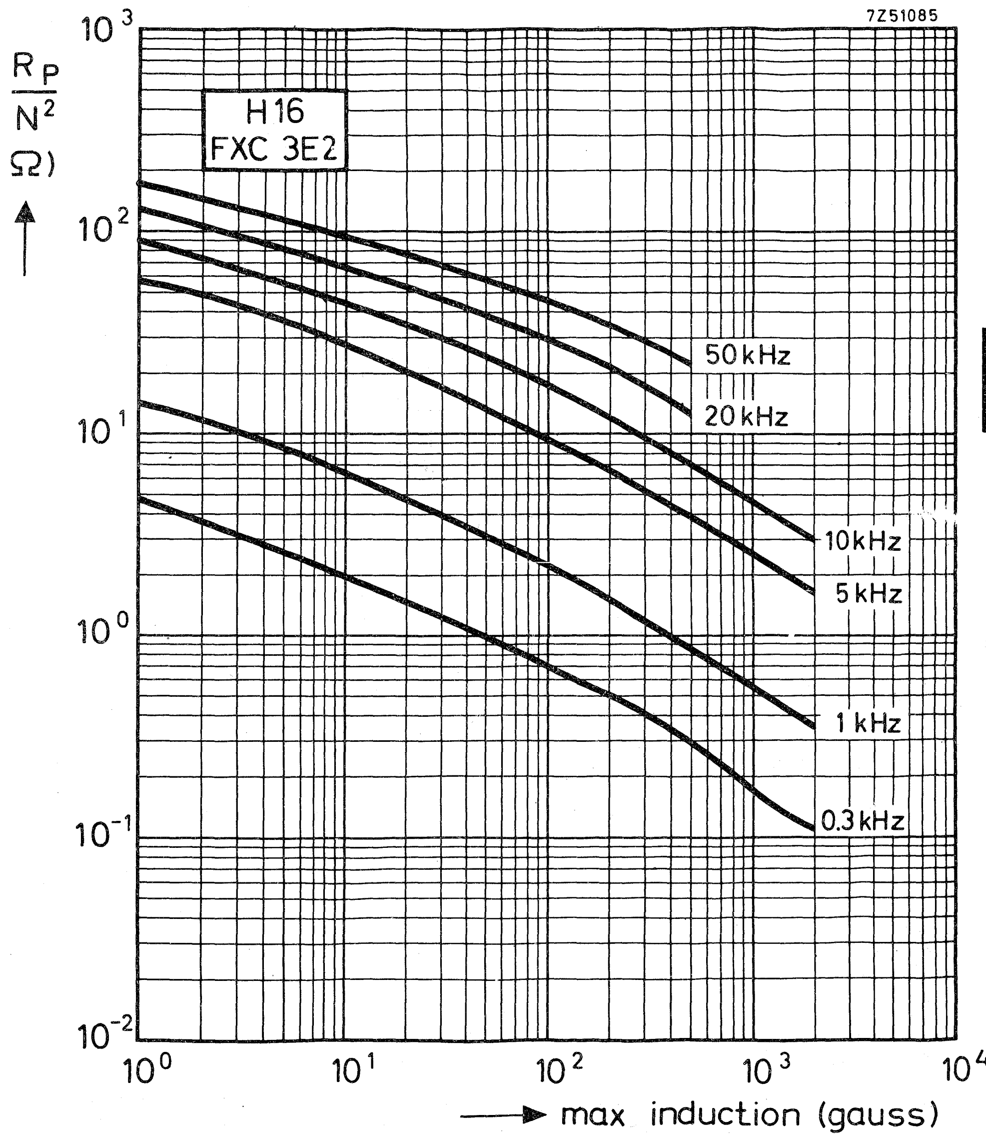

7Z51086
$\frac{R_P}{N^2}$ (Ω)
H16
FXC 3E2
1 gauss
10 gauss
100 gauss
500 gauss
1000 gauss
2000 gauss
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^2
10^3
10^4
10^5
10^6
frequency (Hz)


7Z50441
H16
FXC 3E2
$\hat{B} \approx 1$ gauss
$\frac{\tan\delta}{\mu_i}$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
frequency (Hz)

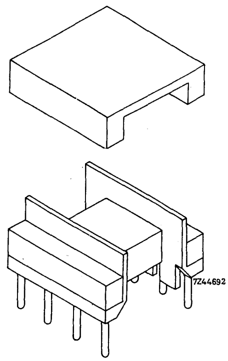
INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)



LOSSES AS A FUNCTION OF THE INDUCTION (typical values)



H-CORE



The H 20-core consists of a ferroxcube H-shape with coil former, a ferroxcube U-shape, a brass container and a silicon rubber washer.
All these components are adapted to each other.

The H 20-core can only be supplied as a complete assembly.
Cat. number of the assembly : 4322 020 33000
Approximate weight of the assembly : 14.8 g

The applied ferroxcube material is the high permeable 3E2 grade.

The jointing surfaces are very flat and smoothly lapped.

Dimensional quantities

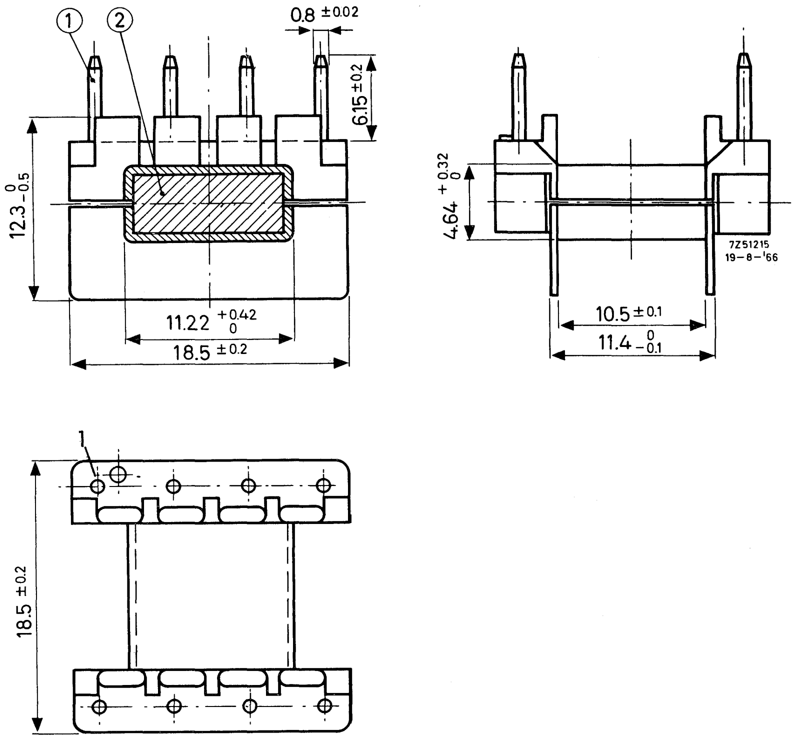
Mean length of lines of force $l_e = 4.12$ cm
Mean area of lines of force $A_e = 0.47$ cm^2
$\Sigma \frac{l_e}{A_e} = 8.8$ cm^{-1}
Effective volume $V_e = 1.93$ cm^3

Electrical requirements, measured with 30 windings of 0.30 mm wire, at $\hat{B} \leq 1$ gauss, f = 4 kHz and a mechanical force of 1.5 Newton in the temperature range from +23 till +70 °C

$\mu_e \geq 3850$
$\alpha \leq 13.5$
$A_L \geq 5500$ nH/N^2

The eight soldering pins are arranged so as to fit printed-wiring boards with 0.1" grid as well as those with a 2.50 mm grid. The board should be provided with holes of max. 1.3 $\pm$ 0.15 mm ϕ.

COIL FORMER



Coil former 4322 020 33290
(1) Pins: phosphorbronze, dipsoldered
(2) H-core: ferroxcube

The coil former and the ferroxcube H-shape are combined to one part.

Material of coil former	reinforced polyester with phosphor-bronze dipsoldered pins
Window area in mm^2	38.5
Mean length of turn in cm	4.68
Max. temperature for dipsoldering	
for 5-6 s in ^{o}C	280
for 1-2 s in ^{o}C	380 - 400
Max. working temperature in ^{o}C	130

For speeding up the soldering operation of the winding wire to the pins, the use of self fluxing wire is advised. In case a terminal of the winding must be connected to the container, it should be soldered to pin 1 (see figure above).

In order to avoid damage of the ferroxcube H-shape, care should be taken that during winding the turning couple exercised on this ferroxcube part is not too high.

MOUNTING PARTS

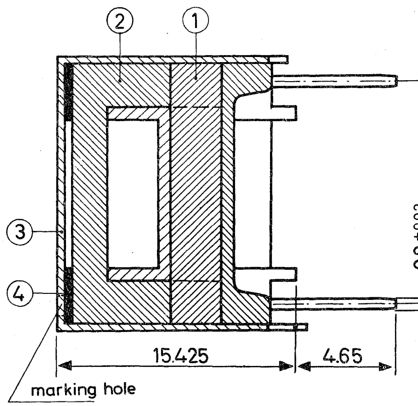


Fig. 1

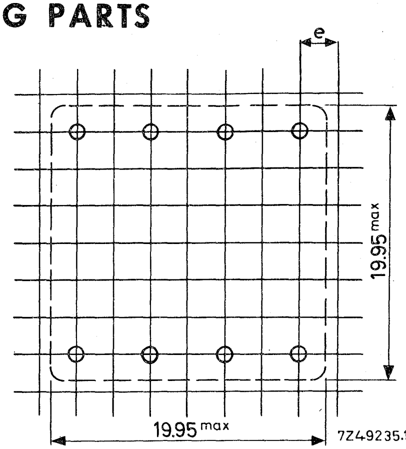


Fig. 2. Hole pattern.
e = 0.1" or 2.50 mm.

The H 20-core is only applied as a complete assembly.
Cat. number of the assembly: 4322 020 33000

Components according to Fig. 1:
(1) Ferroxcube H-shape with reinforced polyester coil former
(2) Ferroxcube U-shape
(3) Brass container 4322 021 20000
(4) Silicon rubber washer 4322 021 20040

Take care that the jointing surfaces of the two core parts are very clean.

On one side of the H-shape and on one side of the U-shape is a mark. These marks must be in one line.

When glueing is desired apply a suitable adhesive around the jointing surfaces of the H-shape and the U-shape (see Fig.3). The spots where the adhesive is to be applied should first be degreased thoroughly. A suitable adhesive is e.g. Araldite type D, with Versamite 140, mixing ratio is 70 : 30; curing time at least 24 hours at room temperature.
Each pin is marked with a figure. There is also a marking hole on the top side of the container. This marking hole must be in one line with soldering pin 1.

If wanted the brass container can be earthed. To that purpose one of the container lips has a somewhat other shape and is tin-plated as well. This lip has to be soldered to pin 1 after bending the lips. If the container has not to be earthed, the tin-plated lip has to be cut down.
For bending the container lips, a simple tool (placed in a press with cranked levers) has been developed. This tool can not be supplied, however drawings of this tool are supplied on request under catalog number 4322 058 00130.

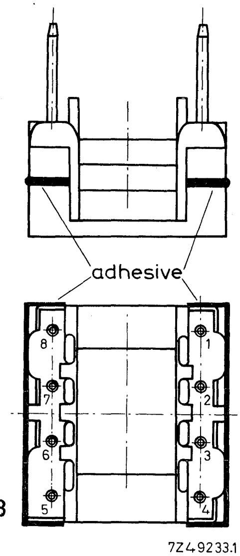
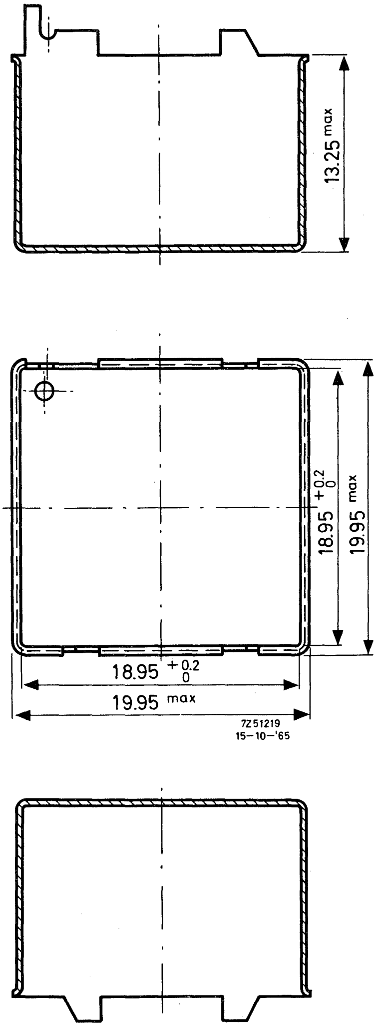
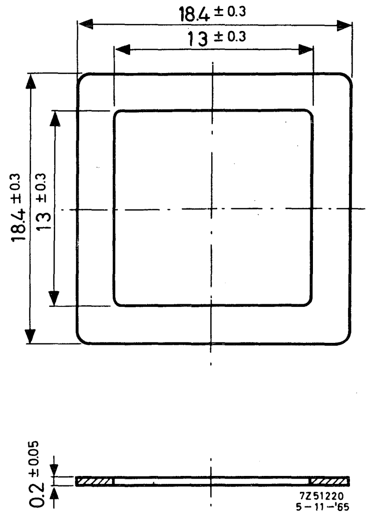


Fig. 3



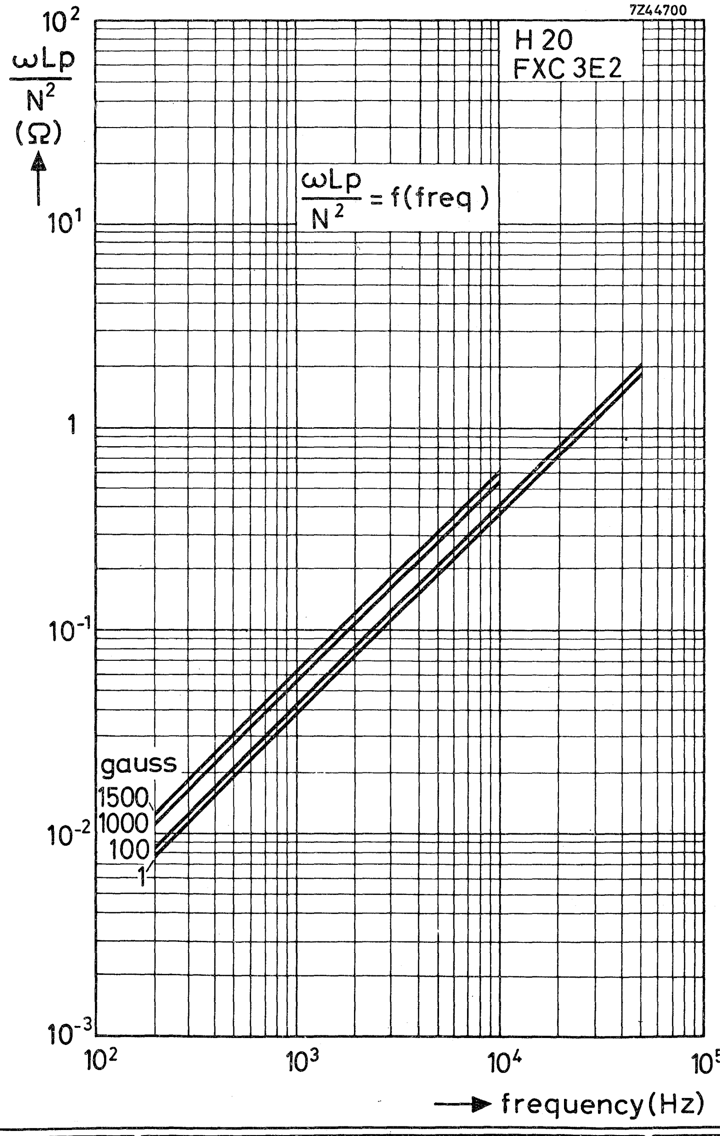
(3) Container 4322 021 20000
Material: brass, nickel-plated

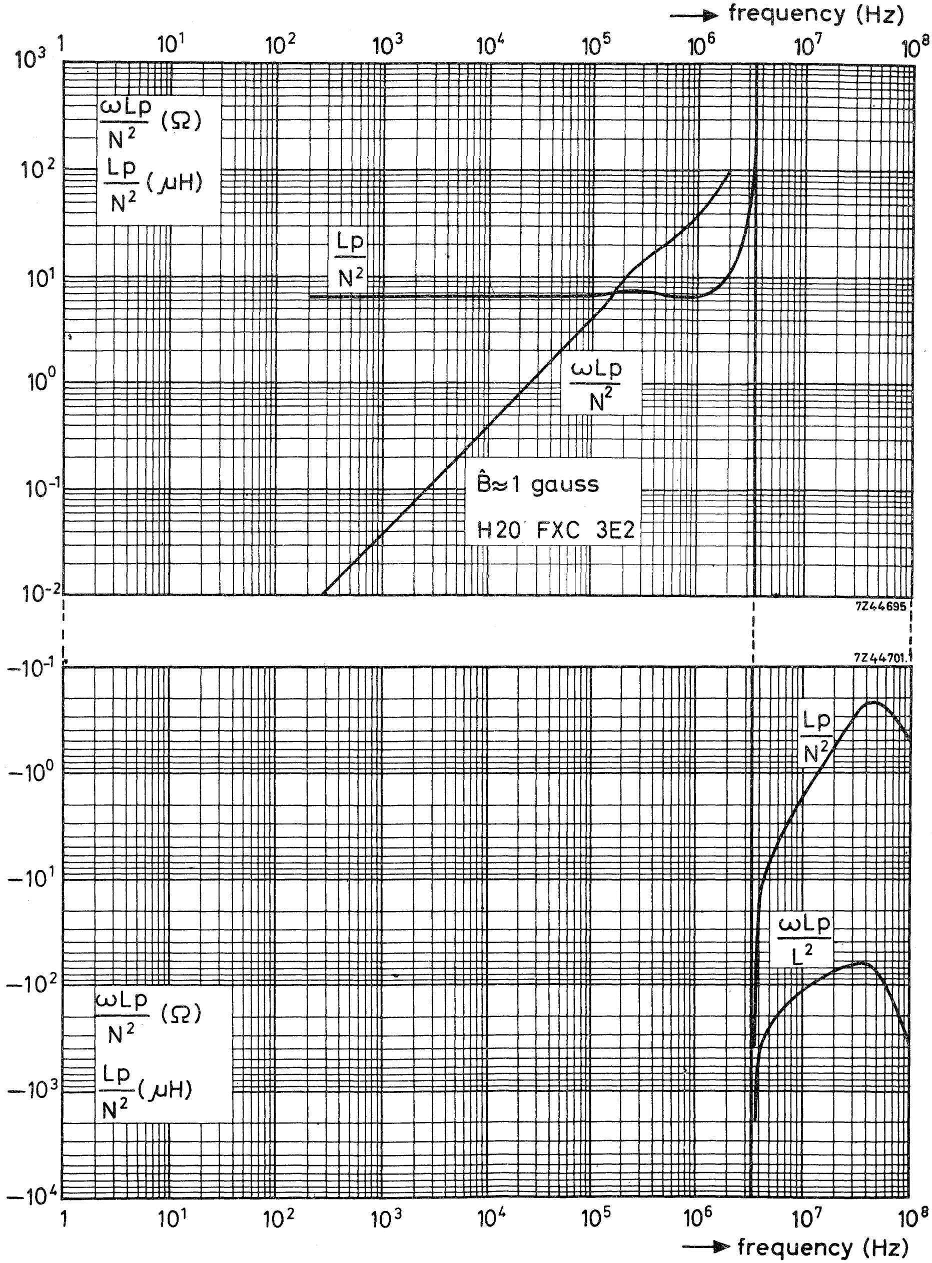


(4) Washer 4322 021 20040
Material: silicon rubber

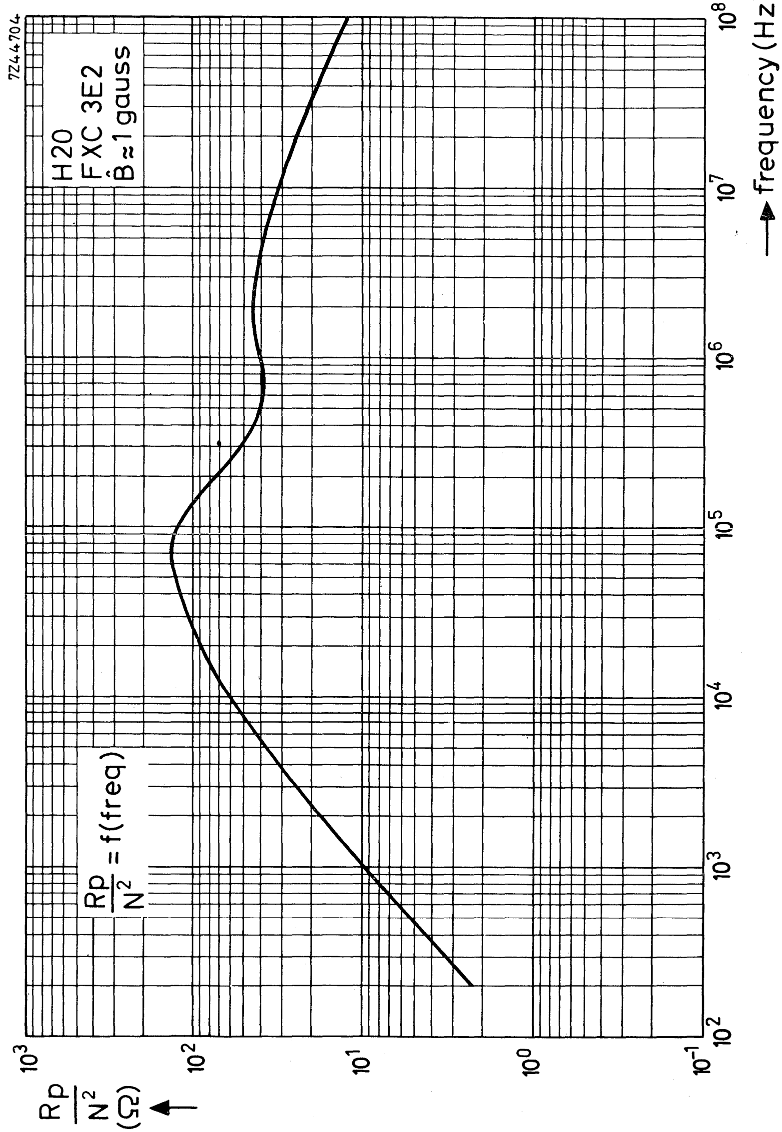
CHARACTERISTIC CURVES

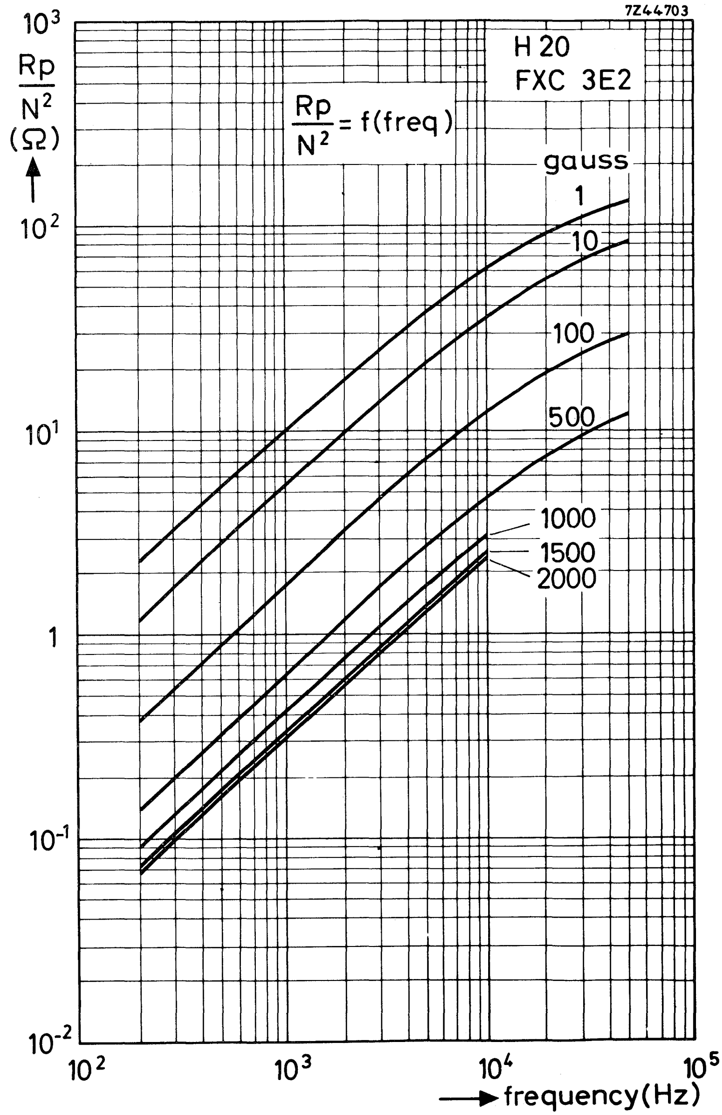
INDUCTANCE AS A FUNCTION OF THE FREQUENCY (typical values)

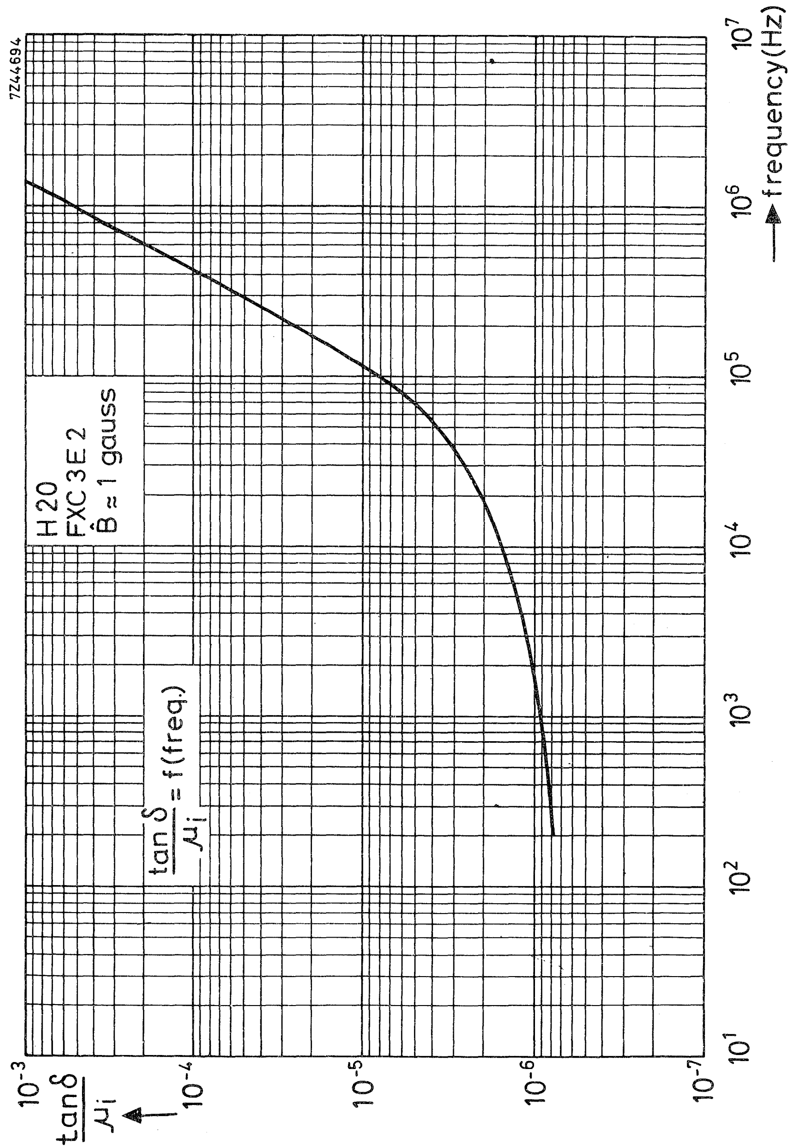



frequency (Hz)
1
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\frac{\omega Lp}{N^2}$ (Ω)
$\frac{Lp}{N^2}$ (μH)
$\frac{Lp}{N^2}$
$\frac{\omega Lp}{N^2}$
$\hat{B} \approx 1$ gauss
H20 FXC 3E2
7Z44695
7Z44701
-10^{-1}
-10^0
-10^1
-10^2
-10^3
-10^4
$\frac{Lp}{N^2}$
$\frac{\omega Lp}{L^2}$
$\frac{\omega Lp}{N^2}$ (Ω)
$\frac{Lp}{N^2}$ (μH)
frequency (Hz)

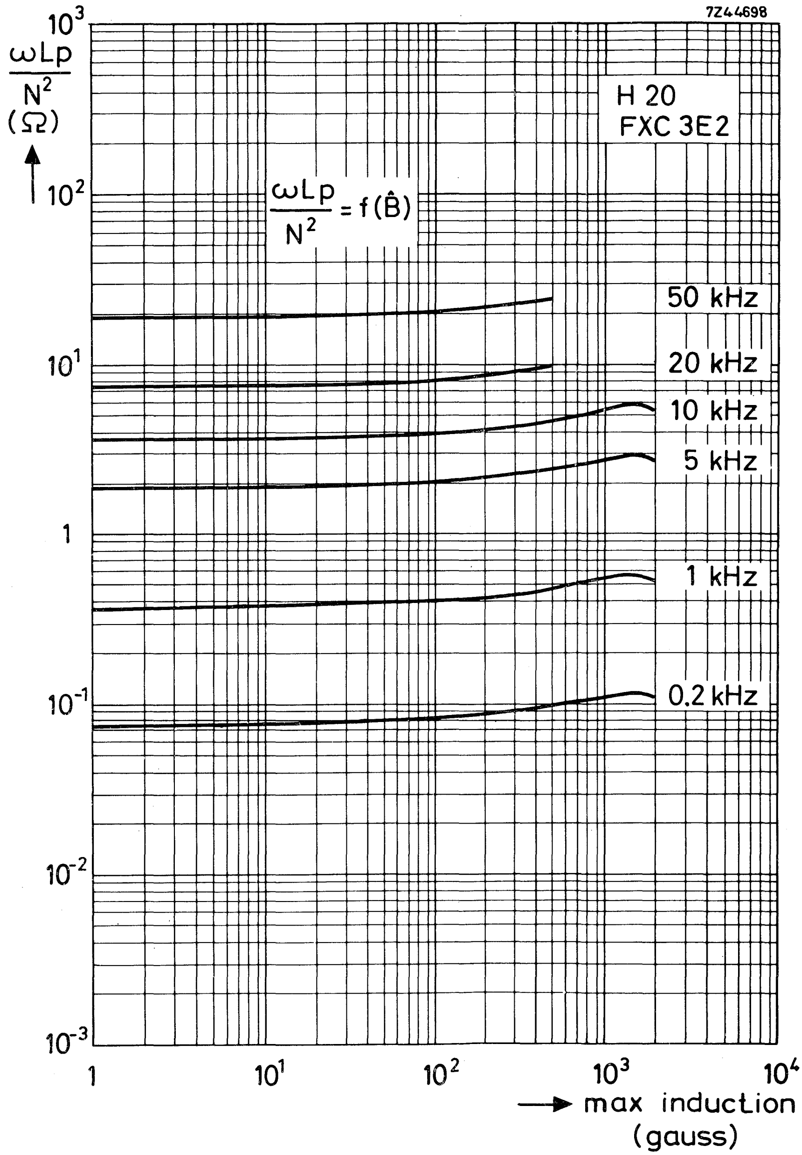
LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)



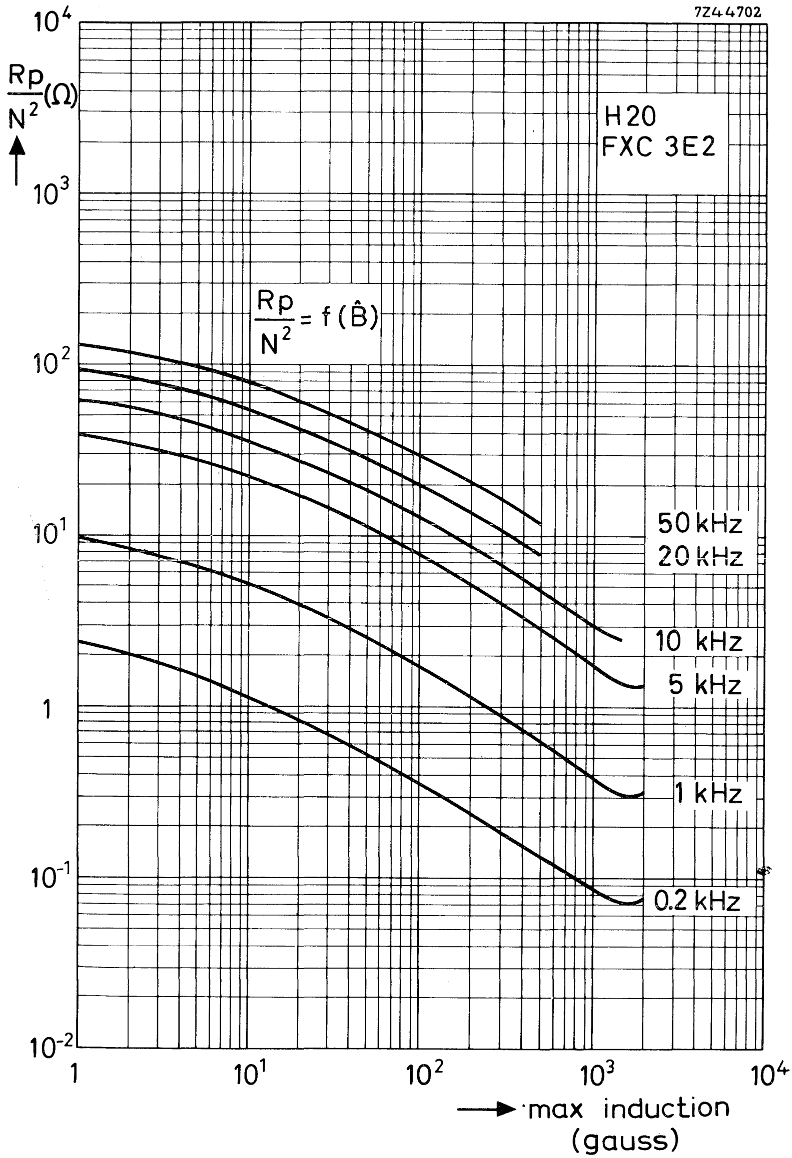

7Z44703
H 20
FXC 3E2
Rp/N² = f(freq)
Rp/N² (Ω)
gauss
1
10
100
500
1000
1500
2000
10³
10²
10¹
1
10⁻¹
10⁻²
10²
10³
10⁴
10⁵
frequency (Hz)


7Z44694
H 20
FXC 3 E 2
$\hat{B} \approx 1$ gauss
$\frac{\tan\delta}{\mu_i} = f(\text{freq.})$
$\frac{\tan\delta}{\mu_i}$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
frequency (Hz)

INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)

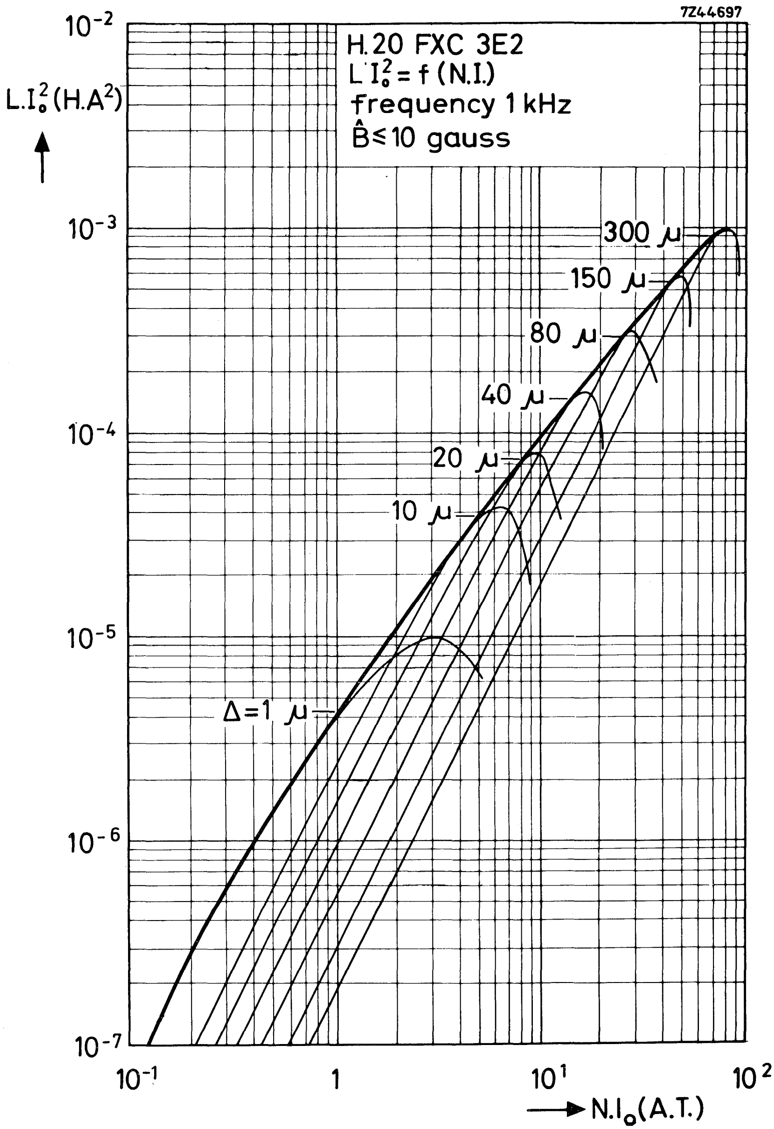


LOSSES AS A FUNCTION OF THE INDUCTION (typical values)



HANNA CURVE (typical values)

Indicating optimum inductance for a certain airgap and direct current.



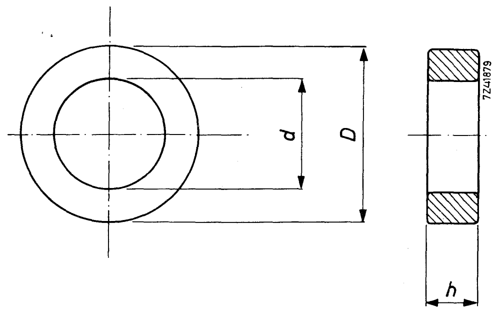
TOROIDS

INTRODUCTION

Toroids have the great advantage of providing more permeability per unit size than any other type of Ferroxcube product. In spite of the closed magnetic circuit, the losses in Ferroxcube toroids are small.

Due to their high permeability, the toroids are mainly used in broadband transformers, pulse transformers and chokes, if however the d.c. current is low. If the d.c. current through the transformer is of some importance, other shapes which can be provided with an airgap are recommended.
Toroids are not recommended for tuned circuits.

TOROIDS



The advantages of toroids over other shapes are:

a. small magnetic stray field,
b. high μ-values.

They are very attractive for those applications in which small dimensions are required, such as broadband transformers and pulse transformers.

The toroids are barrel-finished and covered with an insulating lacquer.

Table I: Dimensional quantities, tolerances and weights.

D mm	d mm	h mm	l_e cm	$\Sigma \frac{l_e}{A_e}$ cm^{-1}	V_e cm^3	weight g
4 ± 0.1	2.2 ± 0.1	1.1 ± 0.1	0.946	95.6	0.00937	0.045
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
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

Note: All dimensions are of the not lacquered version.

Different series are available:

Series A: Ferroxcube grade 3E1
μ_{tor} = 2700 ±20%
green lacquered

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

Series B: Ferroxcube grade 3H1
Sorted into μ groups
Orange lacquered

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

The colour of the circumference of the core indicates the μ group (see table II)

Table II:

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

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

The μ groups are determined with the nominal $\Sigma\frac{l_e}{A_e}$ values at 25 °C (see table 1)

The α factors of the groups 1 - 9 are average values, those of group 10 are maximum values.

D.F. at 23 ± 1 °C $\leq 4.3 \times 10^{-6}$

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

The sorting into μ groups is done merely for the convenience of the user. The toroids are not available per separate group.

Series C: Ferroxcube grade 3E2
μ_{tor} >5000 in the temp. range from +23 to +70 °C

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

Series D: Ferroxcube grade 4C4
μ_{tor} >100 in the temp. range from +23 to +55 °C

dimensions (mm)	catalog number
6 x 4 x 2	4322 020 36500
9 x 6 x 3	4322 020 36510
14 x 9 x 5	4322 020 36520
23 x 14 x 7	4322 020 36530
36 x 23 x 15	4322 020 36540

Note: It should be noticed that the properties of a toroid will deviate more from the material properties in proportion as its dimensions are smaller.
A straight-forward translation of the material figures is therefore not always possible.

Ferroxcube memory cores

The following standard types are available.
For complete information reference is made to handbook "Components and subassemblies for data processing and control".

for cycle times up to	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
1.0 μs	20 mil	6H1	40	833	0.50	0.05	≥ 0.2	55	53	6	0.085	0.17
1.0 μs	20 mil	6H2 *	10-70	900	0.50	0.05	≥ 0.28	48	45	4	0.110	0.22
1.5 μs	30 mil	6F2	40	655	0.50	0.1	≥ 0.5	55	53	6	0.20	0.39
1.5 μs	30 mil	6F3 *	10-70	740	0.50	0.15	≥ 0.6	50	48	5	0.28	0.50
5 μs	50 mil	6C1	40	500	0.50	0.2	≥ 1.1	63	60	8	0.48	0.93
5 μs	50 mil	6C2 *	0-70	755	0.50	0.25	≥ 1.2	66	65	7	0.50	0.95
5 μs	50 mil	6D9	40	450	0.50	0.2	≥ 1.5	60	58	8	0.55	1.20
6 μs	50 mil	6D5	40	365	0.50	0.2	≥ 1.5	64	60	7	0.54	1.15

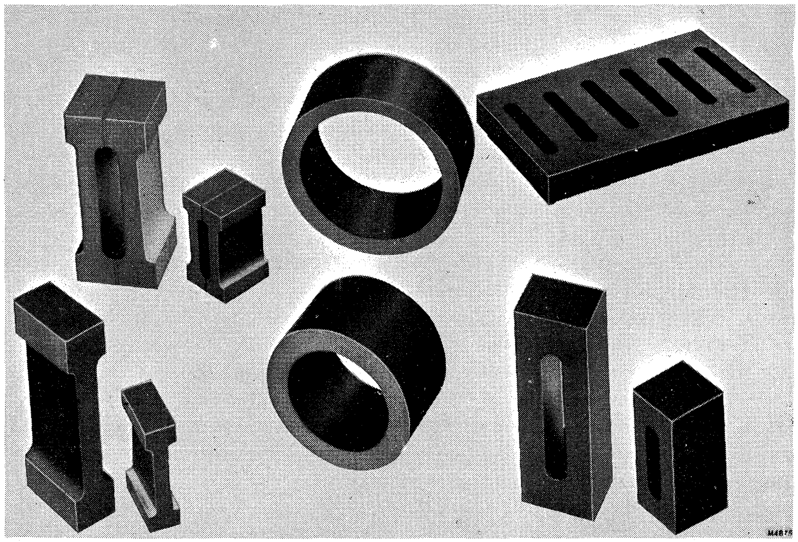
* With this core a memory system can be operated over a wide temperature range without temperature compensation, air conditioning, or other alternates.

Note: For cores differing from those of our range offer on request.

Ferroxcube transducers

Ultrasonic transducers in FXC 7A2

ULTRASONIC TRANSDUCERS
in ferroxcube 7A2



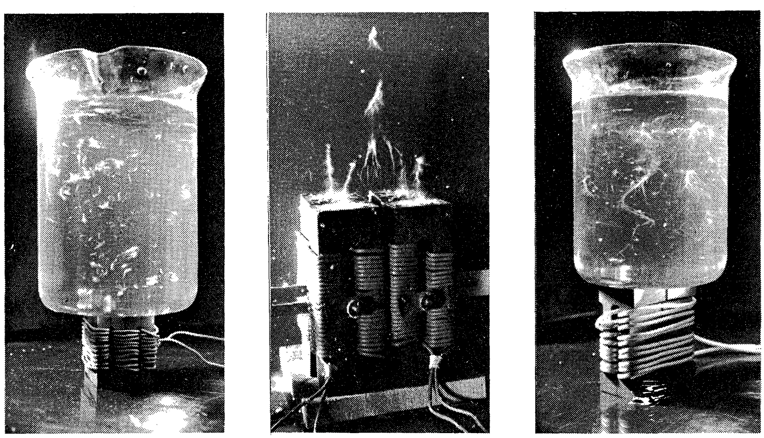
INTRODUCTION

For the past quarter of a century there have grown up a new family of industrial techniques employing sound waves in a variety of ways. Knowledge of the fundamental phenomena underlying these techniques has sprung in many cases from pure research which was not directed towards any immediate application. Subsequent development has brought to perfection a number of valuable industrial tools, others are still being evolved.

The frequencies of sound waves that can be detected by the average human ear lie below approx. 16,000 cycles per second. Frequencies higher than this are known as ultrasonic. Such frequencies - up to some millions of cycles per second - are particularly useful in industry, so much so that the term "ultrasonic" has come to be applied loosely to any industrial or naval process involving sound waves, even when audible.
Sound is transmitted through a solid, liquid, or gaseous medium by elastic waves, which may be of several types. For example, the medium may vibrate in a compressional mode (such as the manner of transmission of ordinary sound

in air), in a shear mode (the particles of the medium moving at right angles to the direction of propagation) or in a torsional mode (as along a long thin rod if one end is suddenly twisted). Sound and also ultrasonic vibrations can normally be propagated in gases and fluids only in a compressional mode.

The particular value of ultrasonic frequencies in industrial work lies largely in two properties which they possess. Frequencies in the range below 100 kHz can produce in liquids the phenomenon known as cavitation. This is the formation of bubbles within the liquid, partly filled with dissolved gas and vapour, which subsequently vibrate, expand and collapse, giving rise to shock-wave pressures of many hundreds of atmospheres. The bubbles are produced when the instantaneous pressure in the liquid falls below the vapour pressure of the liquid, and normally quite substantial sound intensities are required for their initiation. These large shock pressures produce powerful stirring effects and large random local forces, which are utilised in ultrasonic cleaning and other applications (see illustrations in Fig. 1). In the following paragraphs the mechanism of ultrasonic cleaning will be discussed in more detail.
The second property of particular importance is most evident in sound waves generated by a transducer with radiating face much larger than the wavelength of the radiated waves. Such sound waves may easily be "beamed" like light and also be reflected and refracted in a similar manner. They may thus be used for looking into solid materials to find flaws or into sea-water to find obstacles, just as visible light might be used for examining a diamond. The relative transparency of materials to the sound and the manner in which it is reflected and refracted give information about the elastic properties and the presence of local disturbances in the materials.



2 x 20W 22kHz | 4 x 40W 25kHz | 4 x 20W 41 kHz A 32504

Fig. 1

THE PRODUCTION OF ULTRASONIC VIBRATIONS

For almost all industrial applications ultrasonic vibrations are generated with the aid of a so-called solid state or piezo-transducer. Piezo-transducers are energy convertors consisting of a solid material which changes electrical vibrations, usually produced by an electronic generator into mechanical vibrations of the same frequency. To obtain a high efficiency for this conversion of energy, the transducers have to be employed at or near their mechanical resonance frequency, i.e. their effective length must be equal to half the acoustic wavelength in the material concerned.

In other words $l_{eff} = \frac{\lambda}{2} = \frac{c}{2f_r}$

in which λ represents the acoustic wavelength and c the velocity of sound in the material used. The generation of ultrasonic vibrations from electrical vibrations is most conveniently obtained by using the phenomena of "piezomagnetism" or "piezoelectricity". In ferromagnetic materials the magnetic moments of the spinning electrons interact strongly and tend to lie parallel to each other within minute domains. Although these domains are spontaneously magnetised, the direction of magnetisation varies from one domain to the other and in the macroscopally non-magnetised material their effects are cancelled out.
When subjected to an external magnetic field, the parallel magnetic moments of each domain tend to align themselves in the direction of the applied field and the material then becomes macroscopically magnetised. If the external field is removed, the domains tend to revert to the disordered arrangements, the effect being more pronounced as the temperature is raised. If the thermal energy is sufficiently great, the arrangement becomes completely random and at this temperature, known as the Curie point, the material is completely demagnetised. This temperature generally lies between 300 °C and 600 °C.
Ferroelectric materials are polarised instead of magnetised, but further their situation is exactly similar. The magnetising or polarising action is usually accompanied by a certain increase or decrease of the dimension parallel to the magnetising or polarising field. If this effect is sufficiently strong, the materials are classified as magnetostrictive and electrostrictive materials respectively.
Under the influence of an alternating field the domain arrangement in a ferromagnetic material is periodically reversed. This results in dimensional changes, and a bar accordingly contracts and expands in sympathy with the field.
Since the alternation in length is not sensitive to field direction, the mechanical vibration will take place at twice the frequency of the applied alternating field. This frequency doubling can be avoided by polarising with a steady field, which makes the material <u>piezomagnetic</u>, and superimposing a smaller alternating field.
This results in a highly improved conversion efficiency. Both effects are illustrated schematically in Fig. 2. An alternating field applied to the unmagnetised material produces strains at the double frequency shown in Fig. 2d.

Operation around point B results in a vibration at the applied frequency as shown in Fig. 2e Hysteresis effects are neglected in these schematic diagrams.

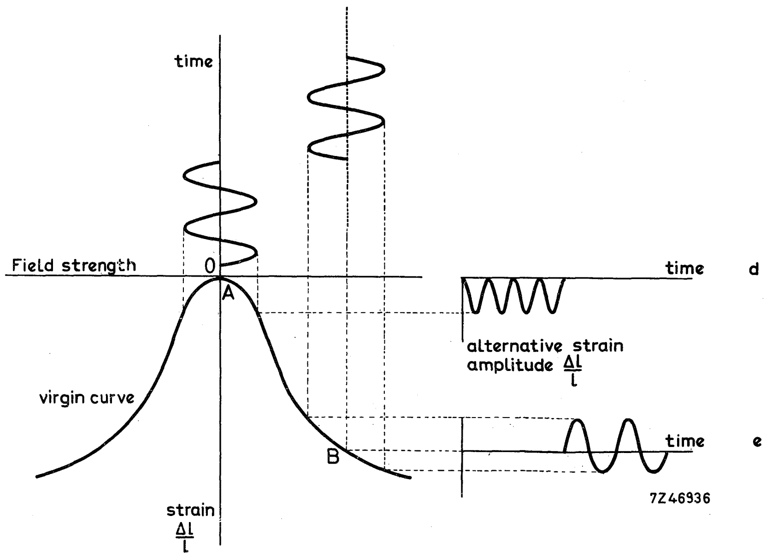


Fig. 2

ULTRASONIC-TRANSDUCER MATERIALS

For solid-state transducers, the following materials can be employed:

A Piezoelectric materials

1. Quartz
   This is mainly used for frequencies above 500 kHz since otherwise thick, and hence expensive blocks are required, or less efficient composite transducers.
2. Modified lead zirconate titanates, as Piezoxide 4 or 5.
   These ceramic materials have rather high Curie points (about 300 °C). They are usually made in blocks or discs for low frequencies, or plates or tubes for higher frequencies, and provided with two silver-plated electrodes. They are often used as compliant central parts with metallic masses on either side to form efficient composite transducers.

B Piezomagnetic materials

1. Metallic nickel is the "classical" material here. It is mainly used in the shape of window-type laminated vibrators, with a winding round the legs, or as scrolls with a toroidal winding.
In addition to the a.c. for generating the ultrasonic vibrations, a d.c. is fed to the winding, giving the necessary bias.
Nickel has a Curie point of approx. 350 °C so that it can be used up to a high temperature if a sufficiently heat-resistant winding is employed. Compared with ceramic materials, metallic nickel is rather robust, so that it is preferably used where high vibrational amplitudes are necessary (e.g. ultrasonic drilling). Because of eddy-current losses nickel is used almost exclusively at low ultrasonic frequencies in the region of 20 kHz. Even then its electroacoustic efficiency is fairly poor as compared with that of ceramic materials (see Fig. 3) because of both eddy-current losses and frictional losses between the laminations.

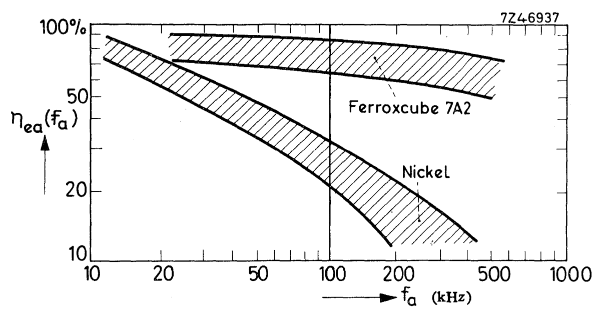


Fig. 3

2. A fairly novel piezomagnetic ceramic material is the nickel-copper-cobalt ferrite ferroxcube 7A2. This can be used to make ring transducers, window type transducers and double-dumb-bell transducers similar to those made of nickel but without the necessity to laminate it. The double-dumb-bell transducer is actually built up from two single dumb-bells mechanically connected by two premagnetising slabs of ferroxdure, a ceramic permanent magnetic material. This FXC 7A2 has a Curie temperature of 550 °C and no serious eddy-current or friction losses, sothat a high electroacoustic efficiency of the order of 70-90% can be obtained. This is approximately the same as for piezoelectric ceramics, and roughly twice that of nickel. Although the maximum permissible input power is lower for ceramic materials than for nickel,it is still quite sufficient for most ultrasonic applications.
A disadvantage of a ceramic vibrator, in particular of one with low internal loss like ferroxcube, is that a very low acoustic load would cause

too high an amplitude of vibration. This can be obviated either by a suitable feedback system or by a correct choice of the electronic circuit. More detailed information about these possibilities is given below.

A definite advantage of the piezomagnetic ceramic FXC 7A2 compared with piezoelectric ceramics is the low transducer impedance, which moreover can be chosen within wide limits by modification of the number of turns on the vibrator. This means the voltage on the winding can be kept low, and in combination with the high efficiency (smaller input power required) enables the use of a cheap and simple feeding system without any insulating problems for the transducer.
This low impedance is particularly favourable for transistorised equipment. By proper impedance adjustment the transducer can be directly fed from a push-pull amplifier output stage, a matching transformer being unnecessary.
The wound transducer must be tuned electrically to the correct mechanical resonance frequency, the so-called anti-resonance frequency f_a.
This can be achieved with a variable capacitor, which is cheaper than the variable coil required for tuning a piezoelectric transducer.
A disadvantage of FXC 7A2 with its low internal stress is the fairly high sensitivity of its electroacoustic properties for pre-stress. For this reason, in robust pre-stressed transducers (e.g. for sonar work) a piezoelectric material is usually preferred.

AVAILABLE TYPES OF TRANSDUCERS IN FXC 7A2

Figs 4-8 show several available standard types of transducers, the ring transducer (Fig. 4), the window transducer (single window Fig. 5 or multiple window Fig. 6) and the single dumb-bell (Fig. 7) or double-dumb-bell transducer (Fig. 8), the parts of the latter being supplied either loose or glued together with the two magnet slabs between (Fig. 8 and 13). A summary of the available types and their mechanical dimensions is given in Table II.

Ring transducers have the advantages of mechanical ruggedness and high permissible power rating, but they must be used immersed in liquid and require a d.c. source for bias. Their ultrasonic energy (and cleaning action) is not distributed homogeneously throughout the liquid, but concentrated along the ring axis, when using a pressure-release cover (e.g. closed-cell foam rubber) on the outer cylindrical face (self-focussing cleaner).
In case a homogeneous cavitation and energy distribution has to be reached with a transducer submerged in a liquid for cleaning purposes a window transducer is recommended. This is a relatively cheap and rugged type, and gives no stability problems concerned with glued connections (which may be difficult for submerged transducers). However it does require a d.c. source. On the other hand, the absence of magnets permits a higher maximum working temperature, the Curie point of ferroxdure (450 °C) lying below that of FXC 7A2 (550 °C). This material is suitable for submerged transducers since there are no insulation problems (except for the wire) and since the ferroxcube is

not corroded by liquids such as sea water and alkaline liquids. It does not withstand strong mineral acids, however.
The disadvantage of submerged transducers compared with transducers glued to an outer wall of a tank, is the erosion by cavitation on the radiating face and the relatively low amount of really useful ultrasonic energy.
The most frequently used type of transducer is the double-dumb-bell transducer (see Fig. 8). This consists of two I-shaped transducers and two magnet slabs, which must be glued or clamped together. Of course, the two magnets must be mounted in such a way that their fluxes act in the same direction, and do not cancel each other. For this reason the south poles of the magnet slabs K6 100 00 and K6 176 00 are marked yellow.
Two standard types of double dumb-bells exist: one for 22 kHz and one for 42 kHz.
Of all standard types of transducers, dimensions and properties are given in Table I and II.

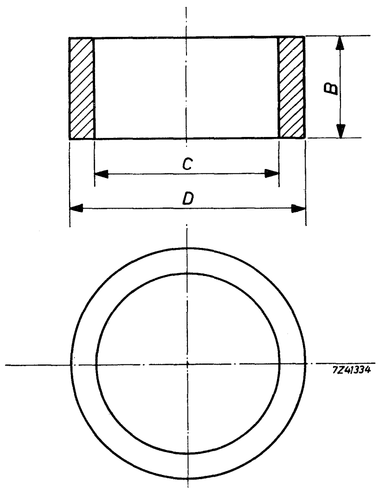


Fig. 4

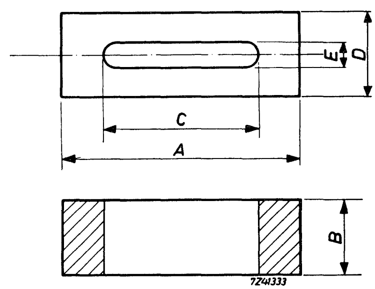


Fig. 5

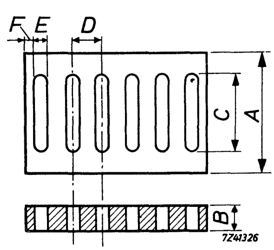


Fig. 6

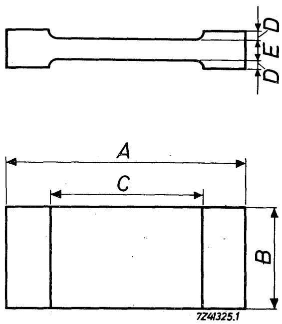


Fig. 7

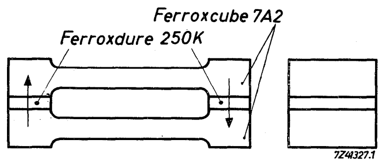


Fig. 8

INDICATIONS FOR PRACTICAL OPERATION

Mechanical resonance

Transducers are operated at their anti-resonance frequency f_a which is identical to the mechanical resonance frequency of the transducer with short-circuited coil. The electronic generator requires a purely ohmic impedance here, which means that the electrical resonance frequency of the transducer with a series or parallel capacitor, must possess the same value. Hence, for ideal operation three frequencies must be exactly equal, namely:

a) The electrical frequency of the generator
b) The electrical resonance frequency of the selfinductance of the wound transducer with its parallel capacitor
c) The mechanical resonance frequency of the transducer under the condition of short-circuited coils (anti-resonance frequency)

In order to achieve this, two frequencies must be adjusted, namely those mentioned under a and b. A simple method is a self-oscillating system by means of a piezoelectric feedback plate. sothat the driving frequency automatically follows the mechanical short-circuit resonance frequency, which varies with temperature, and which is also influenced by variations in the system coupled to the transducer, e.g. a tank with a liquid.
If the transducer is operated in an efficient way and correctly coupled to the load, there is a considerable useful mechanical damping, so that the effective mechanical Q of the transducer drops and the resonance bandwidth increases, thus allowing for some more frequency deviation.
It becomes more difficult when two or more transducers are driven by one feeding system, and their mechanical short-circuit resonance frequencies are different. An exact adjustment is not possible then, and a relatively slight difference in resonance frequency may lead to considerable differences in impedance between the transducers, resulting in unequal performance, and in the

worst case even to breakage of some by overloading. This means of course that the mechanical short-circuit resonance frequency f_a must be as much as possible the same for all transducers, and that the permissible tolerances mainly depend on the mechanical Q during operation Q_{load}.

It can be derived (see for instance Matronics Nr. 15, pp. 278-279) that a maximum electroacoustic efficiency is reached for a value Q_{load} equal to $\frac{a}{1+a} = Q_{unl}$, where Q_{unl} is the mechanical quality factor for the unloaded, already mounted transducer, and a the so-called transducer loss figure

$$a = (1 + k^2_{eff}\, Q_{magn}\, Q_{unl})^{-½}$$

Here k_{eff} is the effective piezomagnetic coupling factor and Q_{magn} the magnetic quality factor as measured at the existing induction under actual circumstances.
Substituting for a high power double-dumb-bell radiator in FXC 7A2 $k_{eff} \approx 0.2$, Q_{magn} = 15-20 and Q_{unl} = 150-300 (in Table I a value > 2000 is given for $(Q_{mech})_{free}$ of the completely free transducer, but the winding and the support introduce some additional damping), the value of a is for instance 0.07 and the optimum Q_{load} value during operation somewhere between 10 and 20.

However, such a low Q_{load} is difficult to realise in practice. Double-dumb-bell transducers fully immersed in a liquid, which also radiate in various unwanted directions, have a Q_{load} of the order of 15-35, but double-dumb-bell transducers glued to the wall or bottom of a vessel which radiate almost exclusively in the wanted direction usually have higher mechanical Q-values ranging from 20 up to about 100. It is clear that the tolerances on mechanical resonance frequency for any transducer used in an array must be smaller than the corresponding bandwidth of the loaded transducer. Allowing for a certain safety margin, this means that for double-dumb-bell transducers driven by one generator the antiresonance frequencies f_a must differ no more than 100 Hz for the 22 kHz type or 200 Hz for the 42 kHz type.
To maintain in production all transducers between those limits is technically possible, but expensive. A good compromise has been found for the completely glued transducer assemblies K3 040 00 and K3 040 05. These are selected into different groups, each with a tolerance of 100 Hz and 200 Hz respectively. On each transducer assembly a letter indicates the group it belongs to, so that a customer can select per apparatus transducers with the same letter and hence lying within narrow tolerances on f_a. For the next apparatus another letter can be used, and the oscillator frequency adjusted, or automatically adapted by means of feedback, e.g. a piezoelectric feedback plate.

The meaning of the letters is the following:

K3 040 00	a	indicates f_a = 21.6 - 21.7 kHz
	b	= 21.7 - 21.8
	c	= 21.8 - 21.9
	d	= 21.9 - 22.0
	e	= 22.0 - 22.1
	f	= 22.1 - 22.2
	g	= 22.2 - 22.3
K3 040 05	a	f_a = 41.2 - 41.4 kHz
	b	= 41.4 - 41.6
	c	= 41.6 - 41.8
	d	= 41.8 - 42.0
	e	= 42.0 - 42.2

Moreover these transducer assemblies carry the letter N beside the north pole of one of the magnet slabs indicating the polarity of the bias. If a coil around the transducer carries d.c., the field produced by this d.c. must have the same polarity as the permanentmagnet bias.

Maximum permissible amplitude and power

As mentioned above, for an efficient operation the transducers must work at both electrical and mechanical resonance.
From the laboratory experiments it follows, that under continuous operation the amplitude of the longitudinal strain $\Delta l/l$ at the center of a complete double-dumb-bell transducer must not exceed 70.10^{-6} at 22 kHz or 80.10^{-6} at 42 kHz. This means that at the ends of types K5 550 16 and K3 040 00 a maximum excursion amplitude of 2.0 microns is permissible and of types K5 550 21 and K3 040 05 a maximum excursion amplitude of 1.2 microns.

For a given type of transducer and irradiated medium the amplitude depends in fact on two factors, the input power and the mechanical Q-factor of the loaded transducer in question. Assuming the leg cross-section of the transducer to be q times the radiating end surface (usually $q \approx 0.5$) and assuming also an efficient way of operation, sothat the electrical and mechanical power loss in the loaded transducer is but a small fraction of the electrical input power, the acoustic output power intensity I_{ac}, expressed in watts per square meter of the radiating surface, is given by

$$I_{ac} = \eta_{ea} \cdot P_{el}/A = \frac{\pi . q}{4} \cdot (\omega \hat{u})^2 \cdot \frac{\rho . v}{Q_{load}}$$

where η_{ea} = electroacoustic efficiency
P_{el} = total electric input power
A = radiating area
ω = $2\pi f$ = angular frequency in Hz
$\hat{u}$ = excursion amplitude in m
q = ratio leg cross-section / radiating area
ρ = density of FXC 7A2 (approx. 5.10^3 kg/m^3)
v = wave velocity in FXC 7A2 (approx. 5600 m/s)
Q_{load} = mechanical Q-factor of the loaded transducer

Example: If a transducer assembly K3 040 05, with a resonance frequency of 42 kHz, a maximum permissible excursion amplitude of 1.2 microns, a radiating area of 9.0 cm^2 and q = 0.5 is well glued to the bottom of a glass or steel beaker, giving a Q_{load} of approx. 40, the permissible acoustic intensity becomes 2.75 watt per square centimeter of the radiating area or for the whole assembly 9.0x2.9= 25 watt. Assuming η_{ea} = 0.7, the permissible input power is 35 watt.

It will be evident, that for less effective coupled transducers, where Q_{load} is higher than 40, the input power must be reduced proportionally. This is another reason for coupling the transducer as strongly as possible to the medium to be excited. Less coupling not only gives lower electroacoustic efficiency, but also the total input power must be reduced, in order to avoid breakage. Moreover, at low Q_{load} value the influence of slight differences in mechanical short-circuit resonance frequency is less critical for an array of transducers driven by one generator.
The safest way to adapt the input power of the transducer to the permissible mechanical amplitude is, of course, the use of a feedback system as described in a later section.

Supply circuits

Fundamentally, a supply circuit for an ultrasonic piezomagnetic transducer must consist of an oscillator, amplifier, output transformer and a polarising current source. Many variations on this arrangement are possible, and some examples are given below.
Omitting the oscillator stage, Fig. 9 indicates an amplifier output stage with two output valves (e.g. EL 34) in push-pull, in which the h.f. voltage is modulated with 50 Hz.
A 50 Hz current through the transducer coils acts as a bias, so that the ring transducers are energised and magnetised in pulse operation. Since the coupling factor (and thus the electroacoustic efficiency) of the transducer lags behind the biasing current, the power stage obtains the same lag from the choke L 50. The load impedance is given the required real (ohmic) value by means of the parallel capacitors C_{par}.
Two single-loaded ring transducers are shown while irradiating small objects on a conveyor belt passing through the strongly cavitating liquid inside the ring. If, as in the case of these ring transducers a permanent magnet bias is not possible, it may be of advantage to use 50 Hz bias instead of d.c.-bias. A 50 Hz supply is usually more easily available and it has been found empirically, that with 50 Hz modulated ultrasonic waves of 0.5 P_o average power (but 1.33 P_o peak power) gave the same actual results as unmodulated ultrasonic waves of average power P_o.
In Fig.10 a conventional push-pull h.f. power amplifier is indicated, driving two transducer assemblies K3 040 00 with biasing slabs of ferroxdure 250 K, which are cemented to the bottom of the tank with hot-set Araldite.
The impedance of the standard transducers per turn is given in Table I. A

standard assembly K3 040 00 with 30 turns e.g. 15 turns per limb will have an impedance of the order of 10 Ω. Two such assemblies in series, with 20 Ω impedance in total are then driven by e.g. 2 valves EL 34 in push-pull, having an anode impedance of 11 kΩ and a supply voltage of 750 V d.c. In this case a transformer ratio of approx. 24 : 1 is required, which can be realised by a transformer using FXC U-cores. In this circuit a secondary tuning capacitor is not used but an equivalent on the primary side for reasons of price, although this makes adjustment somewhat more difficult.

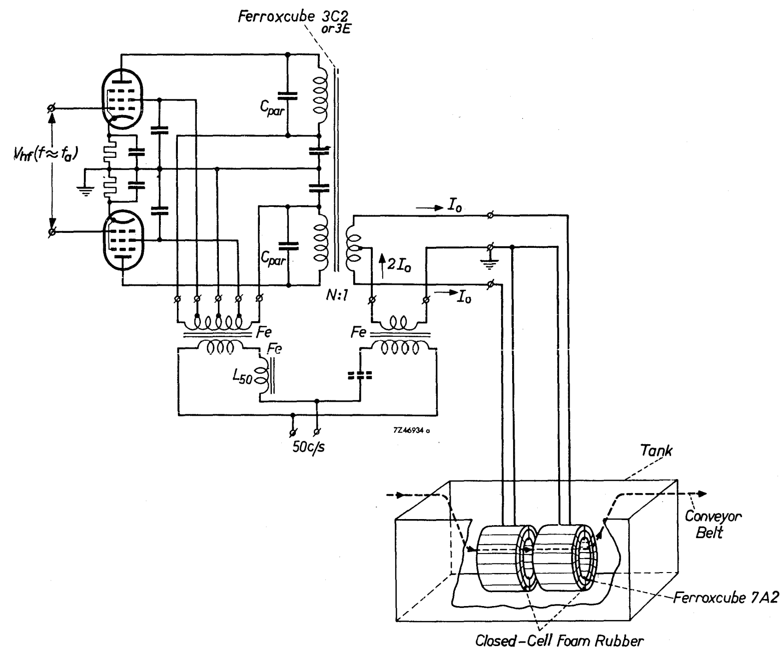


Fig. 9

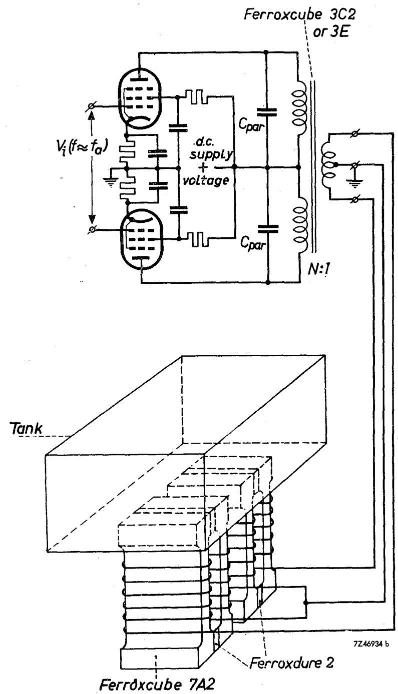


Fig. 10

Amplitude limitation and frequency stabilisation

The acoustic load of a transducer during operation can usually vary within fairly wide limits, both in stationary operation (e.g. by imploding of large cavitation bubbles) and in operation under varying liquid height and varying shape and position of the work pieces.
As already mentioned, this causes considerable changes in excursion amplitude, particularly when two or more transducers are driven by one generator. In extreme cases this may even lead to breakage (as when an underwater signalling device on a ship comes out of the water for a moment by the motion of sea during operation).
For this reason, protection by an immediately working feedback system for limiting the amplitude of the high-Q resonating system is advisable. A simple way to achieve this is the use of one or two piezoelectric feedback plates in PXE 5, a modified lead zirconate titanate.

When cemented to the nonradiating end face or to a side face of the FXC transducer, these give a voltage approximately proportional to the excursion amplitude. This voltage can be fed back negatively to the amplifier thereby serving as a (rectified or non-rectified) automatic amplitude control signal. The amplifier can also be driven by such electronic feedback plates now supplying a positive feedback signal. In this way a self-oscillating system is created, where the operating frequency automatically follows closely the short-circuit mechanical resonance frequency of the transducer under varying loading conditions (see Fig. 11).

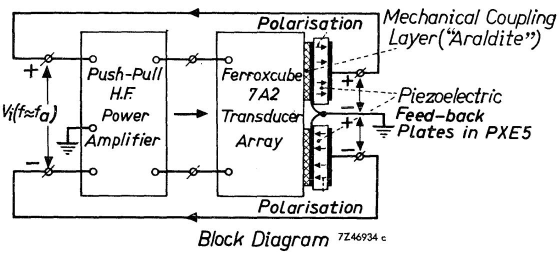


Fig. 11

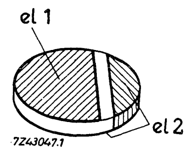
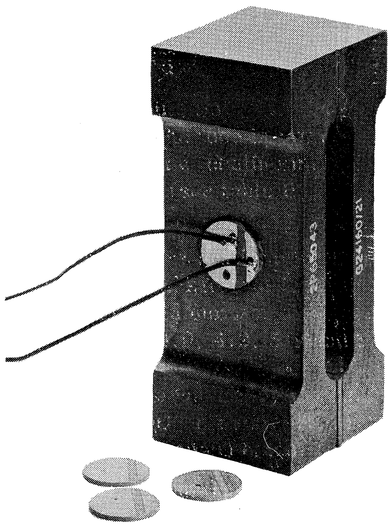


Fig. 12

The discs 2P 61978 or 2P 620 31 can be used as feedback plates.
Both are discs of 16 mm diameter and 1.1 mm thickness made of PXE 5. The discs are provided with two electrodes, one at each side. One of the electrodes is partly extending over the edge of the disc to the other side (see Fig. 12), to permit connection of both leads to one side of the disc, and gluing of the other side of the disc to the transducer (see Fig. 13).
For 2P 61978 the enveloping electrode is a positive pole, for 2P 620 31 it is a negative pole. When two feedback plates are required (push-pull amplifier) one 2P 61978 and one 2P 620 31 should be used.
The leads must be soldered with a silver-saturated solder, in such a way, that the maximum temperature inside the feedback plate does not approach the Curie temperature of PXE 5 (approx. 300 °C).
When glued to the middle of the side face of a 22 kHz double-dumb-bell transducer, the RMS-value of the open-circuit voltage from one feedback plate (in volts) is 7 to 10 times the excursion amplitude of the radiating end face (in microns). For 42 kHz transducers this ratio is 14 to 20.
Apart from this piezoelectric feedback system, where basically a mechanical quantity is fed back, it is also possible to use a purely electric feedback system.*)

*) See among others C.M. van der Burgt and H.S.J. Pijls, IEEE Transactions on Ultrasonics Engineering, volume UE-10, No. 1, 2 - 19, July 1963.



RZ 18105-1

Fig. 13

An example of this is given in Fig. 14 where the transducer is connected in a bridge circuit in such a way, that the open-circuit feedback voltage $(V_{FB})_{open}$ is proportional to

$$uR_3\ h/n$$

where u = excursion of radiating end face
h = magnetostriction constant which for FXC 7A2 is approx. -2.10^7 newton/weber
n = number of turns of the transducer coil

It is required, that the various impedances should be chosen in such a way, that

$$\frac{R_1}{Z_T} = \frac{1}{j\ 2\pi\ f_a\ C_2\ R_3} \quad \text{or}$$

$$j\ 2\pi\ f_a\ R_1\ C_2 = Z_T/R_3$$

$$\text{where } \frac{1}{2\pi\ f_a\ C_2\ R_3} \gg 1$$

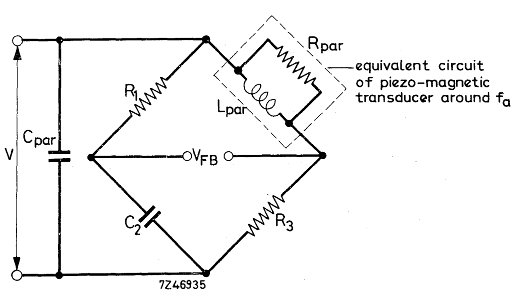


Fig. 14

and Z_T is the total clamped transducer impedance $2\pi f_a L_{par}$ as given in Table I for the standard pieces. Table I also gives the real part R_{par} of the loaded transducer impedance. Preferably R_3 is chosen considerably smaller than R_{par}. C_{par} is the normal parallel capacitor for tuning the transducer at the generator frequency.

For small equipment, where only one or two transducers are used, the piezo-electric feedback is usually the simplest solution. If larger arrays of transducers are involved, a purely electric feedback has the advantage of providing a feedback voltage proportional to the average excursion amplitude without the necessity of providing each transducer with a feedback plate.

For transistorised equipment the whole circuit basically can consist of a transistor amplifier with feedback system, driven directly by the transducers; both oscillator and transformer can be left out. This is only possible with low-impedance magnetostrictive FXC 7A2 transducers.

MOUNTING

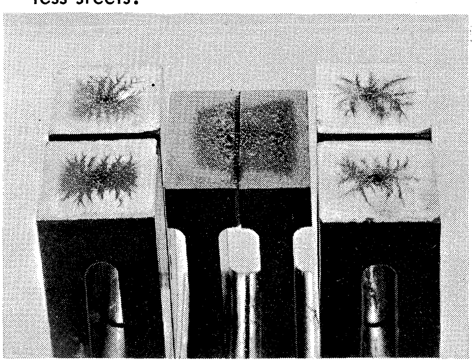
For windows or double dumb-bells with plain end faces, two methods of operation are possible:

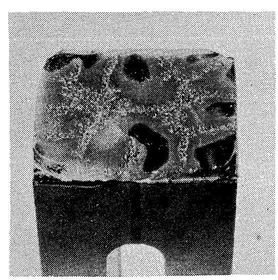
A) Submerged fully or partly in a liquid

B) Operated in air, but mechanically strongly coupled to a solid or liquid load by gluing, clamping or soldering

A) This method has the advantage of good direct contact and good cooling, but excessive erosion of the radiating face may occur. For the ferroxcube this is not too serious. Fig. 15 at the left gives the surface erosion after 1000 hours operation at maximum rating of ferroxcube 7A2. At right is shown a radiating glass face which was part of the bottom of a glass tank filled with water.

The pressure of eroded areas on a radiating surface reduces the efficiency. Only very hard types of stainless steel show minor erosion effects after prolonged operation, beakers and tanks are therefore preferably made of stainless steels.





C 63316A

Fig. 15

C 63316B

It is advisable to avoid glue connections in submerged transducers and to use a ring or window transducer with d.c. or 50 Hz bias. If radiation is wanted in only one direction it is advantageous to surround the remaining sides of the transducer by a fully reflecting material such as foam rubber or foam plastic with closed cells.
If mechanical support is necessary this must be exactly in the middle (in the nodal plane) and preferably with pieces of rubber or another elastic material between. The transducer should never be subjected to steady tensile forces, steady compressive forces to some extent are permissible, but the efficiency decreases when the compression surpasses a certain limit.

B) This method gives no erosion problems for the ferroxcube, only for the glass or steel of the tank. Mechanic clamping is possible, but reduces the coupling factor of the ferroxcube and the efficiency by introducing an additional mechanical damping. On the other hand, the lower mechanical Q and the steady compression permit the use of a higher input power. The best efficiency is obtained by gluing the transducer to the wall or bottom of a cleaning vessel to be filled with liquid, or to the piece of solid material to be brought into vibration.
Here a double-dumb-bell transducer with permanent magnet bias and piezo-electric feedback is usually the best solution (see Fig. 13).
When a ceramic transducer is glued to the bottom of a vessel, the difference in thermal expansion coefficient between the ferroxcube and the vessel material must be accounted for.
Ferroxcube like glass, has a thermal expansion coefficient of 6 to 7.10^{-6} per degree Centigrade. All metals (except titanium) have a considerably higher expansion, e.g. stainless steel approximately 16.10^{-6} and aluminium approximately 23.10^{-6} per degree C. If for example the transducer is cemented to a stainless steel vessel with a very hard hot-setting epoxy resin, the cooling of the assembly after setting may cause such mechanical stress that the transducer breaks at the gluing edge. The best solution in this case is to use a more elastic cement and to reduce the setting temperature. On the other hand, a very elastic glue (e.g. a rubber glue) causes a bad mechanical coupling and reduces the efficiency seriously, so that a suitable compromise must be chosen, dependent on material, temperature etc.

The following are some suitable gluing prescriptions:

1. A cold-setting mixture

33 g Araldite casting resin D
67 g Araldite casting resin F
10 g Hardener 951

} Supplier: CIBA, AG

In humid environment 4.5 g DC 271 paint additive must be added.

setting temperature	time
20 °C	14 - 24 hours
40 °C	5 - 7 hours
70 °C	1 - 3 hours
100 °C	10 - 30 minutes
130 °C	5 - 10 minutes

Suitable for working temperatures up to 80 °C. Above that the output is reduced.

2. A hot-setting mixture

Araldite casting resin F
Hardener 905
Mixing ratio 1 : 1

Supplier: CIBA, AG

setting temperature	time
100 °C	no setting
120 °C	48 hours
140 °C	20 hours
160 °C	5 hours
180 °C	2 hours

Suitable for working temperatures up to 100 °C. Above that the output is reduced.

3. A more elastic glue

Silastic RTV 731 — Supplier: Dow-Corning

This is a silicon rubber glue, supplied in tubes as a white paste. It sets at room temperature by action of humidity from the air, so a very dry environment must be avoided.

A thin layer of paste, approximately 0.5 mm thick, is equally spread over both surfaces, and allowed to dry for 3-4 minutes. Afterwards both surfaces are kept slightly pressed together for 2 hours. The glue connection improves with time, and should not be tested for at least 24 hours. For large non-porous surfaces the moisture must enter by diffusion through the glue layer, which may take several days, but requires no attention. For quick operation, heating at 100 °C for 5 minutes is sufficient. This glue is very elastic and causes some additional damping, but it is very suitable for temperatures above 100 °C, up to approx. 180 °C. An intermediate soft metal (stanniol, aluminum) or glass fabric foil in the glue layer reduces the risk of breakage, but is not absolutely necessary. Before gluing, the metal surfaces must be freed from oxide (e.g. by a sulphuric acid hydrochloric acid mixture, followed by thorough washing and drying). The surfaces of the tank and the transducer must also be degreased, for example with trichloroethylene, again followed by thorough washing and drying.

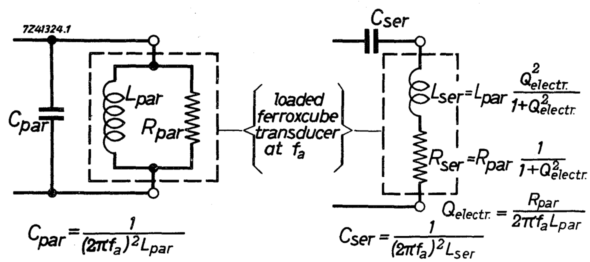

7Z41324.1
C_{par}
L_{par}
R_{par}
loaded ferroxcube transducer at f_a
C_{ser}
$L_{ser} = L_{par} \frac{Q^2_{electr.}}{1+Q^2_{electr.}}$
$R_{ser} = R_{par} \frac{1}{1+Q^2_{electr.}}$
$Q_{electr.} = \frac{R_{par}}{2\pi f_a L_{par}}$
$C_{par} = \frac{1}{(2\pi f_a)^2 L_{par}}$
$C_{ser} = \frac{1}{(2\pi f_a)^2 L_{ser}}$

Fig. 16

Table I. Main properties of the transducers in FXC 7A2

	symbol	ring (Fig. 4)		window (Fig. 5)	
type number		2P 643 87	2P 644 45	K5 550 05	K5 550 11
ampere-turns required for maximum k on vergin magnetisation curve	$(nI_{pol})_{opt}$	230-350	150-240	150-230	100-150
effective piezomagnetic coupling coefficient at optimum bias	$(k_{eff})_{opt}$	0.20-0.24	0.20-0.24	0.19-0.23	0.19-0.23
open-circuit resonance frequency	f_r	20.8-21.4	29.0-29.8	25.0-25.5	40.0-41.0
short-circuit resonance frequency or frequency of maximum efficiency	$f_{max} \approx f_a$	21.4-21.9	29.8-30.5	25.6-26.0	41.0-41.8
mechanical quality factor of free transducer core	$(Q_{mech})_{free}$	>2000	>2000	>2000	>2000
effective mechanical quality factor and equivalent electrical parallel resistance and parallel reactance of single-loaded-submerged[3] transducer at frequency f_{max}	Q_{load}	15-30	25-50	20-45	20-45
	R_{par} [4]	$n^2.0.012$	$n^2.0.015$	$n^2.0.006$	$n^2.0.015$
	$2\pi f_{max} L_{par}$ [4]	$n^2.0.005$	$n^2.0.012$	$n^2.0.009$	$n^2.0.022$
permissible rating of electric HF power of single-loaded submerged[3] transducer and corresponding acoustic intensity at the radiating surface	P	150-180	120-150	40-45	30-35
	J	1.4-1.7	1.6-2.0	3.0-3.5	3.0-3.5
effective mechanical quality factor and equivalent electrical parallel resistance and parallel reactance of transducer cement-coupled to bottom of steel beaker frequency f_{max}[6]	Q_{load} [5]				
	R_{par} [4) 5)]				
	$2\pi f_{max} L_{par}$ [4]				
permissible rating of electric HF power of single-loaded submerged and cement-coupled non-submerged transducers and corresponding acoustic intensity at the radiating surface [7]	P				
	J				

1) The data on the transducers are expressed in terms of the total number of turns n, except those on the multiple-window. They are expressed in terms of the number of turns per individual limb n.
2) These transducers are supplied marked according to groups with narrow tolerance on f_a, see page F12
3) The inside of a ring is the radiating surface, the outer surface is covered by cell-tight foam rubber. Window and multiple-window transducers are placed in water on a sheet of cell-tight foam rubber, their limbs being covered by pressure-release material.
4) For conversion of parallel resistance and reactance into series resistance and reactance see Fig. 16.
5) The mechanical quality factor and the electrical resistance of a cement-coupled non-submerged transducer are highly dependent on the water level and on the geometry and material of the vessel.

multiple window (Fig. 6)	double dumb-bell with d.c. bias 2x (Fig. 7)		glued double dumb-bell with ferroxdure biasing slabs (Fig. 8)		units	remarks
2P 644 56	2x K5 550 16	2x K5 550 21	K3 040 00	K3 040 05		
70-110	150-230	80-130			Amp. turns 1)	
0.18-0.22	0.19-0.23	0.19-0.23	0.17-0.21	0.17-0.21		low-power data for free transducers
22.8-23.3	21.8-22.3	40.9-41.7	21.1-21.8[2]	40.0-40.8[2]	kHz	
23.3-23.7	22.3-22.7	41.8-42.4	21.6-22.3[2]	41.2-42.2[2]	kHz	
>2000	>2000	>2000	>1500	>1500		
20-35	15-35	15-35	15-35	15-35		high-power data for loaded transducers
$n^2.0.07$	$n^2.0.008$	$n^2.0.014$	$n^2.0.015$	$n^2.0.023$	Ω	
$n^2.0.11$	$n^2.0.011$	$n^2.0.021$	$n^2.0.008$	$n^2.0.011$	Ω	
100-120					W (electric)	
2.5-3.0					W/cm^2 (acoustic)	
	20-100	20-100	20-100	20-100		
	$n^2.0.006$	$n^2.0.012$	$n^2.0.011$	$n^2.0.021$	Ω	
	$n^2.0.011$	$n^2.0.021$	$n^2.0.008$	$n^2.0.011$	Ω	
	50-55	30-35	50-55	30-35	W (electric)	
	2.4-2.8	2.7-3.2	2.4-2.8	2.7-3.2	W/cm^2 (acoustic)	

With only one transducer cement-coupled to a small vessel the resistance range may extend from 1/3 to 5/3 times the listed value. Much smaller tolerances, however, can be obtained when arrays of cement-coupled transducers are used (e.g. large tanks).

6) The frequency of maximum efficiency of a cement-coupled transducer is slightly lower than that of the free (or submerged) transducer, because the tank wall represents an additional mass loading. A steel wall of 1 mm thickness usually causes a frequency decrease of 0.3 to 1.0 kHz.

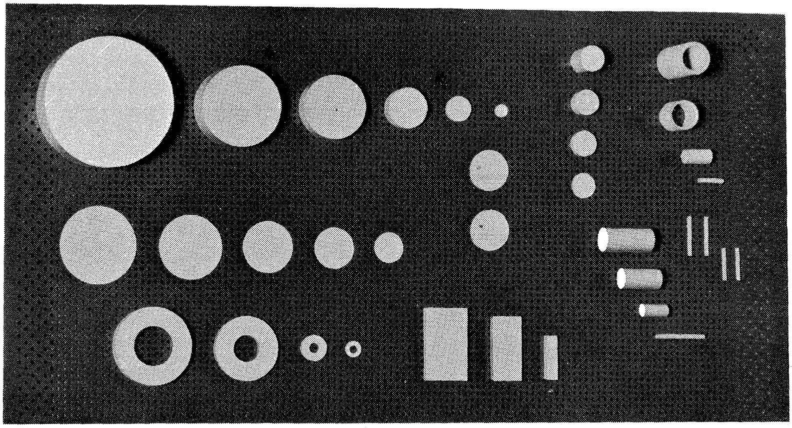
7) These rating values presuppose a Q_{load} not above 100, otherwise they must be reduced proportionally, see page F12.

Table II. Current types of ferroxcube 7A2 transducers and biasing slabs

type number	figure	weight (g)	f_{max} (kHz)	dimensions (mm) A	B	C	D	E	F
TRANSDUCERS									
2P 643 87	4	490	21.7		40 ±0.5	73.5±1.5	92 ±2		
2P 644 45	4	380	30.2		40 ±0.5	49 ±1.5	69 ±1.5		
K5 550 05	5	490	25.8	96 ±1	30 ±1	62 ±1.5	33.2±0.8	9.4+0.8	
K5 550 11	5	210	41.4	58 ±1	30 ±1	35 ±1	24.6±0.8	7.8+0.8	
2P 644 56	6	1100	23.5	98 ±2	20.0±0.1	62 ±1.5	24 ±0.5	10.0±0.2	7+1
K5 550 16	7	320	22.5	96 ±1	40 ±1	62 ±1.5	4.2+1.6	9.8±0.2	
K5 550 21	7	80	42.1	50.4±0.5	30 ±1	32.4±0.6	3.3+0.4	7.0±0.2	
K3 040 00	8	650	22.0	2x K5 550 16 + 2x 2P 667 05 glued together with "Araldite"					
K3 040 05	8	170	41.7	2x K5 550 21 + 2x K6 176 00 glued together with "Araldite"					
BIASING SLABS									
2P 667 05	material: magnetised			40 x 16.6 x 4.0 mm			for use with K5 550 16		
K6 176 00	ferroxdure 250 K			30 x 9.0 x 2.0 mm			for use with K5 550 21		

Piezoxide

INTRODUCTION



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Piezoxide materials are piezoelectric ceramic materials, suitable for almost any electro-mechanical or mechano-electrical energy conversion. Because of their ceramic nature elements in these materials can be preshaped. Their piezoelectric properties are formed during the manufacturing process. This now provides the device designer with a certain freedom of choice for the element shape and its properties for a particular device requirement. A non-polar and unstressed element of these materials has isotropic properties and the crystallographic reference axes may be chosen freely. They exhibit piezoelectricity only when polarised, the direction of polarisation also being chosen freely and made permanent in the process.

MATERIALS AND GRADES

Piezoxide materials are composed of polycrystalline chemical compounds having the general formula ABO_3, where A and B may be cations such as Pb and Zr or Ti; specific examples are the solid solutions of Pb (Ti, Zr) O_3. These materials stem from the family of chemical compounds with perovskite-type structures which have continuous ranges of composition and in which a number of different crystal phases may occur either with ferroelectric or with anti-ferroelectric properties.
Modified forms of these materials are used which may be derived by small atomic disturbances, displacements or substitutions to obtain the permanent ferroelectric phase condition in which the material will be useful for piezoelectric applications.

Physically, piezoxide is a hard non-porous material of a ceramic nature, chemically inert and unaffected by humidity or other atmospheric conditions. It has mechanical properties similar to the more common insulation ceramics, and the manufacturing process resembles the preparation of these although more careful control is exercised in the formation of the electrical properties. Piezoxide is not easily broken but it should be handled with some care.
These materials are, however, extremely "stiff" that is, they are capable of exerting or sustaining very large forces.

A wide range of material properties is required to give complete coverage for all applications. Three grades are available, each having characteristics suitable for particular applications.

PXE 3 - This is a lead zirconate titanate ceramic with a very high shear coupling coefficient, a low dielectric constant and a high voltage sensitivity.
These properties, combined with a good mechanical Q-factor, make PXE 3 extremely suitable for high-frequency shear resonance applications, e.g. ultrasonic delay-line transducers.

PXE 4 - This grade is a modified lead zirconate titanate which has excellent properties for two important fields of application, namely high-power resonance transducers and high-voltage generators for spark ignition of gases.
The high coercive force and the high mechanical Q-factor together with the low amount of dielectric heat dissipation enable PXE 4 to be driven to high strain amplitudes, which are required for e.g. ultrasonic cleaning and sonar.
For high-voltage generation it is important that it can withstand easily repetitive loads of very high quasistatic and dynamic forces.

PXE 5 - This is also a modified lead zirconate titanate. It has a low mechanical Q-factor and a very high coupling coefficient and charge sensitivity.
Therefore this is the ideal grade for all kinds of non-resonance mechano-electrical sensing applications, such as pick-up elements, feedback plates, hydrophones and microphones as well as for low-power electro-mechanical transducer applications. PXE 5 has a better temperature stability than the other grades. The resistivity, even at high temperatures, is extremely large.

PIEZOELECTRIC RELATIONSHIPS

When a voltage V is applied to a thin polarised element between parallel electroded surfaces a distance l apart, the electric field E is equal to the quotient V/l. If these surfaces are held under a constant stress T, the element will undergo a mechanical strain S. Provided that all mechanical changes are kept within the elastic limit of the material, then the general relationships between the elastic and electrical properties are

$$S = s^E T + dE \tag{1}$$

$$D = dT + \epsilon^T E \tag{2}$$

Here D is the dielectric displacement and the constants s^E, d and ϵ^T need to be defined. These may be obtained from a consideration of the boundary conditions of operation for a single element.

If the element is short-circuited, E = 0 and Eq. (2) becomes

$$D = dT \tag{3}$$

For this condition, the dielectric displacement is equal to the dielectric polarisation P, hence

$$D = P = dT \tag{4}$$

This gives a definition of the important constant d, which is defined as the charge density developed per unit applied mechanical stress at constant electric field. The dual definition of d is obtained by considering the element operating in a no-load condition (T = 0) so that Eq. (1) becomes:

$$S = dE \tag{5}$$

Therefore a second definition for the constant d is the mechanical strain produced per unit applied field (piezoelectric strain constant) at constant external stress.

When there is no piezoelectric effect (d = 0) then Eqs. (1) and (2) simplify to the well-known relationships

$$S = s^E T \tag{6}$$

$$D = \epsilon^T E \tag{7}$$

Here s^E is the elastic compliance at constant field strength and ϵ^T is the dielectric permittivity at constant (or zero) stress. Both Eqs. (6) and (7) are valid, if either E or T is zero.

From the above analysis, another important constant can be obtained. When D = 0 (open-circuited element) Eq. (2) becomes

$$E = -\frac{d}{\epsilon^T} T \text{ or, if } \frac{d}{\epsilon^T} = g$$

$$E = -g\,T \tag{8}$$

Thus g, the piezoelectric voltage constant or stress sensitivity constant, is defined as the field developed per unit applied mechanical stress under open circuit conditions.

A second method of defining g is achieved by combining Eqs. (1) and (2) and considering the boundary condition when T = 0. Then

$$S = \frac{d}{\epsilon^T} D = g\,D \tag{9}$$

which gives an alternative definition for g as the strain obtained per unit applied charge density at constant external stress.

All these relationships are true over the range of linear response for either generator or motor applications, and large values for d and g are required for most electro-mechanical and mechano-electrical applications.

PIEZOELECTRIC CONSTANTS d AND g

constant	definition	units (MKS system)
d	$\frac{\text{charge density developed}}{\text{applied mechanical stress}}$	$\frac{\text{coulombs/metre}^2}{\text{newtons/metre}^2}$
	$\frac{\text{strain developed}}{\text{applied field}}$	$\frac{\text{metres/metre}}{\text{volts/metre}}$
g	$\frac{\text{field developed}}{\text{applied mechanical stress}}$	$\frac{\text{volts/metre}}{\text{newtons/metre}^2}$
	$\frac{\text{strain developed}}{\text{applied charge density}}$	$\frac{\text{metres/metre}}{\text{coulombs/metre}^2}$

COUPLING COEFFICIENT

By taking the ratio of the cross products of the coefficients in Eqs. (1) and (2) one obtains:

$$\frac{d^2}{s^E \epsilon^T} = k^2$$

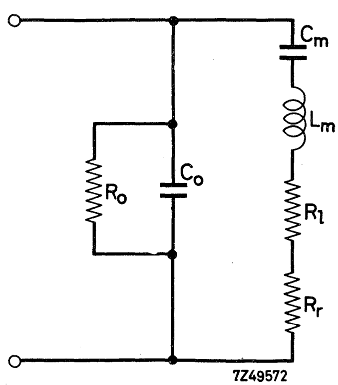
Being introduced like this k can be considered merely as a convenient numerical quantity. It has, however, a basic physical meaning. At frequencies far below the fundamental mechanical resonance frequency k^2 can be expressed as:

$$k^2 = \frac{\text{energy converted}}{\text{input energy}}$$

This formula holds for electro-mechanical and for mechano-electrical energy conversions.

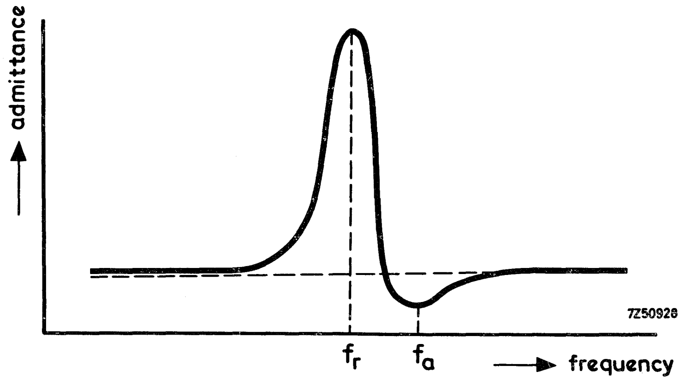
DYNAMIC BEHAVIOUR

A piezoelectric transducer operating near or at the mechanical resonance frequency can be characterised by the following simple equivalent circuit.



C_o = capacitance of the clamped transducer
R_o = dielectric losses of the transducer
R_l represents the mechanical energy losses
R_r represents the radiated energy
C_m and L_m represent the rigidity and the mass of the material

If the electrical admittance of the vibrating transducer is plotted against the frequency, one obtains the following resonance curve.



The frequency f_r, at which the admittance is maximum, is called the resonance frequency. The minimum value of the admittance is found at the anti-resonance frequency f_a.

FREQUENCY CONSTANT

The frequency constant N is the product of the resonance frequency f_r (where the admittance passes through maximum) with the linear dimension h that governs the mechanical resonance. For half wave length resonators one may write $N = f_r\ h$ = half the velocity of sound at constant field intensity.

TECHNICAL DATA

MECHANICAL DATA

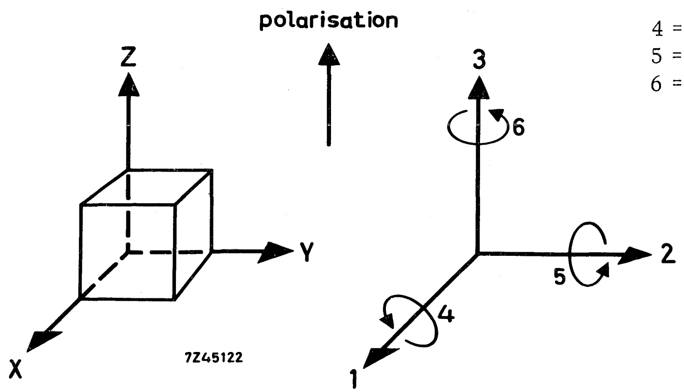
	PXE 3	PXE 4	PXE 5	
Specific mass	7.8×10^3	7.45×10^3	7.65×10^3	kg/m^3
Curie temperature	400	200	280	^oC
Modulus of elasticity $Y^E_{11} = \frac{1}{s^E_{11}}$	0.85×10^{11}	0.77×10^{11}	0.65×10^{11}	N/m^2
$Y^E_{33} = \frac{1}{s^E_{33}}$	0.75×10^{11}	0.79×10^{11}	0.59×10^{11}	N/m^2
Modulus of rigidity $Y^E_{44} = Y^E_{55}$	0.29×10^{11}		0.26×10^{11}	N/m^2
Specific heat	420	420	420	J/kg.deg C
Heat conductivity	1.25	1.25	1.25	W/m.deg C
Compressive strength	2×10^8	2×10^8	2×10^8	N/m^2
ELECTRICAL DATA				
Relative dielectric constants				
$\epsilon^T_{33}/\epsilon_o = \epsilon_r$	570	1500	1750	
$\epsilon^T_{11}/\epsilon_o$	900		1800	
Specific resistance ϱ_{el} at 25 ^oC	$>30 \times 10^{10}$	$>15 \times 10^{10}$	$>100 \times 10^{10}$	Ωm
Time constant $\tau = RC = \varrho_{el} \cdot \epsilon^T_{33}$	>30	>30	>300	min
Dielectric dissipation factor tan δ	0.5×10^{-2}	0.6×10^{-2}	2.0×10^{-2}	
Remanent polarisation P_r	22×10^{-2}	22×10^{-2}	19×10^{-2}	C/m^2
Coercive field E_c	1.6×10^6	1.95×10^6	1.6×10^6	V/m

ELECTRO-MECHANICAL DATA		PXE 3	PXE 4	PXE 5	
Coupling coefficients	k_p	0.48	0.55	0.62	
	k_{31}	0.28	0.32	0.36	
	k_{33}	0.62	0.65	0.70	
	k_{15}	0.70		0.66	
Piezoelectric charge constants					
	d_{31}	-69×10^{-12}	-141×10^{-12}	-178×10^{-12}	C/N
	d_{33}	159×10^{-12}	255×10^{-12}	356×10^{-12}	C/N
	d_{15}	366×10^{-12}		515×10^{-12}	C/N
Piezoelectric voltage constants					
	g_{31}	-13.8×10^{-3}	-9.4×10^{-3}	-11.3×10^{-3}	Vm/N
	g_{33}	33.0×10^{-3}	19.0×10^{-3}	23.2×10^{-3}	Vm/N
	g_{15}	46.0×10^{-3}		32.5×10^{-3}	Vm/N
Quality factor	Q_p	300	500	50	
Frequency constants	N_p	2300	2200	2000	Hz.m
	N_1	1650	1620	1460	Hz.m
	N_3	1550	1610	1390	Hz.m
	N_5	970		930	Hz.m

KEY TO SUBSCRIPTS

For polarised ceramic materials the direction of positive polarisation is usually taken to be that of the Z-axis of a right-hand orthogonal crystallographic axial set X, Y, Z. Since these materials have polar symmetry the senses of X and Y chosen in an element are unimportant and planes parallel to the Z-axis are reflection planes.

If the directions of X, Y and Z are represented as 1, 2 and 3 respectively, and the shear directions to these axes as 4, 5 and 6 respectively then the various related parameters may be written with subscripts referred to these.



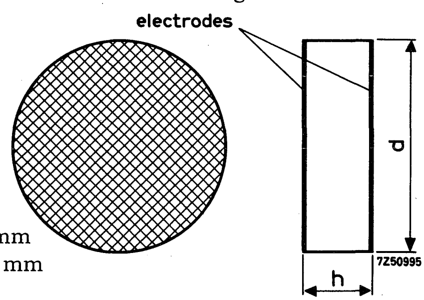
4 = shear in 23-plane
5 = shear in 31-plane
6 = shear in 12-plane

Axial notation

Piezoelectric constants:	The first subscript refers to the direction of the electric field, the second subscript refers to the direction of the strain. (k_p is the planar coupling coefficient.)
Elasticity constants :	The first subscript refers to the direction of the stress, the second subscript refers to the direction of the strain.
Dielectric constants :	The first subscript refers to the direction of the electric field, the second subscript refers to the direction of the dielectric displacement.
Frequency constants :	The subscript refers to the direction of resonance vibration.

TYPE LIST

This survey of types comprises the standard range of shapes and sizes of PXE elements. However, any other shape or size with any tolerance can be supplied within the technical possibilities.
The electrodes normally are silverplated (thickness 0.025 mm). On special request a thicker silver layer can be made, which offers advantages when wires have to be soldered to the electrodes.



DISCS AND CYLINDERS

Direction of polarisation : axial
Standard tolerance
on the diameter (d): ± 2.5%
Standard tolerance on the height (h)
for h ≥ 0.5 mm: ± 0.1 mm
for h < 0.5 mm: ± 0.05 mm

dimensions		catalog number		
d (mm)	h (mm)	PXE 3	PXE 4	PXE 5
3	0.5	8222 293 00250	8222 293 00690	8222 293 01100
3	3	8222 293 00260	8222 293 00700	8222 293 01110
3	8	8222 293 00270	8222 293 00710	8222 293 01120
5	0.2	8222 293 00280	8222 293 00720	8222 293 01130
5	0.3	8222 293 00290	8222 293 00730	8222 293 01140
5	0.5	2P 621 34	2P 621 35	2P 621 36
5	1	2P 621 37	2P 621 38	2P 621 39
5	2	2P 621 40	2P 621 41	2P 621 42
5	4.7	8222 293 00300	8222 293 00740	8222 293 01150
5	7	8222 293 00310	8222 293 00750	8222 293 01160
5	8	8222 293 00320	8222 293 00760	8222 293 01170
5	10	2P 620 87	2P 620 88	2P 620 86
5	12	8222 293 00330	8222 293 00770	8222 293 01180
5	15	8222 293 00340	8222 293 00780	8222 293 01190
6	8	2P 621 80	8222 293 00790	8222 293 01200
6.35 (1/4")	9.5 (3/8")	8222 293 00350	8222 293 00800	8222 293 01210
7	10	8222 293 00360	8222 293 00810	8222 293 01220
7	12	8222 293 00370	8222 293 00820	8222 293 01230
8	13	8222 293 00380	8222 293 00830	8222 293 01240

dimensions		catalog number		
d (mm)	h (mm)	PXE 3	PXE 4	PXE 5
9.5 (3/8")	12.7 (1/2")	8222 293 00390	8222 293 00840	8222 293 01250
9.5 (3/8")	19.05 (3/4")	8222 293 00400	8222 293 00850	8222 293 01260
10	0.2	8222 293 00410	8222 293 00860	8222 293 01270
10	0.3	8222 293 00420	8222 293 00870	8222 293 01280
10	0.5	2P 621 43	2P 621 44	2P 621 45
10	1	2P 621 46	2P 621 47	4322 020 02290
10	2	2P 621 49	2P 621 50	2P 621 51
10	3	8222 293 00430	8222 293 00880	2P 621 77
10	5	8222 293 00440	8222 293 00890	2P 621 74
10	10	2P 621 52	2P 621 53	2P 621 54
10	17	8222 293 00450	8222 293 00900	8222 293 01290
10	20	2P 620 89	2P 621 55	2P 620 77
16	0.2	8222 293 00460	8222 293 00910	8222 293 01300
16	0.3	8222 293 00470	8222 293 00920	8222 293 01310
16	0.5	2P 621 56	2P 621 57	2P 621 58
16	1.1	2P 620 90	2P 620 91	4322 020 02250
16	2	2P 621 59	2P 621 60	2P 621 61
16	3	2P 620 92	2P 620 93	2P 620 76
16	8	8222 293 00480	8222 293 00930	8222 293 01320
16	25	8222 293 00490	8222 293 00940	8222 293 01330
20	0.2	8222 293 00500	8222 293 00950	8222 293 01340
20	0.3	8222 293 00510	8222 293 00960	8222 293 01350
20	0.5	8222 293 00520	8222 293 00970	8222 293 01360
20	1.5	8222 293 00530	8222 293 00980	2P 621 73
20	5	8222 293 00540	8222 293 00990	8222 293 01370
20	10	8222 293 00550	8222 293 01000	8222 293 01380
20	30	8222 293 00560	8222 293 01010	8222 293 01390
20	40			8222 293 01400
25.4	0.5	8222 293 00570	8222 293 01020	8222 293 01410
25.4	1	2P 621 62	2P 621 63	2P 621 64
25.4	2	2P 621 65	2P 621 66	2P 621 67
25.4 (1")	6.35 (1/4")	2P 621 68	2P 620 95	2P 621 69
25.4 (1")	12.7 (1/2")	8222 293 00580	8222 293 01030	8222 293 01420
25.4 (1")	76.2 (3")			2P 620 96
30	1	8222 293 00590	8222 293 01040	2P 621 75
30	6	8222 293 00600	8222 293 01050	8222 293 01430
30	12	8222 293 00610	8222 293 01060	8222 293 01440
30	30	8222 293 00620	8222 293 01070	8222 293 01450
30	75			8222 293 01460
38.1 ($1\frac{1}{2}$")	6.35 (1/4")	8222 293 00630	2P 621 90	8222 293 01470
38.1 ($1\frac{1}{2}$")	12.7 (1/2")	8222 293 00640	8222 293 01080	8222 293 01480

dimensions		catalog number		
d (mm)	h (mm)	PXE 3	PXE 4	PXE 5
38.1 ($1\frac{1}{2}$")	76.2 (3")			8222 293 01490
50	6	8222 293 00650	2P 620 98	2P 620 97
50	12.5	8222 293 00660	2P 620 99	2P 620 72
50	18	8222 293 00670	2P 621 16	2P 620 79
50	30	8222 293 00680	8222 293 01090	8222 293 01500
50	40			8222 293 01510
50	50			8222 293 01520

RINGS AND TUBES

Direction of polarisation : radial

Standard tolerance

on the outer diameter (d_1): ±2.5%

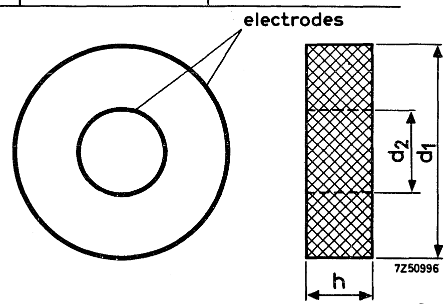
on the inner diameter (d_2): ±2.5%

on the concentricity : 0.1 mm

on the height (h)

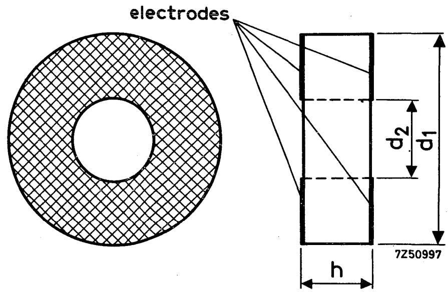
for $h < 20$ mm : ±0.1 mm

for $h \geq 20$ mm : ±0.2 mm



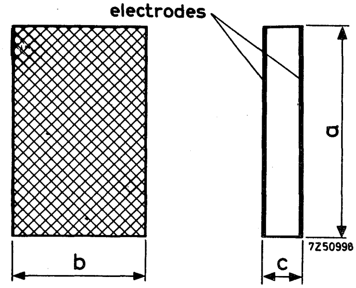
dimensions			catalog number		
d_1 (mm)	d_2 (mm)	h (mm)	PXE 3	PXE 4	PXE 5
3	1	100	8222 293 01530	8222 293 01670	8222 293 01810
5	3.5	50	8222 293 01540	8222 293 01680	8222 293 01820
6.35 ($\frac{1}{4}$")	3.18 (1/8")	3.18 (1/8")	8222 293 01550	8222 293 01690	8222 293 01830
6.35 ($\frac{1}{4}$")	3.18 (1/8")	12.7 ($\frac{1}{2}$")	8222 293 01560	8222 293 01700	8222 293 01840
10	6	6	8222 293 01570	8222 293 01710	8222 293 01850
10	6	10	8222 293 01580	8222 293 01720	8222 293 01860
12	10	10			8222 293 01870
12.7 ($\frac{1}{2}$")	6.35 ($\frac{1}{4}$")	19.05 (3/4")	8222 293 01590	8222 293 01730	8222 293 01880
16	10	10	8222 293 01600	8222 293 01740	8222 293 01890
16	10	16	8222 293 01610	8222 293 01750	8222 293 01900
19.05	7	6.35	8222 293 01620	8222 293 01760	8222 293 01910
25	8	10	8222 293 01630	8222 293 01770	8222 293 01920
25	15	10	8222 293 01640	8222 293 01780	8222 293 01930
35	15	15	8222 293 01650	8222 293 01790	8222 293 01940
50	20	30	8222 293 01660	8222 293 01800	8222 293 01950

Direction of polarisation : axial
Standard tolerance
on the outer diameter (d_1): ± 2.5%
on the inner diameter (d_2): ±2.5%
on the concentricity : 0.1 mm
on the height (h) : ±0.1 mm



dimensions			catalog number		
d_1 (mm)	d_2 (mm)	h (mm)	PXE 3	PXE 4	PXE 5
10	4	6	8222 293 01960	8222 293 02070	8222 293 02150
12.7 ($\frac{1}{2}$")	6.35 ($\frac{1}{4}$")	19.05 (3/4")	8222 293 02000	8222 293 02110	8222 293 02190
12.7 ($\frac{1}{2}$")	3.18 (1/8")	3.18 (1/8")	8222 293 01980	8222 293 02090	8222 293 02170
14	4	1.1	8222 293 01970	8222 293 02080	8222 293 02160
19.05	7	6.35	8222 293 01990	8222 293 02100	8222 293 02180
25	8	10	8222 293 02010	8222 293 02120	8222 293 02200
30	15	5.3	8222 293 02020	2P 621 01	2P 621 00
35	15	15	8222 293 02030	8222 293 02130	8222 293 02210
38.1 (1$\frac{1}{2}$")	12.7 ($\frac{1}{2}$")	6.35 ($\frac{1}{4}$")	8222 293 02040	2P 621 91	8222 293 02220
45	12	10	8222 293 02050	8222 293 02140	8222 293 02230
50	10.2	6	8222 293 02060	2P 621 06	2P 621 05

RECTANGULAR PLATES



Direction of polarisation : parallel to dimension c

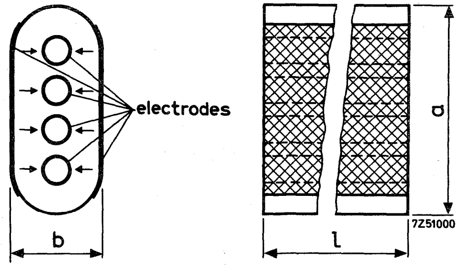
Standard tolerance
on the length (a) : ±0.1 mm
on the width (b) : ±0.1 mm
on the thickness (c)
for c ≥ 0.5 mm : ±0.1 mm
for c < 0.5 mm : ±0.05 mm

dimensions			catalog number		
a (mm)	b (mm)	c (mm)	PXE 3	PXE 4	PXE 5
6	2	0.25	8222 293 02240	8222 293 02470	8222 293 02700
7	7	0.2	8222 293 02250	8222 293 02480	8222 293 02710
10	2	0.3	8222 293 02260	8222 293 02490	8222 293 02720
10	2	0.5	8222 293 02270	8222 293 02500	8222 293 02730
12	6	0.2	8222 293 02280	8222 293 02510	8222 293 02740
12	6	0.3	8222 293 02290	8222 293 02520	8222 293 02750
12	6	0.5	8222 293 02300	8222 293 02530	8222 293 02760
12	6	1	8222 293 02310	8222 293 02540	8222 293 02770
16	12	0.5	8222 293 02320	8222 293 02550	8222 293 02780
16	12	1	8222 293 02330	8222 293 02560	8222 293 00030
20	4	0.3	8222 293 02340	8222 293 02570	8222 293 02790
20	4	0.5	8222 293 02350	8222 293 02580	8222 293 02800
25	3	0.3	8222 293 02360	8222 293 02590	8222 293 02810
25	3	0.5	8222 293 02370	8222 293 02600	8222 293 02820
25	5	1	8222 293 02380	8222 293 02610	8222 293 02830
25	10	2	8222 293 02390	8222 293 02620	8222 293 02840
25	15	1	8222 293 02400	8222 293 02630	8222 293 02850
25	15	2	8222 293 02410	8222 293 02640	8222 293 02860
30	5	0.3	8222 293 02420	8222 293 02650	8222 293 02870
30	5	0.5	8222 293 02430	8222 293 02660	8222 293 02880
30	5	1	8222 293 02440	8222 293 02670	8222 293 02890
30	10	1	8222 293 02450	8222 293 02680	8222 293 02900
30	10	1.5	8222 293 02460	8222 293 02690	8222 293 02910

MULTIMORPH STRIPS

Direction of
polarisation: indicated by arrows, see figure (outer electrodes negative)

Material : PXE 5

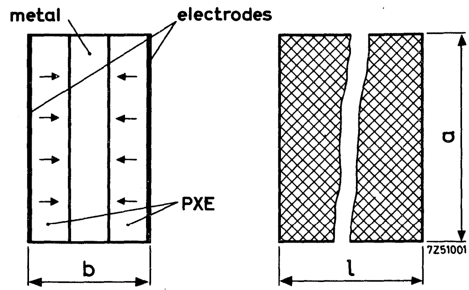


dimensions			catalog number
a (mm)	b (mm)	l (mm)	
1.6	0.67	12.7	4322 020 02480
1.6	0.67	15.5	4322 020 02490
1.6	0.67	30	8222 293 02920
1.6	0.67	45	8222 293 02930
1.6	0.67	70	8222 293 02940
4	1	30	8222 293 02950
4	1	45	8222 293 02960
4	1	70	8222 293 02970
2.4	0.9	30	8222 293 02980
2.4	0.9	45	8222 293 02990
2.4	0.9	70	8222 293 03000

Complete electrical and mechanical specification is delivered on request.

BIMORPH STRIPS

Direction of
polarisation: indicated by arrows, see figure (outer electrodes negative)
Material : PXE 5



dimensions			catalog number
a (mm)	b (mm)	l (mm)	
1.27	0.48	8.9	8222 293 03010
1.60	0.62	12.7	8222 293 03020
2.20	0.62	14.0	8222 293 03030

Complete electrical and mechanical specification is delivered on request.

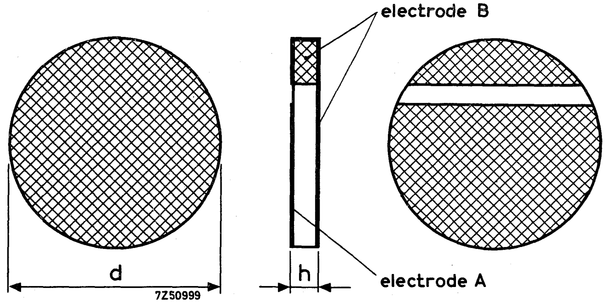
Direction of polarisation: opposite to the direction given in the figure above (outer electrodes positive)
Material : PXE 5

dimensions			catalog number
a (mm)	b (mm)	l (mm)	
2.20	0.62	14.0	8222 293 03040

Complete electrical and mechanical specification is delivered on request.

FEEDBACK PLATES

Direction of polarisation : axial
Material : PXE 5

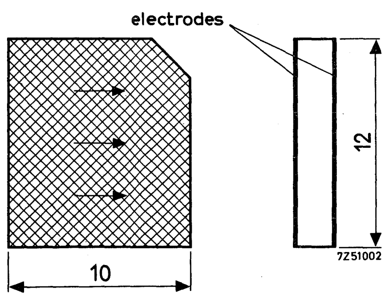


dimensions		polarity of electrode A	catalog number
d (mm)	h (mm)		
16	1.1	–	4322 020 02260
16	1.1	+	4322 020 02270

Complete electrical and mechanical specification is delivered on request.

DELAY-LINE TRANSDUCERS

Direction of polarisation: indicated by arrows, see figure
Material : PXE 3
Frequency of the thickness shear vibration : approx. 4 MHz
Catalog number : 4322 040 00600



Complete electrical and mechanical specification is delivered on request.

APPLICATION POSSIBILITIES

Modern piezoelectric ceramics are of continually increasing importance to device and equipment designers throughout industry.
They may be used where mechanical energy is required to be transformed into electrical energy, or they may be used where electrical energy is available to be transformed into mechanical energy. Such transformations being produced within single solid-state elements offer a wide field of application, which can be divided into five groups.

a. High-voltage generators:
- ignition of pilot lights in gas heaters
- cigarette lighters
- ignition of fuses in artillery ammunition.

b. High-power transducers:
- ultrasonic cleaning and degreasing
- ultrasonic plastic and metal welding
- ultrasonic machining, e.g. drilling
- sonar transducers
- ultrasonic humidifier.

c. Low-power transducers:
- non-destructive testing
- puls-echo technics for medical diagnosis and therapy
- sonar hydrophone
- acoustic delay-line transducers.

d. Flexure systems:
- gramophone pick-up cartridges
- fine-movement control
- piezoelectric bell
- ultrasonic sensing in air
- microphones
- telecommanding receivers.

e. Miscellaneous
- Intermediate-frequency ceramic filters
- liquid-level tester
- feedback plates
- accelerometers
- strain gauges.

Insulating and dielectric materials

INSULATING AND DIELECTRIC MATERIALS

These materials are manufactured from white ceramics and intended for use in the electrotechnical and electronic industry.
The insulating materials are suitable for all kinds of insulating parts for low and high tension at low or high frequencies and at high temperatures, e.g. switches, tube sockets, envelopes of transmitting tubes or semiconductors, lead-through insulators, etc.
The dielectric materials are mainly used for capacitors.

For the shaping of ceramic piece parts different methods are used:

a. extrusion: the method generally used for parts which have a uniform cross-section in one direction.
b. dry pressing: in this case a slightly moistened mass is used.
c. casting or rolling: this method is used for the manufacture of thin sheets.

More complicated parts can be made by machining (e.g. drilling or turning) pressed or pre-sintered parts. For each design it is recommended to contact the manufacturer because a slight change in the shape of the part required often results in a form which is better suited for mass production.
Sintered products can be finished only by grinding.

When desired, non-porous materials can be glazed, silvered or siliconized (made water-repellent). By this latter treatment the surface resistance increases.

INSULATING MATERIALS

Below is given a description of the 9 most inportant insulating materials which can be obtained from our ceramic works.
Quantitative data are given in table I.

K512 (steatite). Composition: mainly $MgO.SiO_2$.
This material can be used as a construction material for low- and high tension insulators. It is suitable for high frequencies. It has a high mechanical strength. Application examples: wire wound resistors, tube sockets.

K758 Composition: mainly $MgO.SiO_2$.
Moderate mechanical but good electrical properties. Suitable for applications in vacuum. Easy to machine. Application example: construction material in electron tubes.

K617 (Alkaline earth porcelain). Composition: mainly $3Al_2O_3.2SiO_2$.
For applications where h.f. losses cause no problem. At elevated temperatures very good insulating properties.
Application example: deposited carbon- and metal film resistors.

K756 (forsterite). Composition: mainly 2 $MgO.SiO_2$.
Good mechanical properties. High thermal expansion coefficient, which is a drawback for applications with large temperature variations. It is gastight and suitable for metal-to-ceramic connections.

K751 Composition: 90% Al_2O_3.
Insulating and construction material with fairly good mechanical and electrical properties.
Application example: insulators for thermo-couples.

K099 Composition: more than 97.5% Al_2O_3.
Resistant to chemical influences. Can be used at high temperatures.

K748 Composition: more than 99% Al_2O_3.
This insulating material can be used as a construction material and is suitable for use in vacuum. At very high temperature it still has good insulation properties.
Application example: insulation between cathode and filament.

V003 Composition: 94 to 96% Al_2O_3.
Very good insulating material with high mechanical quality. Resistant to nitric acid. The material is also wear-resistant, gastight and suited for metal-to-ceramic connections.
Application examples: envelopes of transmitting tubes and semiconductors, substrates for integrated circuits.

K1134 (D.G.A). Composition: more than 99.9% Al_2O_3.
Gastight and translucent. It has very good mechanical strength; therefore it is very well suited for envelopes of high pressure gas discharge devices. Resitant to alkaline vapor.

DIELECTRIC MATERIALS

Originally ceramic capacitors were used for small capacitances only. But the modern ceramics, which are in general on the base of modified alkaline earth metal titanates, present the possibility of making capacitors with very high capacitances which meet the requirements for many purposes.

A range of ceramic dielectrics with ϵ - values from 6 up to 10.000 is available. Properties are given in table II. As a rule these ceramics are supplied in a tubular shape, but also discs and thin sheets are made on order.
As a consequence of the mechanised manufacturing process the products are very homogeneous as to composition and density. Their surface is smooth and free from holes, blisters and stains, so that an extra finish by grinding is unnecessary and even undesirable.

The capacitance of a tubular capacitor is calculated from the formula:

$$C = \frac{0.0241\ l\,\epsilon}{\log\frac{D}{d}}\quad 10^{-6}\ \mu F. \ \text{---}\ (1),$$

Where: l = length of the tube in mm.
D = outer diameter of the tube in mm.
d = inner diameter of the tube in mm.
ϵ = dielectric constant (see table II).

Ceramic tubes for capacitors are available with outer diameters of 1.8, 2.2, 3.0 4.2, 5.9 and 8.4 mm each with different inner diameters.
A constant ratio can be found in our range of ceramic tubes for capacitors with outer diameters of 1.8, 2.2, 3.0, 4.2, 5.9 and 8.4 mm each with different inner diameters.
They are delivered in lengths which may vary between 120 and 180 mm or cut into pieces of any desired length. A maximum total length of 2000 m can be manufactured from a single homogeneous batch.

The break-down voltage of a tubular capacitor is:

$$E = 1.15\ F\ \ d \log\frac{D}{d}\quad kV \ \text{--}\ (2)$$

where F is the break-down field strength in kV_{rms}/mm measured at 25 ^{o}C and 50 Hz (see table II).

In contrast with the capacitance, the break-down field strength varies with the wall thickness of the tube (if D/d is constant).

Ceramic sheets should preferably be ordered in the following materials only

V103 with ϵ = 7
K521 with ϵ = 18
K493 with ϵ = 40
K507 with ϵ = 90
K508 with ϵ = 2200
K520 with ϵ = 10.000

Sheet thicknesses between 0.11 and 0.47 mm are available.

All further information on white ceramic materials will be gladly sent on request.

TABLE I. SURVEY OF INSULATING MATERIALS

PROPERTIES	UNITS	K512	K758	K617	K756	K751	K099	K748	V003	K1134
Loss factor tan δ (20 °C, 1 MHz)	$\times 10^{-3}$	< 2	< 1	< 2.5	< 0.4	-	-	< 0.5	< 0.5	< 0.5
Dielectric constant ϵ (20°C, 1 MHz)		6.5	4.5	5.5	6.5	-	-	8.5	9.5	9.5
Break down field str. (20 °C, 50 Hz)	kV_{rms}/mm	> 15	4	> 15	> 15	-	-	4	> 15	> 15
Volume resistivity:										
at 20 °C	Ω cm	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	-
at 200 °C	Ω cm	$> 10^{12}$	$> 10^{9}$	$> 10^{12}$	$> 10^{14}$	$> 10^{9}$	$> 10^{12}$	$> 10^{12}$	$> 10^{13}$	-
at 500 °C	Ω cm	$> 10^{7}$	$> 10^{5}$	$> 10^{7}$	$> 10^{9}$	-	$> 10^{8}$	$> 10^{8}$	$> 10^{8}$	-
Compressive strength	N/mm^2	> 900	> 150	450	> 600	> 80	-	> 700	> 2000	> 2000
Tensile strength	N/mm^2	> 45	-	30	> 50	-	-	-	> 150	> 150
Flexural strength	N/mm^2	> 120	> 40	90	> 100	> 70	> 40	> 100	> 250	> 250
Hardness	Mhos scale	7 - 8		7	7 - 8				9	
Young's modulus	N/mm^2	1.3×10^5	0.7×10^5		2×10^5				3.4×10^5	4×10^5
Max. working temp.	°C	1100	1100	1100	1200	1200	1500	1700	1400	1700
Linear coeff. of thermal expansion (from 20° - 700 °C)	$\times 10^{-6}$/deg C	8	8	8	9-11	8	8	8	6 - 8	7
Heat conductivity	$\times 10^{-3}$ cal/cm.sec.deg C	5.6	4	3	15	-	-	-	60	70
Resistance to thermal shocks		moderate	good	moderate	bad	good	good	good	good	excellent
Specific gravity	g/cm^3	2.7	2.5	2.5	2.8	2.4	2.3	3.2	3.4	3.98
Water absorption	%	0	10-30	0	0	10-30	10-30	10-30	0	0
Porosity		0		0	0				0	0
Colour		cream white	cream	white	white	off white	white	white	white	translu-cent

TABLE II. SURVEY OF DIELECTRIC MATERIALS

PROPERTIES	UNIT	K041	K817	K818	K833	K521	K503	K493	K820	K821	K822	K823	K505	K825	K826
Dielectric constant ϵ		7 ±10%	16 ±10%	16 ±10%	18 ±10%	18 ±10%	38 ±10%	40 ±10%	40 ±10%	40 ±10%	42 ±10%	45 ±10%	45 ±10%	50 ±10%	54 ±10%
Ageing of ϵ	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Max. spread of capacitance per mm tube length	%	5	5	5	5	6	5	5	5	5	5	5	5	5	5
Temp. coefficient of ϵ	10^{-6}/deg C	+80 - +160	+40 - +120	on request	on request	+10 - −40	−660 - −870	+10 - −40	on request	on request	on request	on request	−140 - −190	on request	on request
Loss factor tan δ	10^{-4}														
20 °C		≤20	≤5	≤3	≤3	≤5	≤5	≤5	≤4	≤4	≤4	≤4	≤5	≤4	≤4
85 °C			≤10	≤6	≤6		≤10	≤10	≤7	≤7	≤7	≤7	≤10	≤7	≤7
Breakdown field strength F_d at 50 Hz 25 °C	kV_{rms}/mm	≥15	≥10	≥10	≥10	≥10	≥7	≥7	≥7	≥7	≥7	≥7	≥7	≥7	≥7
Max. permissible working field strength F_b	kV_{dc}/mm	3	2.5	2.5	2.5	2.5	2	2	2	2	2	2	2	2	2
Min. volume resistivity	Ωm	10^{12}	10^{11}	10^{11}	10^{11}	10^{12}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}
Specific gravity	g/cm³	3.1	3.5	3.5	4.2	3.6	3.6	4.5	4.3	4.3	4.3	4.3	4.4	4.4	4.4
Flexural strength	N/mm²	≥120	≥100	≥100	≥100	≥120	≥80	≥80	≥80	≥80	≥80	≥80	≥80	≥80	≥80
Linear coeff. of thermal expansion 30 - 200 °C	10^{-6}/deg C	7.7				9.0	9.3	9.3					9.1		

PROPERTIES	UNIT	K500	K827	K507	K830	K516	K517	K569	K511	K508	K832	K519	K510	K520
Dielectric constant ϵ		54 ±10%	65 ±10%	90 ±10%	120 ±10%	250 ±15%	650 ±15%	≥1760	1700 ±20%	2200 ±20%	2200 ±20%	2500 ±20%	4200 ±20%	10000 ±20%
Ageing of ϵ	%	-	-	-	-	+1.5	+4.5	+1.5	+6	+1.5	+1.5	+5	+6	-
Max. spread of capacitance per mm tube length	%	5	5	5	5	10	10		10	10	10	10	10	
Temp. coefficient of ϵ	10^{-6}/deg C	on request	on request	-660 - -870	on request	on request	on request	on request	on request	on request	on request	on request	on request	on request
Loss factor tan δ	10^{-4}													
20 °C		≤4	≤4	≤5	≤5	≤25	≤75	≤250	≤100	≤250	≤300	≤250	≤200	≤250
85 °C		≤7	≤7	≤10	≤10									
Breakdown field strength F_d at 50 Hz 25 °C	kV_{rms}/mm	≥7	≥7	≥7	≥6	≥4.5	≥3	≥3.5	≥2.5	≥3.5	≥3.5	≥2.5	≥5	≥1.5
Max. permissible working field strength F_b	kV_{dc}/mm	2	2	2	1	1	1.5	2	1.5	2	2	1.5	1.5	0.8
Min. volume resistivity	Ωm	10^{11}	10^{11}	10^{11}	10^{11}	10^{10}	10^{10}	10^{10}	10^{10}	10^{10}	10^{10}	$5x10^9$	10^{10}	10^9
Specific gravity	g/cm^3	4.4	4.2	4.1	3.6	4.3	4.5	5.85	4.9	5.85	5.85		5.5	5.6
Flexural strength	N/mm^2	≥80	≥80	≥120	≥80	≥90	≥70	≥70	≥80	≥70			≥70	
Linear coeff. of thermal expansion 30 - 200 °C	10^{-6}/deg C			8.0		10.2	9.9	9.1	9.5	9.1			8.8	

Permanent magnet materials

Cast alloys

RECO
"TICONAL"

Sintered ceramic materials

Plastic ceramic materials

FERROXDURE

Contents

FOREWORD

The place of permanent magnets in modern life is so evident that their importance cannot be overlooked. Every home contains at least a few of these devices, and it is hard to imagine present day technology without the aid of the modern permanent magnet. Examples are found in

Communication,
Power distribution,
Timing devices,
Vehicles,
Traffic control etc.

Modern permanent magnets are available in cast alloys ranging in size from large castings to tiny cubes, and available also in ceramic material in any geometric form.

The excellent properties of the modern materials allow permanent magnets to be made with very small dimensions and exceptional stability. They are ideal for use in

electrotechnical and
mechanical equipment and for
applied physics.

In these applications, permanent magnets offer considerable economic advantages over electrically energised systems, not only in initial outlay but also during operation because power supplies - with their attendant costs and complications - are eliminated.

INTRODUCTION

Permanent magnets - either isotropic* or anisotropic* - can be classified as being basically either

metallic alloy
ceramic material or
plastic bonded ceramic material

The table shows the class to which each of our materials belongs.

	metallic alloy	ceramic material	plastic bonded ceramic material
isotropic *	reco	ferroxdure	ferroxdure
anisotropic *	"Ticonal" **	ferroxdure	-

The most obvious differences between the groups are that the ferroxdure magnets are characterised by exceptionally high values of coercive force and resistivity while "Ticonal" magnets possess higher values of remanent magnetism and energy product.

Ferroxdure is therefore most suitable for applications in which demagnetising influences (either from external sources or resulting from the use of short magnets) are large and also in high frequency applications.

"Ticonal" is particularly suitable for applications in which high values of magnetic energy are required from small volumes of magnetic material.

The isotropic materials in general are inferior in magnetic properties to the anisotropic ones but are particularly suitable for applications in which multipolar magnets are to be used or where less expensive magnets are necessary giving a reasonable performance.

The plastic bonded ferroxdure magnets combine the characteristic magnetic properties of isotropic ferroxdure (however on a lower level) with the mechanical properties of the plastic material used. These magnets open a new field of applications, especially where the price is of prime importance.

Each of the permanent magnet materials is manufactured in a variety of grades possessing different properties that result from differences in composition and treatment.

The grades are distinguished by the addition of numbers to the name of the material. The numbers are approximately relative to the nominal energy product of the grade.

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* Isotropic materials can be magnetised equally well in any direction. Anisotropic materials have optimal magnetic properties in one direction only.

** "Ticonal" is a registered trade name.

SURVEY OF PERMANENT MAGNET MATERIALS

MAIN MAGNETIC PROPERTIES

The survey on the following pages shows data on some of the principal magnetic properties for the complete range of permanent magnet materials.

Demagnetising curves are given after the tables.

The meaning of the survey is to facilitate the selection of the permanent magnet materials for the proper use. The designer can focus his interest for permanent magnets on materials yielding :

a. high performance magnets with either
   1) high values of coercivity (H_{cb}) and intrinsic coersive field strength (H_{ci}).

or

   2) high values of remanence (B_r)

or on

b. cheaper magnets.

The typical magnetic values are indicated for good comparison of the different grades, while the minimum values quoted are guaranteed for test pieces or for minimum-flux standard magnets only.

Notes

The minimum values of B_r and H_{cb} never occur simultaneously. Generally the minimum value of B_r will coincide with a value of H_{cb} well above the quoted average, whereas the minimum value of H_{cb} is coupled with a high value of B_r.

(M) stands for Pb, Sr or Ba etc.

permanent magnet material typical chemical composition	max. energy product (BH)max. in megagaussoersteds		occurs at		remanence B_r in gausses		coercivity H_{cb} in oersteds		intrinsic coercive field strength H_{ci} in oersteds	
	min.	typ.	B_d gausses	H_d oersteds	min.	typ.	min.	typ.	min.	typ.
ISOTROPIC PLASTIC-BONDED FERROXDURE Ferroxdure P30, P40 and SP50 magnets are extruded, injection moulded and punched, D55 magnets are pressed and machined.										
Ferroxdure P30 KPN-K-992 85% ferroxdure powder $(M)Fe_{12}O_{19}$ 15% thermoplastic material	0.3	0.35	700	500	1150	1250	1050	1100	2500	2700
Ferroxdure P40 KPN-K-989 90% ferroxdure powder $(M)Fe_{12}O_{19}$ 10% thermoplastic material	0.4	0.45	800	550	1350	1450	1150	1200	2300	2500
Ferroxdure SP50 KPN-K-7028 93% ferroxdure powder $(M)Fe_{12}O_{19}$ 7% thermoplastic material	0.5	0.55	800	690	1550	1600	1225	1275	2300	2400
Ferroxdure D55 KPN-V-815 95% ferroxdure powder $(M)Fe_{12}O_{19}$ 5% thermosetting material	0.55	0.60	850	700	1650	1700	1300	1400	2500	2750

permanent magnet material typical chemical composition	max. energy product (BH)max. in megagaussoersteds		occurs at		remanence B_r in gausses		coercivity H_{cb} in oersteds		intrinsic coercive field strength H_{ci} in oersteds	
	min.	typ.	B_d gausses	H_d oersteds	min.	typ.	min.	typ.	min.	typ.
ISOTROPIC FERROXDURE All magnets are pressed, sintered and ground.										
Ferroxdure 100 KPN-K-359 100% ferroxdure powder $(M)Fe_{12}O_{19}$	0.9	0.95	1200	800	2100	2200	1600	1650	2600	2700
ISOTROPIC ALLOYS-RECO All magnets are cast and can be ground only.										
Reco 100 24% Ni, 14% Al, bal. Fe	1.00	1.20	4000	300	5800	6200	460	480	480	530
Reco 120 1% Ti, 4% Co, 26% Ni, 13% Al, 3% Cu, bal. Fe	1.10	1.30	3100	400	5300	5900	500	600	550	650
Reco 140 0.8% Ti, 5% Co, 25% Ni, 10% Al, 7% Cu, bal. Fe	1.30	1.40	3500	400	6200	6500	530	565	550	600
Reco 160 1.9% Ti, 13% Co, 18.5% Ni, 10% Al, 7.5% Cu, bal. Fe	1.50	1.65	4150	400	6000	6600	600	680	650	750
Reco 170 5% Ti, 10% Co, 24% Ni, 9.5% Al, 6% Cu, bal. Fe	1.50	1.65	3300	500	5200	5600	830	890	900	1000
Reco 220 7% Ti, 26% Co, 15% Ni, 7% Al, 5% Cu, bal. Fe	2.00	2.30	3750	600	5600	6300	1100	1200	1200	1300

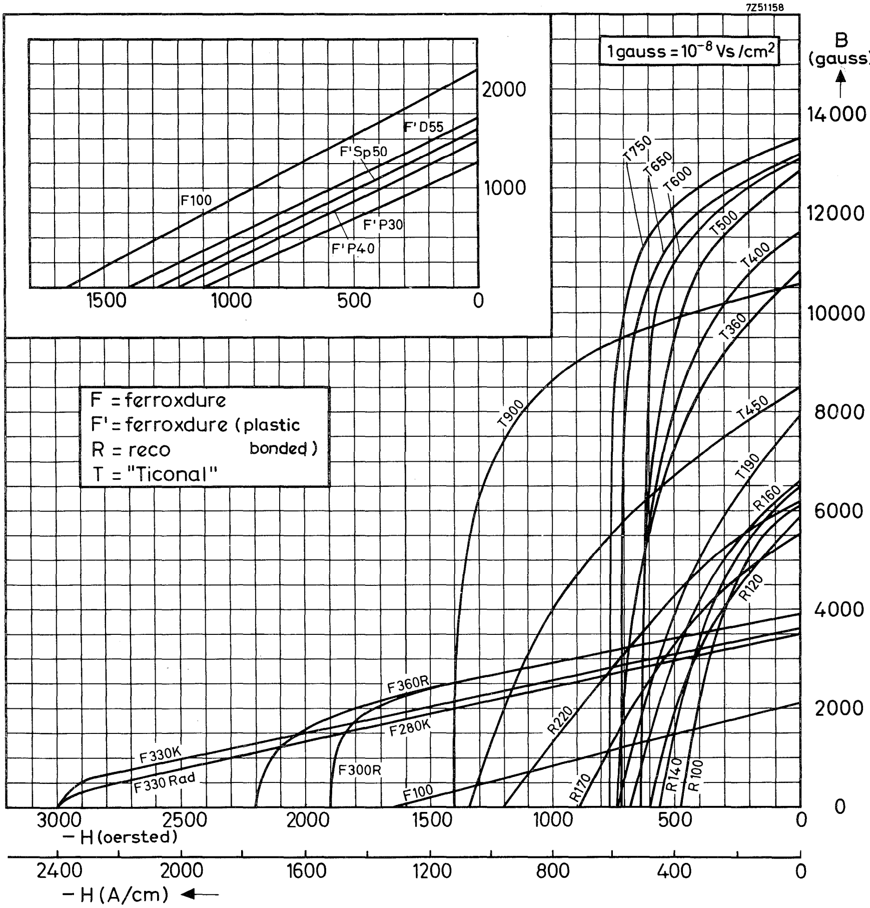
permanent magnet material typical chemical composition	max. energy product (BH)max. in megagaussoersteds		occurs at		remanence B_r in gausses		coercivity H_{cb} in oersteds		intrinsic coercive field strength H_{ci} in oersteds	
	min.	typ.	B_d gausses	H_d oersteds	min.	typ.	min.	typ.	min.	typ.
ANISOTROPIC FERROXDURE All magnets are pressed, sintered and can be ground only.										
Ferroxdure 280K KBN-K-435 100% ferroxdure powder $(M)Fe_{12}O_{19}$	2.60	2.80	1800	1600	3400	3550	2800	3000	3000	2700
Ferroxdure 300R KBN-K-434 100% ferroxdure powder $(M)Fe_{12}O_{19}$	3.10	3.30	2000	1650	3800	3900	1600	1900	1700	2000
Ferroxdure 330 (Rad) KBN- 100% ferroxdure powder $(M)Fe_{12}O_{19}$	2.7	2.9	1800	1600	3400	3500	2800	3000	3000	-
Ferroxdure 330K KBN-V-252 100% ferroxdure powder $(M)Fe_{12}O_{19}$	3.20	3.40	1900	1700	3600	3700	2800	3000	2900	3300
Ferroxdure 360R KBN-V-254 100% ferroxdure powder $(M)Fe_{12}O_{19}$	3.40	3.60	2000	1800	3800	3900	2000	2200	2100	2400

permanent magnet material typical chemical composition	max. energy product (BH)max. in megagaussoersteds		occurs at		remanence B_r in gausses		coercivity H_{cb} in oersteds		intrinsic coercive field strength H_{ci} in oersteds	
	min.	typ.	B_d gausses	H_d oersteds	min.	typ.	min.	typ.	min.	typ.
ANISOTROPIC ALLOYS - TICONAL All magnets are cast and can be ground only.										
Ticonal 190 14% Co, 21% Ni, Al, 3% Cu, balance Fe	1.80	2.10	5000	400	7400	8000	650	730	670	800
Ticonal 360 1.5% Ti, 24% Co, 15% Ni, 8.5% Al, 3% Cu, bal. Fe	3.20	3.60	7200	500	10500	10700	680	710	700	760
Ticonal 400 0.8% Ti, 24% Co, 14% Ni, 8.5% Al, 3% Cu, bal. Fe	3.80	4.00	8000	500	11200	11600	610	640	620	680
Ticonal 450 5% Ti, 34% Co, 14.5% Ni, 7.5% Al, 4.5% Cu, bal. Fe	4.00	4.25	5300	800	8000	8500	1200	1335	1300	1500
Ticonal 500 24% Co, 14% Ni, 8.5% Al, 3% Cu, balance Fe	4.50	4.80	9600	500	12300	12800	600	630	610	650
Ticonal 600 24% Co, 14% Ni, 8.5% Al, 3% Cu, balance Fe	5.50	5.77	10500	550	13000	13100	630	645	640	680
Ticonal 650 24% Co, 14% Ni, 8.5% Al, 3% Cu, balance Fe	6.20	6.50	11000	565	12800	13000	640	700	650	780
Ticonal 750 [1)] 24% Co, 14% Ni, 8.5% Al, 3% Cu, balance Fe	7.00	7.50	11500	650	13200	13400	720	760	730	780
Ticonal 900 [2)] 5% Ti, 34% Co, 14.5% Ni, 7.5% Al, 4.5% Cu, bal. Fe	7.50	9.00	8000	1100	10000	10600	1300	1400	1350	1500

1) Only for circular cross-sections, from 10 to 23 mm diameter.

2) Only for rectangular and tiny magnets.

Demagnetisation curves



Conversion table for Giorgi units.

1 gauss = 10^{-4} weber/sq.metre

1 oersted = $\frac{10^3}{4\pi}$ = 79.6 amperes/metre

1 gauss oersted = 8×10^{-3} VA sec/m^3 = 8×10^{-3} joule/m^3

OTHER MAGNETIC AND PHYSICAL PROPERTIES

Grade	required magnetising force Hsat (Oe)	L/D ratio for open circuits	permeance −B/H at (BH)max. (Gs/Oe)	recoil permeability μ_{rec} (Gs/Oe)	density (gr/cm^3)	specific electrical resistivity (Ω mm^2/m)	temperature coefficient of remanence (%/deg C)	Curie temperature (°C)	coefficient of thermal expansion (10^{-6}/deg C)
Ferroxdure P30	12000	0.5	1.4	1.10	3.2	10^{13}	−0.2	–	–
P40	12000	0.5	1.5	1.15	3.6	10^{11}	−0.2	–	–
Sp50	12000	0.5	1.2	1.19	4.05	10^{10}	−0.2	–	–
D55	12000	0.5	1.2	1.15	4.10	10^{10}	−0.2	–	–
Ferroxdure 100	12000	0.5	1.5	1.112-1.118	4.9	10^{10}	−0.2	450	8.5
Reco 100	2500	3.0	13	4.0-6.5	6.9	0.7	−0.015	730	12.5
120	2500	3.0	8	4.4-5.0	6.9	–	−0.015	700	12.5
140	2500	3.0	9	5.0-6.0	7.0	0.75	−0.015	770	11.5
160	2500	3.0	11	4.0-5.0	7.0	0.65	−0.015	810	11.5
170	3000	2.2	7	3.4-4.0	7.0	0.60	−0.015	790	11.5
220	5000	2.2	6	3.2-3.8	7.2	–	−0.015	750	11.5
Ferroxdure 280K	12000	0.5	1.2	1.08-1.15	4.8	10^{12}	−0.2	450	15.0
300R	8000	1.0	1.25	1.08-1.15	5.0	10^{12}	−0.2	450	10.5
300Rad	12000	0.3	1.1	1.08-1.15	4.8	10^{12}	−0.2	450	15.0
330K	12000	0.5	1.1	1.08-1.15	4.9	10^{12}	−0.2	450	15.0
360R	10000	1.0	1.1	1.08-1.15	5.0	10^{12}	−0.2	450	10.5
Ticonal 190	2500	3.0	13	3.8-5.0	7.0	–	−0.015	750	11.5
360	2500	3.5	15	4.0-5.0	7.3	0.50	−0.015	860	10.8
400	2500	4.5	16	4.0-5.0	7.3	0.50	−0.015	800	10.8
450	5000	2.2	7	2.5-3.0	7.3	0.50	−0.015	850	10.8
500	2500	4.5	20	4.0-5.0	7.3	0.45	−0.015	850	10.8
600	2500	5.0	19	3.0-4.0	7.3	0.45	−0.015	850	10.8
650	2500	4.5	20	3.0-4.0	7.3	0.45	−0.015	850	10.8
750	2500	4.3	17	3.0-4.0	7.3	0.45	−0.015	850	10.8
900	5000	2.2	7	1.7-2.5	7.3	0.50	−0.015	850	10.8

Conversion of electrical resistivity: 1 Ω mm^2/m = 10^{-4} Ωcm = 10^{-6} Ωm.

MAGNETISING AND DEMAGNETISING RECOMMENDATIONS

MAGNETISATION

Efficient magnetic circuit design requires that a magnet should be magnetised after it has been assembled into its associated magnetic circuit. Failure to do this exposes the magnet to the maximum self-demagnetisation influences. Furthermore, adoption of this procedure also simplifies handling and assembly.

Design equations are usually based on an assumption of magnetisation to saturation, and the magnetising force required to produce this is proportional to the coercivity of the magnetic material. The recommended minimum values of magnetising field strength are given in the Table. It is extremely important that the magnetising field strength used is not less than the specified minimum, otherwise the maximum performance of the materials will not be achieved.

Table - Recommended Minimum Magnetising Force

Material	Magnetising Field Strength * (Ampere-turns per centimetre length of magnet)
Ferroxdure	9600
Ferroxdure	
300R	6400
360R	8000
Reco	2000
Reco 170	2400
220	4000
Ticonal	2000
Ticonal 450	4000
900	4000

* For unshielded magnet

If the magnet to be magnetised is assembled in a circuit which shields the magnet, then the required field strength will be greater than the minimum value stipulated in the Table by the amount required to saturate the shielding circuitry. For complicated magnetic circuits, advice should be sought.

The required magnetising current can be obtained from metal rectifiers, ignitron pulse circuits, storage accumulators, charged capacitors or motor generators. To obtain the maximum effect from the magnetising current, the magnetic circuit should be closed during magnetisation by a heavy iron yoke.

DEMAGNETISATION

Partial demagnetisation of permanent magnets may be necessary for stabilisation purposes and, provided that the magnets are relatively small - about 1 kg or less - satisfactory demagnetisation can usually be achieved using the normal 50 Hz power supply. The partial demagnetisation is usually achieved by a controlled alternating field. The magnet is usually placed in an open coil in which the alternating current is controlled by means of a variable transformer.

Complete demagnetisation is often undertaken to facilitate handling and assembly. The complete demagnetisation of ferroxdure is best produced by raising the temperature of the magnet beyond its Curie temperature (about 450 °C). This heating process will not in any way affect the magnetic properties of the ceramic material.

Complete demagnetisation of Ticonal is achieved in a similar way to partial demagnetisation, although considerably more power is required. It is generally more convenient to connect the supply directly to the coil and to move the magnet slowly through the coil.

Theoretically, alternating fields of about 2000 oersted per centimetre length of the magnet are sufficient to demagnetise Ticonal magnets, but the effectiveness of the field is reduced considerably by the screening provided by associated iron circuits. The exact extent of this screening is difficult to calculate, and in practice the quickest method of finding the actual field and current requirements is by experiment.

Under no circumstances should Ticonal be demagnetised by raising the temperature of the magnet above the Curie temperature (about 850 °C). Raising the temperature above only 600 °C will permanently ruin the magnetic performance.

Demagnetisation of very large magnets is a special problem, and advice should be sought in each case.

STANDARD TERMINOLOGY SPECIFYING AXIS AND DIRECTION OF MAGNETISATION

PRE-MAGNETISED MAGNETS

Permanent magnets made from materials such as isotropic ferroxdure and the anisotropic grades FXD 330K and FXD 330Rad - having a long straight-line range in their demagnetisation curves - can be demagnetised, in some cases even into the region around B = 0, without any appreciable shift of the working point after removal of the demagnetising force.

These magnets can therefore be ordered in the magnetised state.

Permanent magnets not made from these materials are generally magnetised only after being built into the magnetic circuit, since the shorter straight-line range of their demagnetisation curves may not permit them to be demagnetised to the same extent.

Within the straight-line range of the demagnetisation curve, magnets of ferroxdure are less sensitive to demagnetising forces than most of the reco and "Ticonal" magnets.

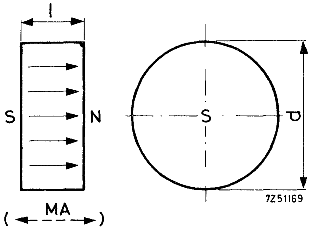
Where ready-magnetised magnets are required it is recommended that the direction of magnetisation be indicated on the drawing by means of standard terminology, to avoid misunderstanding.

STANDARD TERMINOLOGY

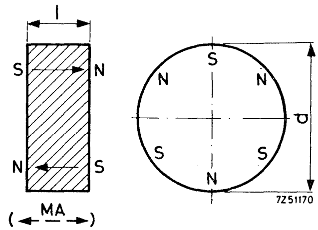
For anisotropic magnets the axes of magnetisation should also be indicated, even if magnetisation by the manufacturer is not required.
For the axis of orientation (unmagnetised magnets) the symbol $\overset{MA}{<---->}$ is used, and for the direction of magnetisation the symbol →N (or S→) is used with the standard terminology as indicated in the following examples.

For isotropic and anisotropic magnets

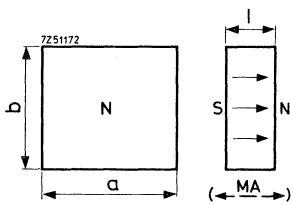
Magnetisation



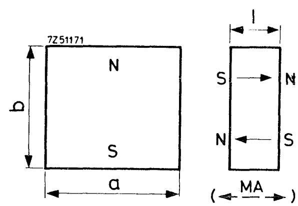
parallel to the length,
or axial.



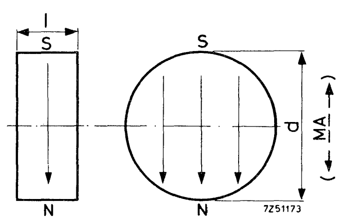
axial (n) poles
(in figure n = 6).



parallel to the side l or
normal to a x b.

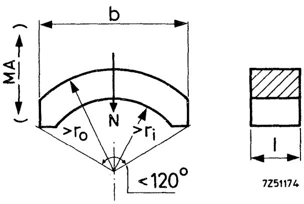


parallel to the side l,
n poles.
(in figure n = 2).

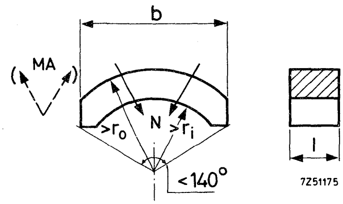


parallel to the diameter
or diametrical.

Magnetisation for segments



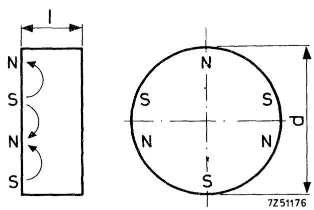
diametral



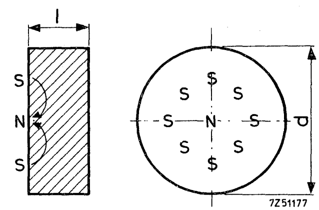
radial

For isotropic magnets only

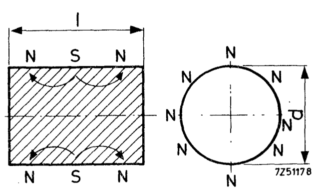
Magnetisation



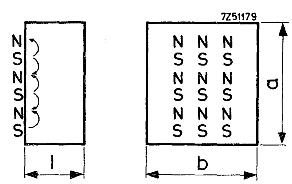
lateral,
n poles on one cross-sectional surface.
(in figure n = 6).



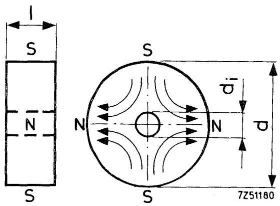
lateral,
2 poles on one cross-sectional surface with one pole in the centre.



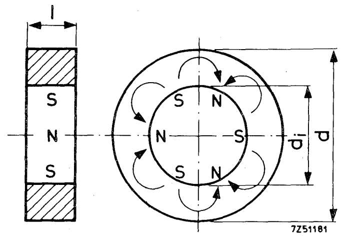
lateral,
n poles on circumference
(in figure n = 3).



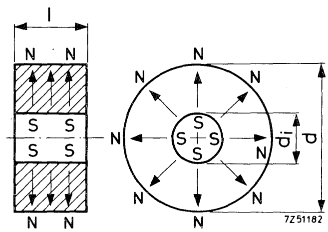
lateral,
n poles on the side a x b,
neutral zones parallel to side b.
(in figure n = 6).



lateral,
n poles on outer circumference.
(in figure n = 4).



lateral,
n poles on inner circumference.
(in figure n = 6).



radial,
N- or S- pole inside.
(in figure S-pole inside).

MARKING OF PERMANENT MAGNETS

When it is necessary to identify magnetised magnets of the same type but with different ways of magnetisation, a colour code is recommended.

The poles can then be marked by spots of paint or some other identification mark,

either south pole yellow
or north pole red
or neutral side white.

If the accuracy obtainable by spots of paint is not sufficient for the marking of the pole position, it is possible for example to use grooves, which must be indicated on the drawing.

For larger permanent magnets a marking by means of the article number can be used.

SHAPE INACCURACIES AND TOLERANCES

In the interests of rational and economical manufacture there should be as little restriction placed on the tolerances as possible in order to avoid additional processing operations.

FERROXDURE

Ferroxdure magnets are shaped during manufacture. The raw material is pressed under high pressure in dies or extruded through jets prior to sintering.

Preference should be given to simple designs, because changes in shape due to shrinkage after sintering are then less troublesome.

For the wet manufacturing process linear shrinkage is larger than for the dry process and thus somewhat greater tolerances are required.

Tolerances for "as sintered" products are approximately:

dimension	tolerance
5 mm	±0.3
5 - 10 mm	±0.4
10 - 25 mm	±0.5
above 25 mm	±2.5 %

If closer tolerances are required, however, grinding will then be necessary. This is often the case with parallel pole faces.

Ceramic parts in general may not only exhibit departures from linear dimensions but also slightly bent or warped surfaces.
Furthermore ellipticity, eccentricity and conicity lead to deviations in diameter and wall thickness.

Apart from the inaccuracies inherent in unmachined parts, errors may also occur during machining. For instance, rings ground on the outer periphery will run out-of-true if the ring is incorrectly clamped.

RECO AND "TICONAL"

Reco and "Ticonal" magnets may be sand cast, shell moulded or cast to the required shape by any other modern technique.

These permanent magnets being hard and brittle cannot be machined economically by conventional methods. Holes are cored with sand or graphite and the magnets are finished by grinding.

For smaller holes inserts can be used which can subsequently be drilled out.

For the high energy product materials, holes and inserts have to be avoided as they spoil the crystal orientation.

Tolerances for "as cast" products are approximately:

dimension	tolerance
< 50 mm	± 0.5 mm
50 - 100 mm	± 0.8 mm
> 100 mm	± 1.0 mm

It is recommended to apply "as cast" tolerances in all dimensions and to restrict grinding to the pole faces only.

Tolerance between two ground parallel surfaces is ± 0.05 mm

Tolerance perpendicularity

between one ground and one cast surface is ± 1.5 degrees

between two ground surfaces is ± 0.5 degree.

Tolerance parallelity

between two ground parallel surfaces, measured at opposite ends is 0.05 mm.

Magnets cut from bars have a diameter tolerance of

dimension	tolerance
∅10 - 18 mm	± 0.05 mm
∅ > 18 mm	± 0.15 mm

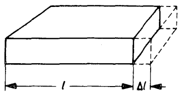
SYMBOLS FOR DIMENSIONAL DEVIATIONS

In general, shape inaccuracies are kept within the dimensional tolerances.
For special requirements of dimensional deviation it is recommended to use in the drawing the following symbols:

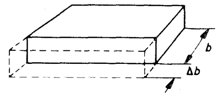
- ↗ Tolerance of eccentricity
- — Tolerance of bending or curvature
- ▱ Tolerance of plainness
- ○ Tolerance of roundness
- ⌭ Tolerance of cylindricity
- ⌒ Tolerance of accuracy to shape
- ⌓ Tolerance of surface uniformity
- // Tolerance of parallelity
- ⊥ Tolerance of perpendicularity
- < Tolerance of angularity
- ⌖ Tolerance of position
- ◎ Tolerance of concentricity
- ⌯ Tolerance of symmetry
- 80√ Surface roughness in ru (1 ru = 40 μm)

DIMENSIONAL DEVIATIONS

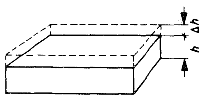
In the following table are given a few deviations of shape and dimensions consequent on the manufacturing techniques used.



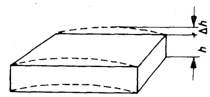
Δl length tolerance



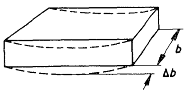
Δb width tolerance



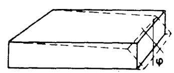
Δh height tolerance



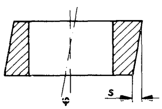
Δh curvature



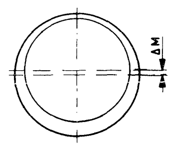
Δb curvature



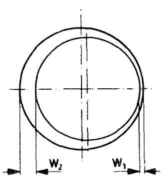
φ twisting with long rods



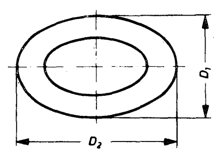
out of true running because of angular deviation in the case of grinding of outer circumference



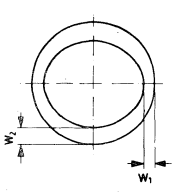
ΔM eccentricity in the case of grinding outer circumference



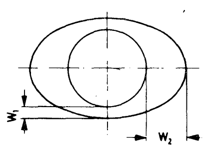
$\Delta W = W2 - W1$ difference in wall thickness on account of eccentricity with ground outer circumference



$\Delta D = \frac{D2 - D1}{2}$ deviation in diameter on account of ovality



$\Delta W = W2 - W1$ difference in wall thickness in the case of inner ovality, with outer circumference ground



$\Delta W = W2 - W1$ difference in wall thickness in the case of outer ovality, with inner circumference ground

STANDARDS FOR TESTING

VISUAL STANDARDS FOR FERROXDURE MAGNETS

Visual requirements are laid down by means of limit samples of which photographs have been made.

For each visual characteristic two limit samples have tobe determined of which one is marked X and the other is marked O.

In all cases it is to be understood that X means bad and is to be rejected
O means good and is acceptable.

MAGNETIC STANDARDS FOR PERMANENT MAGNETS

The best method of testing magnets is to measure their performance under actual working conditions. For this reason the test requirements for any type of magnet should be laid down in concert with the customer.

Often a simplified mo l of the magnetic circuit will suffice for measuring flux, voltage or force of attraction etc. according to the application.

For series and mass production of permanent magnets the testing of the material specifications on each magnet is impracticable. It has become common practice to test each magnet in comparison with a magnet of minimum guaranteed flux. Copies of these so-called minimum flux standard magnets are available on request.

The minimum guaranteed flux magnet standards are laid down in the following way:

A standard magnet is made out of a material having either

min. B_r value (min. flux standard) or
min. H_c value (min. coercive force standard)

and has the following dimensions:

Ring magnets: minimum dimensions perpendicular to pressing direction and nominal dimensions parallel to pressing direction.

Block and disk shaped magnets: ditto
Segmentary magnets : ditto

Ring magnets with diametrical magnetisation:
minimum wall thickness,
minimum length or height.

Cylinders and disk shaped magnets with diametrical magnetisation:
minimum cross section, minimum diameter.

SSS SYSTEM

Our Standard Sampling System is a non-destructive inspection system for products which are received or supplied in batches, and in respect of which it is economically justified to allow a (small) percentage of rejects.

The magnets are delivered on the condition that the amount of rejects
either mechanically
or visually
or magnetically
does not exceed the permissible quantity in accordance with the SSS system with a "point of control" $p_o = 2\%$.

"TICONAL" AND RECO

INTRODUCTION

One of the most important groups of industrial permanent magnet materials are the anisotropic Titanium, Cobalt, Nickel, Aluminium alloys known by the trade name "Ticonal".

The earliest group of permanent magnet materials of this composition and known as the isotropic reco alloys, are used today mainly in older designs which would not benefit from a replacement by stronger magnetic materials.

"Ticonal" and reco are precipitation-hardened alloys made by modern foundry techniques and specialised heat treatment. The available range of these high efficiency metallic permanent magnet materials gives a wide coverage of performance and characteristics.
The correct choice from this range enables magnetic circuits to be designed having efficiencies hitherto unattainable. The reduction in the size of magnets and the associated circuits usually results in a significant reduction in costs.

"Ticonal" and reco permanent magnets are manufactured from the purest materials, and every process of their production is subject to close laboratory control to ensure that the high standards of performance of these magnets are maintained.
These materials are melted in an induction furnace, which is essential for the close control required in the production of "Ticonal" and reco.

There have been marked advantages in the manufacturing of these precipitation hardened alloys since the first reco grades became available, and the few original grades have been expanded to today's standard range with grades in values of

coercive field strength from 400 to 2000 oersteds and
maximum energy products over 9×10^6 gauss-oersted.

"Ticonal"
190 The earlier "Ticonal" grades where achieved by applying a magnetic
360 field to the magnet during cooling.
400 The precipitate formed is aligned in the direction of the applied field,
450 resulting in stronger magnetic properties in this direction.
500

"Ticonal"
600 The newer "Ticonal" grades are achieved by orienting the crystal structure of the alloy in the desired direction of magnetic orientation. This is accomplished by casting the molten metal against steel plates, which chill the metal and cause rapid cooling and growth of long crys-

tals in the preferred direction, resulting in a higher value of the external energy product.
This technique can only be followed for straight sections and solid magnets.

"Ticonal"
650
750
The newest "Ticonal" grades show a further improvement in the magnetic properties which were achieved by complete directional crystal growth. This type of structure is achieved by a special casting process which is responsible for more complete directional crystal growth. Because the direction of magnetisation must correspond to the direction of crystal growth, the highest magnetic performances can only be developed in forms with a straight axis of magnetisation.

"Ticonal"
900
The "Ticonal" grade combining a high coercive fieldstrength with a high external magnetic energy product - one of the most recent grades - opens new fields for permanent magnets where larger demagnetising influences have to be withstood.

Due to the heat treatment the "Ticonal" and reco grades have a structure which is very stable, so that there are practically no changes of the magnetic properties in the course of time.

MECHANICAL PROPERTIES

The "Ticonal" and reco permanent magnets after heat treatment are very hard and brittle and cannot be machined other than by finish grinding.

The tolerances "as cast" - particularly with the highly automated casting process - can generally be kept within such narrow limits that only the surfaces through which the magnetic flux is passing need further processing.

Holes may be cored during the original casting, or alternatively, mild-steel inserts may be cast in. These inserts can then be drilled and tapped to give accurately located fixing holes.

For the "Ticonal" grades with crystal orientation, holes have to be avoided and inserts cannot be cast in.

The "Ticonal" and reco permanent magnets can be fixed by means of screws (only non-magnetic screws to be used in a direction parallel to the field lines and only if the magnet can be manufactured with a hole), adhesive or soft soldering. Hard soldering may lead to deterioration of the magnetic properties.

The "Ticonal" and reco permanent magnets should as far as possible, only be exposed to compressive loading.

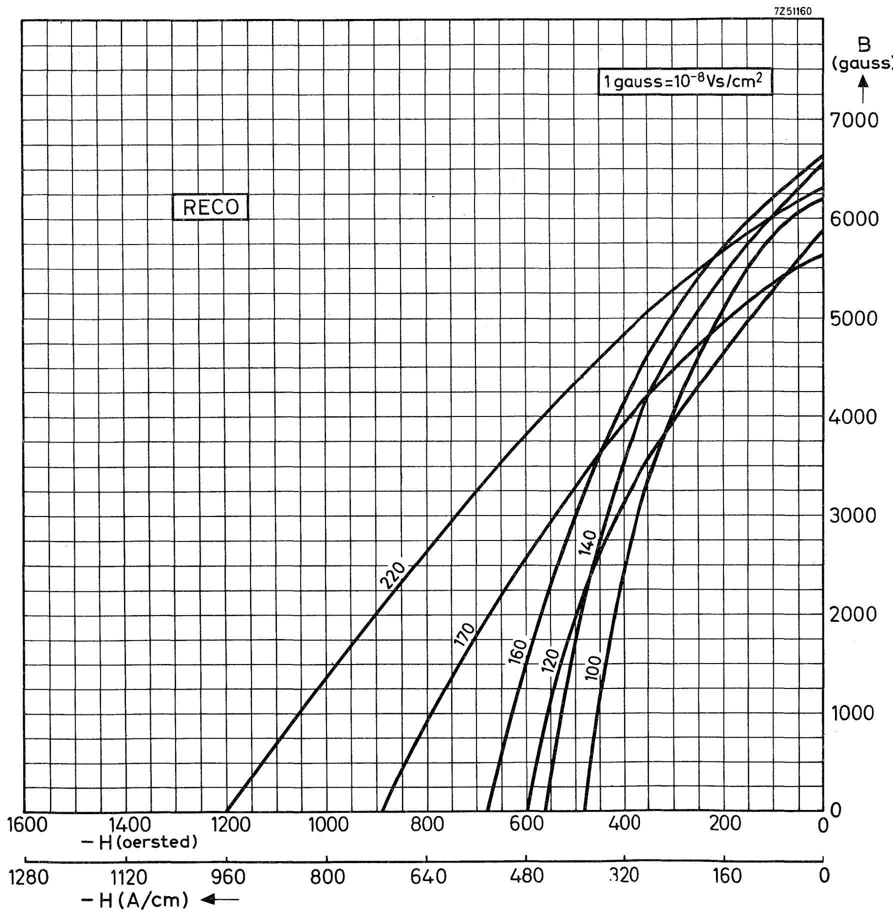
Great resistance of the "Ticonal" and reco magnets against corrosion and attack by acids is ensured by the high nickel content.

RECO

The reco permanent magnet materials are isotropic which means they have the same magnetic properties regardless of the direction of magnetisation.

The various grades show different external energy products as a result of different percentages of nickel, cobalt and titanium in the alloys.

Demagnetisation curves.



The types reco 170 and reco 220 are characterised by their higher values of coercive field strength.

Chemical composition in %

Material	Ni	Al	Co	Cu	Ti	Fe
Reco 100	24	14	–	–	–	bal.
Reco 120	26	13	4	3	1	bal.
Reco 140	24	10	5	7	0.8	bal.
Reco 160	18.5	10	13	7.5	1.9	bal.
Reco 170	24	9.5	10	6	5	bal.
Reco 220	15	7	26	5	7	bal.

Design data

See Survey of permanent magnet materials.

"TICONAL"

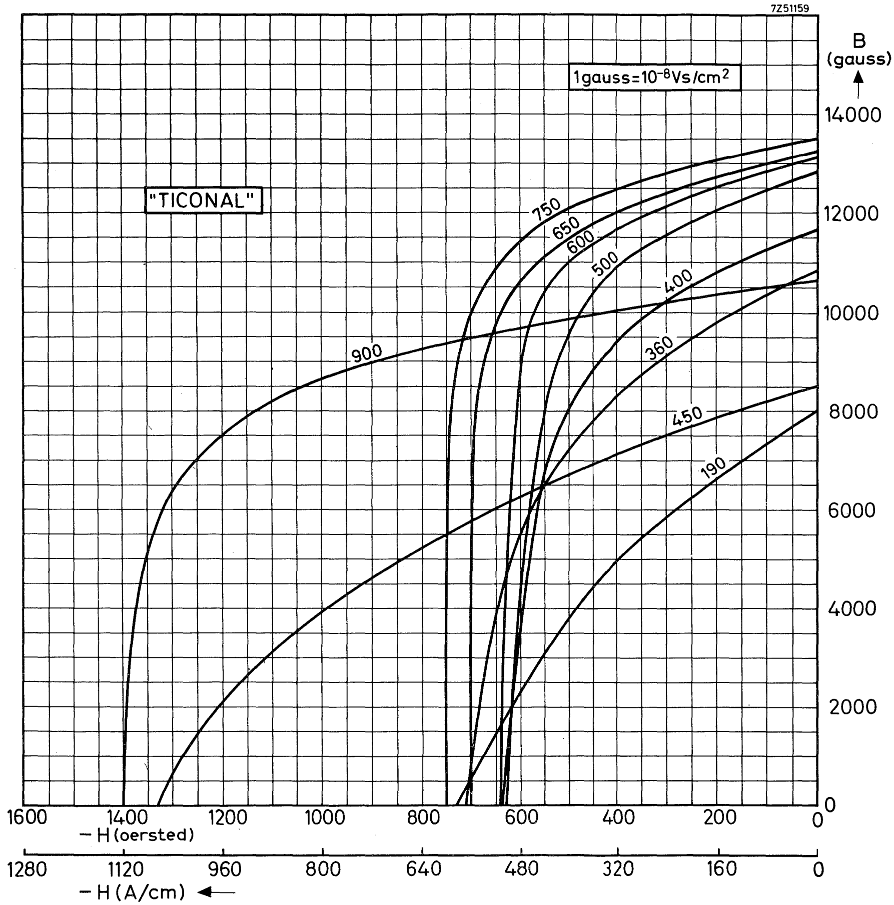
The "Ticonal" permanent magnet materials are anisotropic, which means that the high magnetic properties are achieved only if the magnets are magnetised in the direction of orientation - the magnetic axis.

An axial direction of orientation is most easily obtained in the casting and heat treatment process. For optimum magnetic properties therefore, the magnets to be produced should have a straight axis of magnetisation (coincident with the axial direction of orientation or magnetic axis).

This means that the only practical cross sections are circular, rectangular or prismatic. The manufacture of magnets with a complicated shape or with more than two poles is generally laborious and expensive.

The methods of production of the grades "Ticonal" 190 - 360 - 400 - 450 and 500 are similar. For "Ticonal" 600 chilling by means of steel plates is introduced to achieve crystal orientation.
"Ticonal" 750 compared with these types has a high degree of crystal orientation due to the continuous highly automated casting process. "Ticonal" 650 is somewhat lower in external energy product and is manufactured by multi-cavity hot moulding or by one of the other methods of manufacturing crystal oriented "Ticonal" magnets.

Demagnetisation curves



Grades of "Ticonal"

"Ticonal"

190
360
400
500

are the first anisotropic grades cast by normal foundry practice, which provide less restrictions to form and magnetisation than the production methods for the crystal oriented "Ticonal" grades.

The external energy products may be considered good, having values between 1.8 and 5 x 10^6 gauss-oersteds.

"Ticonal"
600 is a crystal oriented anisotropic permanent magnet material with excellent magnetic properties. It is advantageous when the dimensions perpendicular to the direction of orientation are greater than in the direction of orientation, since otherwise the crystal orientation might be incomplete.

"Ticonal"
750 is a crystal oriented anisotropic permanent magnet material with nearly ideal monocrystals. The extremely high energy product of this grade is the result of the highly automated casting process for long circular bars from which magnets of any length can be cut.

Preferrable diameters 10 to 22 mm.
The length of the magnet should be calculated according to the circuit and performance required.

Note: It should be remembered that the demagnetisation curve has a sharp knee just at the value (BH)max. Therefore the working line of a statically used magnetic circuit - without an external demagnetising field - should intersect the BH-curve in the (BH)max. point. Otherwise the optimum performance will not be achieved, and the use of "Ticonal" 750 would not lead to a higher performance or to a smaller system than obtainable with "Ticonal" 600 or even "Ticonal" 500.

"Ticonal"
650 is a crystal oriented anisotropic permanent magnet material with lower magnetic properties than "Ticonal" 750. The various manufacturing processes, of which multi-cavity hot moulding is the most common, have the advantage that magnet shapes are not limited to circular cross sections. Nevertheless holes should be avoided, because they degrade the magnetic values as a result of incomplete crystal orientation.

Note: The knee in the demagnetisation curve is less sharp than with the 750 grade.
For diameters smaller than 15 mm it is recommended that the diameter/length ratio be greater than unity.

"Ticonal"
450 has a very high coercive field strength due to its high cobalt and titanium content.

"Ticonal"

900 (previously Ticonal XX) has the highest energy product of permanent magnet materials combined with a high coercive field strength.

It is economically attractive for tiny cube shaped magnets. Owing to the great coercive field strength the optimum length of the magnet will usually be small.
The material is often used with success where previously platinum-cobalt was the only solution.

Chemical composition in %

Material	Ti	Co	Ni	Al	Cu	Fe
Ticonal 190	–	14	21	12	3	bal.
Ticonal 360	1.5	24	15	8.5	3	bal.
Ticonal 400	0.8	24	14	8.5	3	bal.
Ticonal 450	5	34	14.5	7.5	4.5	bal.
Ticonal 500, Ticonal 600, Ticonal 650, Ticonal 750	–	24	14	8.5	3	bal.
Ticonal 900	5	34	14.5	7.5	4.5	bal.

Design data

See "Survey of permanent magnet materials".

APPLICATIONS FOR RECO AND "TICONAL" PERMANENT MAGNETS

Reco magnets are used today mainly in older designs which would not benefit from a replacement by stronger magnetic materials.

"Ticonal" magnets having the highest external magnetic energy are used in all those applications requiring superior performance.

Also the need for small dimensions (watches),
high acoustic quality (loudspeakers),
sensitivity (microphones and telephones),
accuracy (meters),
ease of starting (magnetos),
high torque (motors),
cold stability

requires the use of "Ticonal" permanent magnets.

The crystal oriented "Ticonal" permanent magnets therefore find wide use in

- Pick-ups
- Microphones
- Loudspeakers
- Meters
- Magnetos
- Magnetrons
- Instrumentation such as
  - Watt-hour meters
  - Magnetic detectors
  - Ampere-, volt-, and lumen meters
  - Tachometers/Speedometers
  - Temperature control
  - Circuit breakers
- Timing devices in clocks and watches.

See also the general list of applications of permanent magnet materials.

FERROXDURE

INTRODUCTION

Another important group of industrial permanent magnet materials are the ferromagnetic oxides, one of which is a ceramic material known as ferroxdure.

Ferroxdure is a major development in permanent magnet materials and represents a complete departure from the conventional permanent magnet.

Ferroxdure, a ceramic material containing only non-critical raw materials, is distinguished by its high coercive field strength - up to more than 4000 oersteds - and such high electrical resistivity that it may be considered to be an insulator.

The high coercive field strength means that magnets with very short lengths can be used without excessive self-demagnetisation. The high electrical resistivity - some 10^{10} times that of iron-minimises eddy current losses and thus makes ferroxdure an ideal material for high frequency applications.
The relative low induction values require larger cross sections than for conventional permanent magnets.

These properties have led to new applications and new designs for existing applications.

Ferroxdure corresponds approximately to the chemical formula $(M)Fe_{12}O_{19}$ where M stands for Ba, Sr, Pb etc.

Ferroxdure being a true ceramic material is brittle, and close dimensional tolerances can only be achieved by grinding.

Ferroxdure has a low specific gravity which introduces a weight advantage over other permanent magnet materials.

Ferroxdure isotropic permanent magnets are manufactured from carefully selected raw materials which are milled to give an intimate mixture of powder. The powder - in some cases after pre-firing - is granulated and formed to the required shape in dies by high pressure pressing or extrusion. The fragile, compacted piece then undergoes an accurately controlled firing process in a special furnace from which it emerges with a ceramic structure and a black colour.

Ferroxdure anisotropic permanent magnets are produced by an extension of the above manufacturing process.

The isotropic ferroxdure material is remilled after firing to a very fine powder. The powder or slurry is then formed to the required shape by high pressure pressing in dies with simultaneous application of an intense homogeneous magnetic field. The pieces are now magnetically orientated.

After this magnetic treatment the orientated compacted pieces are again fired in the furnace in which atmosphere and temperature are accurately controlled, and from which the pieces emerge with a ceramic structure and a black colour.

Compared with isotropic ferroxdure, the orientated or anisotropic ferroxdure permanent magnets possess a very much improved performance in the direction of the magnetic field used during pressing.

Note: During sintering the compacts shrink to about 85% of the dimensions of the pressed form.

Specific gravity is about 4.8.
The higher the coercive field strength, the lower the specific gravity.

Ferroxdure plastic bonded, isotropic permanent magnets are manufactured starting from a mixture of isotropic ferroxdure powder with either thermoplastic or thermosetting materials as bonding agents. Familiar plastics-manufacturing techniques such as extrusion, injection moulding and pressing are used for the shaping of the magnets.

The plastic bonded isotropic ferroxdure magnets combine the magnetic properties of isotropic ferroxdure (but at a slightly lower level) with the mechanical properties of the plastics.

Thus they can be used to make magnets which

- can be bent and even cut with a knife or pair of scissors
- meet narrow size tolerances without being machined
- have complicated shapes
- can be machined with conventional tools.

PLASTIC BONDED ISOTROPIC FERROXDURE

Ferroxdure P30 (norm KPN - K - 992)

A soft, flexible and resilient permanent magnet material with 85 wt% ferroxdure powder $(M)Fe_{12}O_{19}$ and 15 wt% thermoplastic material, shaped by extrusion or injection moulding.

Ferroxdure P40 (norm KPN - K - 989)

A flexible permanent magnet material with 90 wt% ferroxdure powder $(M)Fe_{12}O_{19}$ and 10 wt% thermoplastic material, shaped by extrusion or injection moulding in bars, strips, rods and suchlike.

Ferroxdure Sp50 (norm KPN - K - 7028)

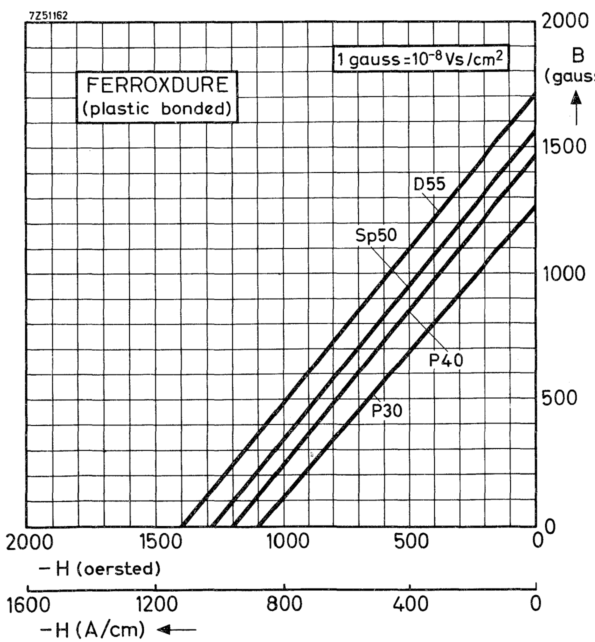
A relatively flexible permanent magnet material with 93 wt% ferroxdure powder $(M)Fe_{12}O_{19}$ and 7 wt% thermoplastic material, shaped by injection moulding to the required shapes.

Ferroxdure D55

A hard and rigid permanent magnet material with 95 wt% ferroxdure powder $(M)Fe_{12}O_{19}$ and 5 wt% of thermosetting material, shaped by pressing.

The plastic bonded isotropic ferroxdure magnets find use where magnets have been unsuitable till now for either technical or economical reasons.

Demagnetisation curves

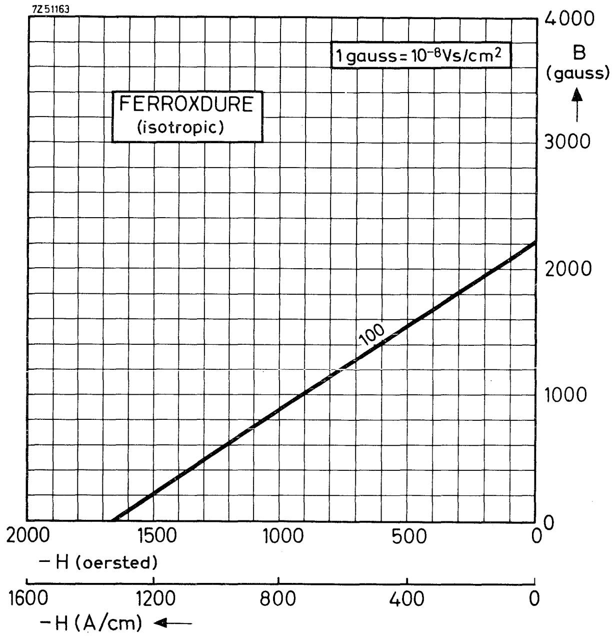


ISOTROPIC FERROXDURE

Ferroxdure 100 (KPN - K - 359)

The individual crystals have a random orientation and poles can therefore be induced wherever the application demands. The material is best suited either for applications where high magnetic values are not essential or else where the isotropic properties are required.

Demagnetisation curve



ANISOTROPIC FERROXDURE

Ferroxdure 280K and 330K (KBN - K - 435-252)

The materials have high values of coercive field strength and are therefore ideal for applications where strong demagnetising influences are encountered.

Note: Ferroxdure 280K is an improved grade of ferroxdure 250K.

Ferroxdure 330 Rad.

This material has a higher intrinsic coercive field strength and lower remanence compared with ferroxdure 330K, but has a radial orientation which is especially suitable for the manufacture of segmental magnets for use in d.c. motors.

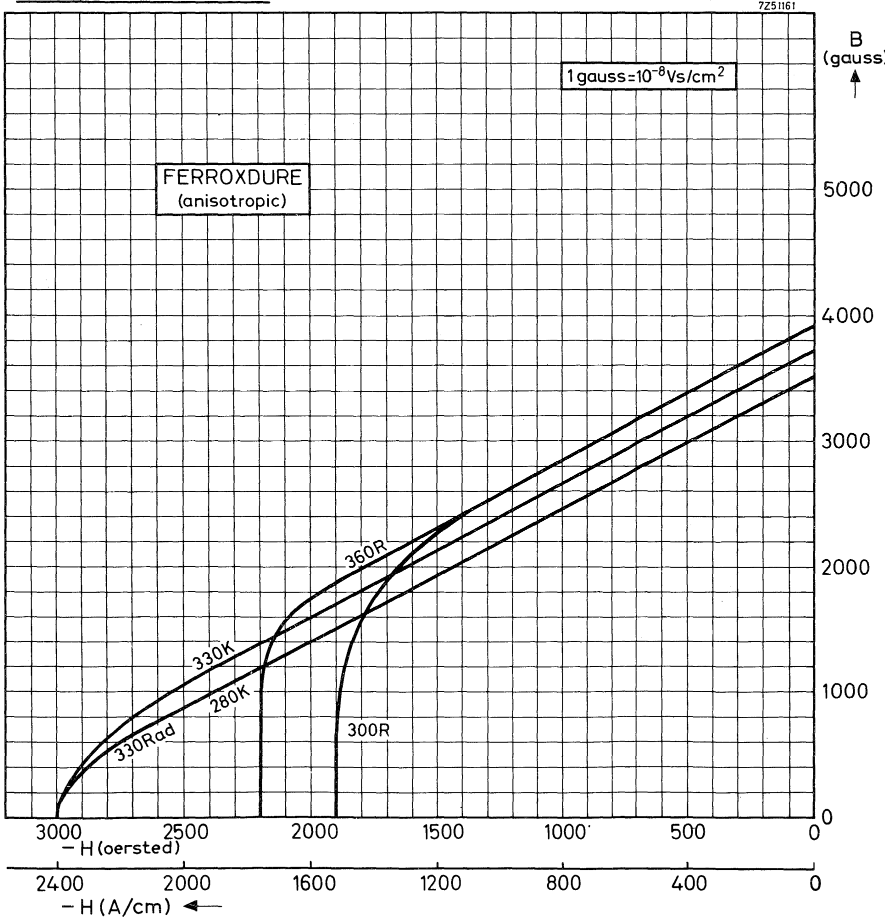
Ferroxdure 300R and 360R (KBN - K 434 - V-254)

The materials have the same high values of flux density but ferroxdure 360R has a higher coercive field strength (and a greater distance of the point (BH)max from the knee in the demagnetisation curve), which permits designs to operate at the maximum energy product of the material.

Both materials are particularly suitable for applications demanding high values of external energy product.

If dismounting requirements and/or highest flux requirements are imposed, it is recommended that the magnet be magnetised in its system.

Demagnetisation curves



DESIGN DATA

See "Survey of permanent magnet materials".

CHEMICAL COMPOSITION

The pure ceramic ferroxdure permanent magnet materials contain 100 wt% $(M)Fe_{12}O_{19}$.

CHEMICAL PROPERTIES of ferroxdure containing 100 wt% $(M)Fe_{12}O_{19}$.

Ferroxdure is chemically rather inert. Its chemical resistance is characterised as follows:

Ferroxdure is not attacked by:
- sodium chloride in a 30% solution;
- a mixture of benzol-trichlorine ethylene in a 50% solution;
- petrol;
- nitric acid;
- nitric acid in a 50% solution;
- acetic acid;
- cresol;
- phenolic solutions;
- sodium sulphate solution.

Ferroxdure is lightly attacked by:
- dilute sulphuric acid;
- hydrochloric acid in a 50% solution.

Ferroxdure is subject to attack by: concentrated hydrochloric acid.

TEMPERATURE COEFFICIENT AND THE EFFECT IN MAGNETIC PERFORMANCE

With the isotropic ferroxdure grades the effect of variations in temperature on the induction is practically reversible. In other words, after temporarily heating or cooling, the starting point on the BH curve is regained within some percent without remagnetisation being necessary. Only after heating above the Curie point does permanent demagnetisation occur.

The same applies to anisotropic ferroxdure grades, but with these materials care should be taken that when cooling the magnets below room temperature (which gives an increase of B and a decrease of H) the working point of the magnets does not pass the knee of the demagnetisation curve. Otherwise a lower working point will be obtained after reheating to the original temperature.

In the sequence

ferroxdure 300R
360R
280K
330K
330Rad

the materials have a decreasing sensitivity, due to the higher coercive field strength values, resulting in a favourable shift of the knee.

GLUING OF FERROXDURE MAGNETS

For making very large magnets it is possible to glue individual ferroxdure parts to each other. Ferroxdure parts can also be glued to metal fittings. Here it should be noted that ceramic materials have a considerably smaller coefficient of thermal expansion than most metals.

The coefficient of expansion is for

ferroxdure	8.5×10^{-6}/deg C
steel	$11 - 20 \times 10^{-6}$/deg C
brass	18×10^{-6}/deg C

With a very rigid connection the inevitably occurring thermal stresses may easily lead to damaging of the ferroxdure crystal structure and may even cause fracture.
With some epoxy resins particularly, the formation of cracks has been observed.

Generally a less rigid, reasonably strong but elastic adhesive joint is adequate. Frequently it is reinforced by the magnetic clamping force. Experience with adhesives on a neoprene base has been good.

In the design stage it should be noted specially that ferroxdure permanent magnets can resist large pressure more readily than tension.

APPLICATIONS

Some applications in which ferroxdure permanent magnets are commonly used today are

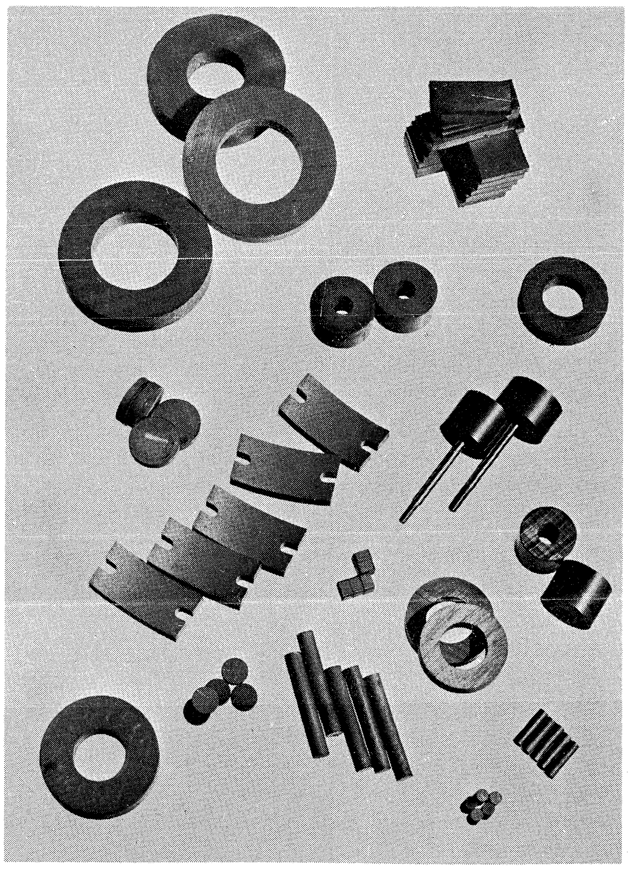
- Loudspeakers
- Bicycle dynamos
- Generators and magnetos
- Synchronous and d.c.-motors
- Separators, filters and chucks
- Couplings and sticking devices
- Deflection units and biasing magnets in soft magnetic circuits
- Travelling wave tubes
- Clocks and watches.

The radially orientated ferroxdure 330 Rad will no doubt further stimulate the use of segments in fractional horse power motors

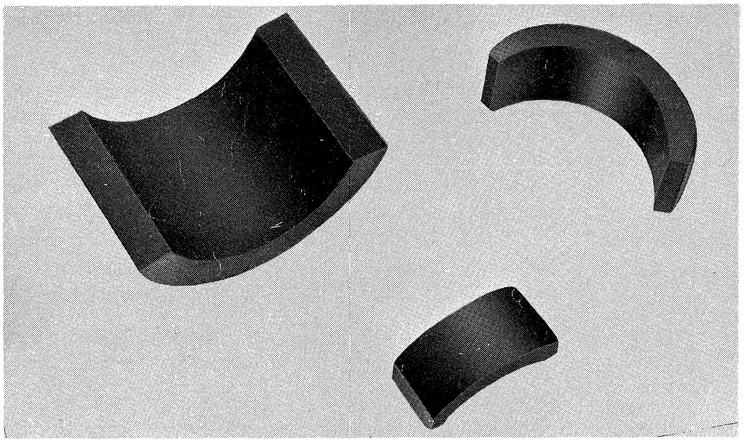
a) for the automotive industry such as starter motors, screen wiper motors, ventilator motors, screen washer motors and all those motor-equipped devices which make car driving more comfortable.

b) for the household appliances such as electric tooth brushes, mixers, coffee mills, knives, small vacuum cleaners, polishers, etc.

All the grades with nearly straight demagnetisation curves will expand the applications for permanent magnets in sandwich type devices and the more professional applications such as travelling wave tubes, watches, magnetos, alternators, generators, synchronous motors, filters and separators.



ANISOTROPIC FERROXDURE SEGMENTS



RZ 18440-2

Besides the already well known ferroxdure magnets in the form of rings, disks, cylinders, rods and blocks, a new and rather important form has been introduced: the ferroxdure magnet in the form of a segment with either diametrical or radial orientation.
Material for diametrical magnetisation: ferroxdure 330 K
for radial magnetisation : ferroxdure 330 Rad.

Segmentary permanent magnets are used in the magnetic circuit of e.g.

D.C. motors and
Fly-wheel magnetos.

These circuits are composed of a soft iron armature (with coils) and a soft iron ring with segmentary magnets.

The following data are of major consequence for both the circuit engineer and the manufacturer of the magnets.

A. The internal radius of the ring.
B. The external radius of the armature.
C. The min. acceptable air gap between rotor and magnet.
D. The angle of the segment: $< 120^{\circ}$ for diametrically orientated magnets; 120°-140° for radially orientated magnets.
E. The required flux from which the length of the segment is derived.

On enquiry, please give at least these data complete with tolerances. A check list is also available on request.

The radii of the segments should slightly exceed the radii of the ring and of the (armature + min. acceptable air gap). In this way, the segments will touch the ring at their edges and so the risk of breakage during mounting is reduced. Also, the varying air gap occurring between segments and armature will favourably influence the silent running of the device, without adversely affecting the magnetic performance.

Apart from checking the width and length of the magnet, the segment height and thickness are checked by means of a jig having the same radius as the soft iron ring.

Normally, a static check is made of magnetic flux with the segment enclosed by a soft iron ring and surrounding a soft iron cylinder, around which is a longitudinal measuring coil. The radius of the cylinder is equal to the armature radius plus air-gap. Comparison is made with results obtained from a standard segment. This procedure may be varied in accordance with a customer's wishes.

Attention is drawn to the fact that the material for radially orientated segments has a high intrinsic coercive field strength which enables them to withstand high demagnetising influences.

Special requirements for the values of intrinsic coercive field strength should be stated.

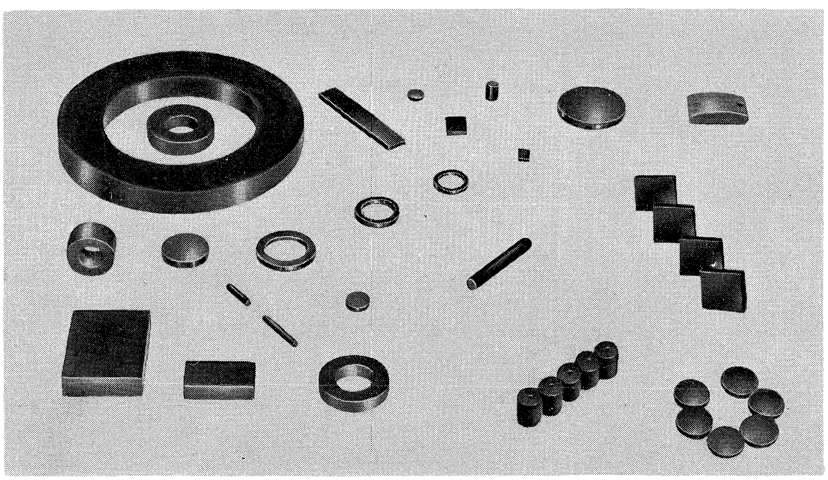
LIST OF PREFERRED PERMANENT MAGNETS

Permanent magnets may be

a. Ordered to your own design (within the limits of the materials and manufacturing techniques).

b. Selected from the list of preferred types. The list contains data on types for which the dies and moulding plates already exist. In a lot of cases stock is available for immediate dispatch to enable trials and small series production in short time.
   Choice of a preferred type eliminates the need for additional tools and development work at the factory. Please use catalog number for ordering.

Our technical assistance on the design and application of permanent magnets is always at your disposal - see the section "Design advisory service".



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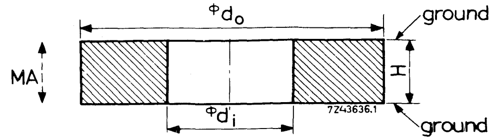
ANISOTROPIC FERROXDURE

Ring magnets for loudspeakers etc.

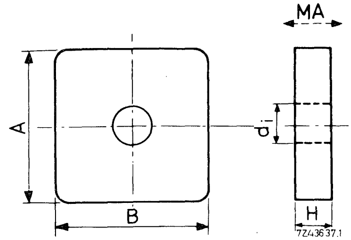


Material: Fxd 300R
Direction of magnetisation: axial
Version: unmagnetised

dimensions						type number	catalog number
outer diam.		inner diam.		H			
mm	tolerance	mm	tolerance	mm	tolerance		
36	±0.8	18	±0.5	8	±0.1	K6 150 71	4322 020 60071
38.5	±0.6	23	±0.5	9	−0.1	K6 154 81	60381
40	+1.3 −0.7	15	±0.4	7	±0.1	K6 152 61	60081
40	±0.9	22	±0.5	9	±0.1	K6 152 11	60091
45	±1	22	±0.6	8	±0.1	K6 153 01	60101
45	±1	22	±0.6	9	±0.1	K6 152 41	60111
45	±1	22	±0.6	10.5	±0.1	K6 150 51	60121
45	±1	24	±0.6	8.5	±0.1	K6 154 51	60411
45	±1	24	±0.6	9	±0.1	K6 154 21	60131
51	±1.2	24	±0.6	9	±0.1	K6 151 21	60151
51	±1.2	24	±0.6	10	±0.1		60031
55	±1.2	24	±0.6	8	±0.1	K6 150 81	60161
55	±1.2	24	±0.6	12	±0.1	K6 152 01	60171
60	±1.5	24	±0.6	8	±0.1	K6 153 11	60181
60	±1.5	24	±0.6	12	±0.1	K6 151 91	60191
60	±1.5	24	±0.6	13	±0.1	K6 150 61	60201
60	±1.5	30	±0.7	10	±0.1	K6 152 71	60211
68	±1.5	32	±0.7	13	±0.1	K6 151 51	60231
72	±1.5	32	±0.7	15	±0.1	K6 151 11	60241
73	±2.2	31	±0.9	10	±0.1	K6 153 21	60261
84	±1.8	32	±0.9	15	±0.1	K6 152 81	60271
90	±1.8	36	±0.9	17	±0.15	K6 152 51	60281
96	±2.4	40	±1	25	±0.15	K6 153 31	60291
102	±3	51	±1.5	10	±0.15	K6 153 61	60301
102	±3	51	±1.5	14	±0.15	K6 153 71	60311
121	±3.6	57	±1.7	12	±0.2	K6 153 91	60321
134	±4	57	±1.7	14	±0.2	K6 153 51	60331
134	±4	57	±1.7	14	±0.2	K6 154 01[1]	60341
134	±4	57	±1.7	20	±0.2		60021
155	±4.5	57	±1.7	17.5	±0.15		60011
184	±5.5	73	±2.2	18.5	±0.2	K6 153 41	60351
184	±5.5	81.3	±2	18.5	±0.2		60001

[1]Outer diameter provided with 3 slots

Square magnets for loudspeakers

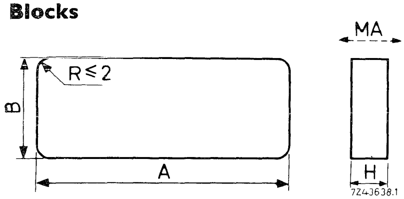


Material: Fxd 300
Direction of magnetisation: ⊥ A × B
Version: unmagnetised

dimensions								type number	catalog number
A		B		H		diam. hole			
mm	tolerance	mm	tolerance	mm	tolerance	mm	tolerance		
30.6	±0.8	30.6	±0.8	5	±0.1	12.4	±0.4	K6 137 51	4322 020 63011
32	±0.8	26	±0.6	8	−0.1	15.5	+0.8	K6 176 51	63091
41	±1	41	±1	8	±0.1	15.5	+0.8	K6 137 61	63041
50	±1	50	±1	10	±0.1	26	±0.6	K6 175 65[1]	63021[1]
50	±1	50	±1	12	±0.1	26	±0.6		63001[1]

[1] Inner diameter provided with 2 slots.

Blocks

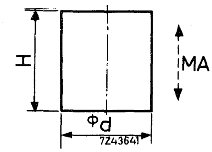


Material: see below
Direction of magnetisation: ⊥ A × B
Version: magnetised

dimensions						material	type number	catalog number
A		B		H				
mm	tolerance	mm	tolerance	mm	tolerance			
7	±0.2	1.4	±0.1	0.8	±0.1	300R		4322 020 62161[2]
5	±0.2	5	±0.2	4	−0.2	300R	K6 175 90	62021
7	±0.3	7	±0.3	4.2	±0.05	250K		62001
15	±0.3	9	±0.5	5	±0.25	250K	K6 176 10	3122 104 92701
20	±0.5	10	±0.5	5	±0.1	250K	K6 176 30[2]	4322 020 62031[2]
20	±0.5	10	±0.5	5	±0.1	250K	K6 176 40	62041
30	±0.8	30	±0.8	15	±0.1	250K	K6 176 20[2]	62071[2]
40	±1	25	±0.75	10	±0.1	330K		62181
50	±1.3	19	±0.5	4.9	−0.25	250K	K6 175 30[2]	62091[2]
50	±1.3	19	±0.5	4.9	−0.25	250K	K6 175 50	62101
50	±1.3	19	±0.5	6.1	±0.1	250K	K6 175 70[2]	62111[2]
50	±1.3	19	±0.5	6.1	±0.1	250K	K6 175 80	62121
131	−3	51	±1.5	17.5	±0.2	330K		62141[2]

[2] Magnets are not magnetised.

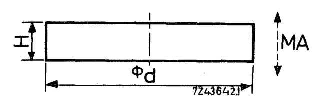
Slugs



Material: see below
Direction of magnetisation: axial
Version: magnetised

dimensions				*material*	*type number*	*catalog number*
d		*H*				
mm	*tolerance*	*mm*	*tolerance*			
10	±0.5	10	±0.2	250K	K6 038 00	4322 020 61021
10	±0.5	12	±0.2	250K	K6 038 10	61011
10	±0.5	15	±0.2	250K		61001

Discs

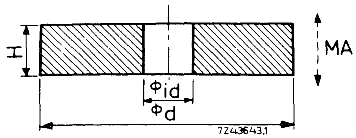


Material: see below
Direction of magnetisation: axial
Version: unmagnetised

dimensions				*material*	*type number*	*catalog number*
d		*H*				
mm	*tolerance*	*mm*	*tolerance*			
5.5	±0.05	1.8	±0.03	330K	—	4322 020 62591
10	±0.2	2	±0.05	330K	—	62502
10	±0.5	4.6	±0.1	250K	—	62581
12	±0.3	6	±0.25	300R	K6 112 75	62541 [3]
28.8	−0.3	12.5	±0.5	250K	—	62511
40.6	±1	9	±0.1	250K	K6 112 65	62551
45	±1.1	9	±0.1	250K	K6 075 00	62561

[3] Magnets are magnetised

Rings (other than for Loudspeakers)



Material: see below
Direction of magnetisation: axial
Version: unmagnetised

dimensions						*material*	*type number*	*catalog number*
outer diam.		*inner diam.*		*H*				
mm	*tolerance*	*mm*	*tolerance*	*mm*	*tolerance*			
20	±0.2	5.15	±0.15	4	±0.1	300R	K6 153 81	4322 020 60041
24	+0.08	10.2	±0.3	4.05	±0.1	250K	K6 154 11	60052
30	±0.6	12.7	±0.5	6.35	±0.05	250K	K6 152 20	60061
42	+2.3	10	−0.5	8	+1.6	250K	K6 152 30	60391

Segments

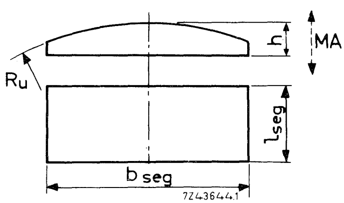
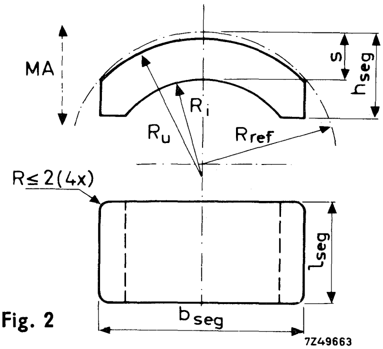


Fig. 1

Material: Fxd 300R
Direction of magnetisation: axial
Version: unmagnetised

dimensions							*type number*	*catalog number*
R_u		b_{seg}		l_{seg}		*h*		
mm	*tolerance*	*mm*	*tolerance*	*mm*	*tolerance*	*mm*		
49	+10	34	±0.9	23	±0.6	7.1	K6 200 10	4322 020 61541
55	+10	35	±0.9	23	±0.6	10.4	K6 200 05	61531

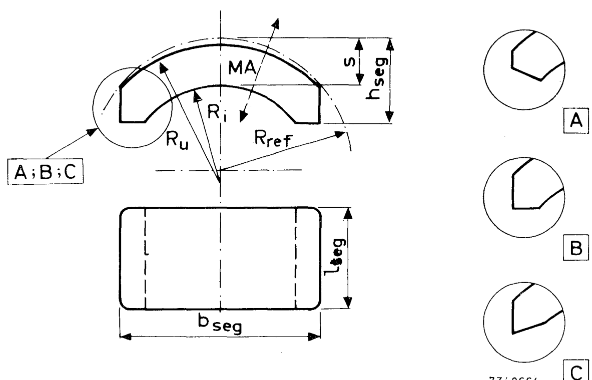
Segments for d.c. motors



Material: Fxd 330 K
Direction of magnetisation: diametrical
Version: not magnetised

Fig. 2

R_i	R_u	s	h_{seg}		b_{seg}		l_{seg}		catalog number	Fig.
mm	tol.	mm	mm	tol.	mm	tol.	mm	tol.		
≥ 8.315	≥ 12.025	≤ 3.66	8	±0.6	18	±0.5	15	+1	4322 020 61561	2
≥ 20.3	≥ 29	≤ 8.7	16	±0.6	42	±1	19.8	±0.5	4311 021 30471	2
≥ 20.3	≥ 29	≤ 8.7	16	±0.6	42	±1	41	+1	4311 021 30362	2



Material: Fxd 330 Rad.
Direction of magnetisation: radial
Version: not magnetised

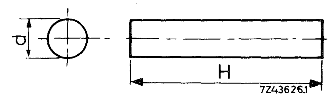
Fig. 3

R_i	R_u	s	h_{seg}		b_{seg}		l_{seg}		catalog number	Fig.
mm	mm	mm	mm	tol.	mm	tol.	mm	tol.		
≥ 27.94	≥ 35.41	≤ 7.39	24.99	—0.93	60.71	+2.5	25.4	+1.27	4322 020 61601	3B
≥ 28.58	≥ 35.13	≤ 6.55	25.5	±0.6	62.4	+0.4	26.7	±0.75	4322 020 61512	3A
≥ 28.41	≥ 35.55	≤ 7.15	21.4	—1.2	60.3	+3.0	39.4	+1	4322 020 61581	3C
≥ 29.03	≥ 36.02	≤ 7.49	21.79	±0.38	62.7	+3.0	27.88	±1.25	4322 020 61591	3B
≥ 26.85	≥ 35.09	≤ 8.18	24	±0.7	60	±1.5	40	±1	4322 020 61621	3B

ISOTROPIC FERROXDURE

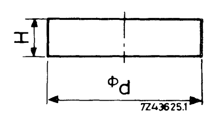
Discs and bars

Material: Fxd 100



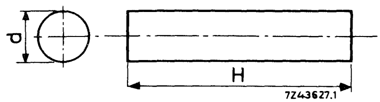
a) axially magnetised

dimensions				type number	catalog number
diam. d		H			
mm	tolerance	mm	tolerance		
3	±0.2	7.5	±0.25	VK.300.23	4312 020 60131
5	±0.3	10	±0.5	VK.300.03	60021
5	±0.2	20	±0.5	VK.300.00	60001
5	±0.3	30	±0.8	VK.300.02	60011
5	±0.2	39	−1	VK.300.25	60101
5	±0.3	50	±1.0	VK.300.22	60151
6	±0.3	33	±0.6	VK.300.17	60071



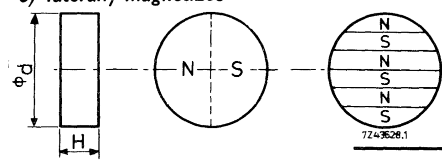
dimensions				type number	catalog number
diam. d		H			
mm	tolerance	mm	tolerance		
4	±0.2	3.5	±0.2	VK.310.07	4312 020 65951
5.5	±0.3	5	±0.3	VK.310.09	65931
8	±0.3	3	±0.3	VK 310 11	65911
8	±0.5	5	±0.5	VK 310 06	65961
10	±0.3	2.5	±0.3	VK 310 05	65971
10	±0.5	5	±0.5	VK 310 08	65941
14	±0.5	4	±0.5	VK 310 12	65901
14	±0.5	5	±0.3	VK 310 13	65891
14	±0.3	10	±0.5	VK 310 17	65831
20	±0.35	5	±0.3	VK 310 27	65881
25	±0.5	5	±0.4	VK 310 18	65871
32	−1	8.7	±0.3	VK 310 34	65811

b) diametrically magnetised



dimensions				type number	catalog number
diam. d		H			
mm	tolerance	mm	tolerance		
4	±0.1	5	±0.2	VK 300 18	4312 020 60081
4	±0.1	10	±0.2	VK 300 13	60041
4	±0.1	20	±0.2	VK 300 14	60051
4	±0.1	30	±0.2	VK 300 15	60061
5	±0.5	15	±0.5	VK 300 26	60111

c) laterally magnetized

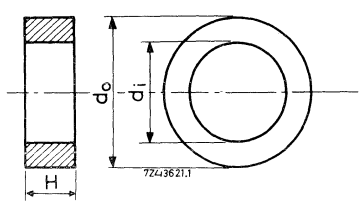


dimensions				type number	catalog number
d		H			
mm	tol.	mm	tol.		
14	±0.5	5	±0.3	VK 310 21[1]	4312 020 65861
20	±0.4	3	±0.3	VK 310 36[2]	65791
25	±0.5	5	±0.4	VK 310 23[2]	65851

[1] 2 poles on 1 face. [2] 6 poles on 1 face.

Rings

Material: Fxd 100



a) diametrically magnetised

dimensions						type number	catalog number
outer diam.		square hole		H			
mm	tolerance	mm	tolerance	mm	tolerance		
12.25	±0.25	3.2	±0.5	10	±0.5	VK 320 06	4312 020 62111
12	+0.5	3.2	±0.5	12	±0.5	VK 320 07	62121

Rings

Material: Fxd 100

b) axially magnetised

dimensions						type number	catalog number
outer diam.		inner diam.		H			
mm	tolerance	mm	tolerance	mm	tolerance		
11.9	±0.4	5.75	±0.25	6.5	±.05	VK 320 19	4312 020 62211
14	±0.5	1.5	±0.5	5	±0.5	VK 320 16	62181
14	±0.5	4	±0.25	4	±0.25	VK 320 18	62201
15.6	±0.3	6.25	±0.2	3	−0.1	VK 320 03	62101
18	±0.45	5	±0.2	5	±0.2	VK 320 12	62141
29.9	−0.05	10	±0.3	5	−0.1	VK 321 10	62271[1]
36	−0.1	10	±0.2	5	−0.1	VK 321 18	62731[1]
37	±0.8	25	±0.5	3.5	±0.5	VK 321 06	62261

[1] 4p axially magnetised.

c) radially magnetised

dimensions						magnetisation	type number	catalog number
outer diam.		inner diam.		H				
mm	tol.	mm	tol.	mm	tol.			
13	±0.3	5.3	±0.2	8	±0.3	N pole on o.d.	VK 320 13	4312 020 62151
13	±0.3	5.3	±0.2	8	±0.3	S pole on o.d.	VK 320 14	62161
18	±0.5	12	±0.5	3	±0.5	S pole on o.d.	VK 320 47	62251
27	±0.7	20	±0.6	3.5	±0.5	S pole on o.d.	VK 321 28	62341

d) laterally magnetised

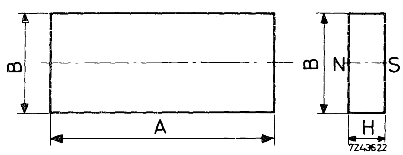
dimensions						magnetisation	type number	catalog number
outer diam.		inner diam.		H				
mm	tol.	mm	tol.	mm	tol.			
24	−0.05	10	±0.5	21.25	±0.45	8 poles on outer ø	VK 375 14	4312 020 62471
24	−0.04	12	±0.3	12	±0.4	16 poles on outer ø	VK 321 30	62351
29.9	−0.05	10	±0.5	18.2	±0.4	4 poles on outer ø	VK 375 23	62481
37	±0.8	25	±0.5	3.5	−0.5	4 poles on one surface	VK 321 42	62401

e) *rings for couplings (laterally magnetised)*

dimensions						*magnetisation*	*type number*	*catalog number*
outer diam.		*inner diam.*		*H*				
mm	*tol.*	*mm*	*tol.*	*mm*	*tol.*			
48	±0.05	30	±0.05	12	±0.1	14 poles on outer ø	VK 321 24	4312 020 62751
55	±0.05	15	±0.5	13	±0.1	12 poles on outer ø	VK 322 09	62431
72	±0.05	52	±0.05	12	±0.1	14 poles on inner ø	VK 322 07	62791
78	±1.5	58	±0.05	13	±0.1	12 poles on inner ø	VK 322 08	62421
86	+0.2	32	±0.5	23	±0.1	8 poles on outer ø	VK 322 10	62441
120	±0.5	96	−0.2	23	±0.1	8 poles on inner ø	VK 323 00	62451

Blocks

Material: Fxd 100

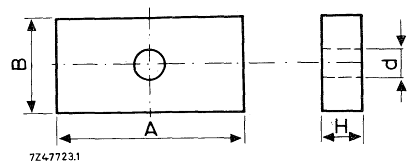


magnetised ⊥ *A* × *B*

dimensions						*type number*	*catalog number*
A		*B*		*H*			
mm	*tolerance*	*mm*	*tolerance*	*mm*	*tolerance*		
50	±1.25	22	±0.55	5	±0.1	VK 312 02	4312 020 66981
40	±1	25	±0.75	10	±0.1	VK 312 10	66931
40	±1	17	±0.4	4	±0.1	VK 312 04	66971
28	−0.5	13	−0.5	3.5	+0.5	VK 312 13	66751
15	±0.5	15	±0.5	5	±0.3	VK 312 08	66951
8	±0.5	8	±0.5	5	±0.5	VK 312 11	66771
10	±0.5	5	±0.5	3	±0.5	VK 312 12	66761

Blocks with holes

Material: Fxd 100

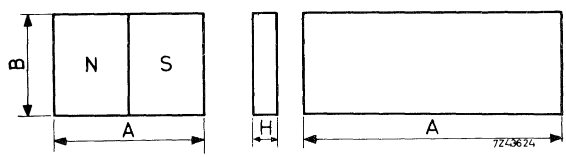


magnetised ⊥ A × B

dimensions								type number	catalog number
A		B		H		D			
mm	tolerance	mm	tolerance	mm	tolerance	mm	tolerance		
25	±0.4	15	±0.3	5.5	±0.3	4.6	±0.25	VK 312 20	4312 020 66711
25	±0.4	12	±0.3	5	±0.3	4.6	±0.25	VK 312 21	66901

Blocks

Material: Fxd 100

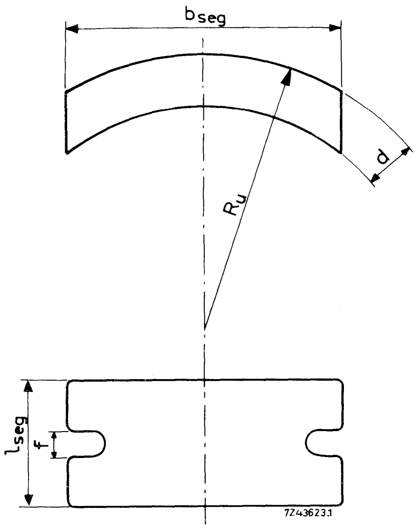


laterally magnetised

dimensions						magnetisation	type number	catalog number
A		B		H				
mm	tolerance	mm	tolerance	mm	tolerance			
18	±1	7	±1	6	±1	2 poles on 18 × 6	VK 303 01	4312 020 66801
20	±0.35	10	±0.25	4	±0.25	2 poles on 20 × 10	VK 312 14	66741
75	±2	15	±0.4	4	±0.05	8 poles on 75 × 15	VK 303 02	66861

Segments

Material: Fxd 100



not magnetised

type number		**VK 360 04**	
catalog no.		**4312 020 61501**	
		mm	*tolerance*
dimensions	R_u	54.55	+2.5
	b_{seg}	54	±0.5
	l_{seg}	27	±0.3
	f	5.2	+0.5
	d	7.4	±0.2

ISOTROPIC PLASTIC-BONDED FERROXDURE

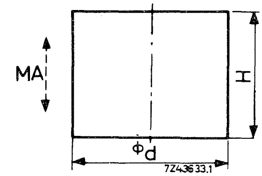
Material: see below
Direction of magnetisation: see below
Version: magnetised

article	*dimensions*	*material*	*direction of magnetisation*	*catalog number*
Strip	$(9\pm0.3)\times(3\pm0.1)$	P40	2 poles lateral	4312 020 70021
Ring	$\varnothing(21.5+0.3)\times(16-0.25)\times(12+0.4)$	D55	2 poles radial	4312 020 72011
Block	$(10.6-0.6)\times(10.6-0.6)\times(3\pm0.15)$	P30	diametrical	3122 104 93541
Bar	$\varnothing(5\pm0.2)\times(40-1)$	P30	axial	3122 104 90361

ANISOTROPIC "TICONAL"

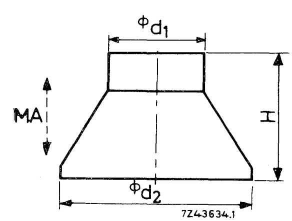
Slugs (I)

Material: see below
Direction of magnetisation: axial
Version: unmagnetised



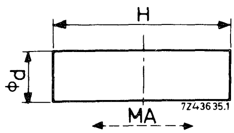
dimensions				material	type number	catalog number
d		H				
mm	tolerance	mm	tolerance			
9.1	+0.2	5	−0.05	"Ticonal" 750	—	4322 059 75001
9.1	−0.1	10	−0.05	,, 750	—	75011
12.9	−0.3	10	−0.05	,, 750	—	75061
15.1	−0.03	11.5	±0.05	,, 750	—	75041
15.8	−0.1	13.4	±0.1	,, 750	—	75031
16.4	±0.3	13.4	−0.1	,, 650	3C 010 33	65021
18	−0.4	12	−0.1	,, 600	3C 010 18	60001
19.4	±0.3	9.4	±0.1	,, 750	—	75081
19.4	±0.3	15.4	−0.1	,, 650	3C 010 32	65031
19.4	±0.3	15.4	±0.1	,, 750	—	75071
21	±0.5	16	±0.05	,, 600	3C 007 45	60011
21	±0.5	22.5	±0.05	,, 600	3C 010 30	60041
24.2	−0.4	16	±0.05	,, 600	3C 009 96	60021
27.5	±0.5	18.5	±0.05	,, 600	3C 007 46	60031

Slugs (II)



dimensions						material	type number	catalog number
d1		d2		H				
mm	tolerance	mm	tolerance	mm	tolerance			
13.2	−0.5	18	−0.5	13	±0.05	"Ticonal" 600	3C 007 44	4322 059 60051
18	−0.3	26	±0.5	17.5	±0.05	600	3C 010 35	60061

Rods

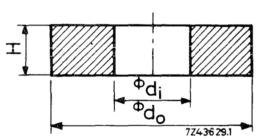


Material: Ticonal 500
Direction of magnetization: axial
Version: see below

dimensions				*version*	*type number*	*catalog number*
d		*H*				
mm	*tolerance*	*mm*	*tolerance*			
4	±0.2	6	±0.2	unmagnetised	3C 009 80	4322 059 50071[1]
5	±0.3	13	±0.1	unmagnetised	3C 010 16	50081
5	±0.3	19.5	±1	magnetised	3C 009 82	50091
5.5	−1	25	±0.5	magnetised	3C 001 24	50101[1]
8.1	−1	65	±0.5	magnetised	3C 002 36	50111[1]

[1] Bars in these diameters can be supplied in any length between 8 and 100 mm.

Rings



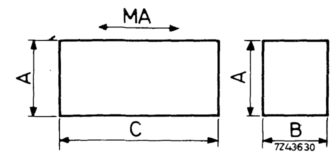
Material: see below
Direction of magnetisation: see below
Version: see below

dimensions						*material*	*d/m*	*version*	*type number*	*catalog number*
outer diam.		*inner diam.*		*H*						
mm	*tol.*	*mm*	*tol.*	*mm*	*tol.*					
18.1	+0.1 −0.2	5	+1	10	−0.05	"Ticonal"600	a	unmagnetised	3C 010 36	4322 059 60071
30	±0.5	7	±0.5	25	±0.2	400	a	magnetised	3C 000 60	40001
56	±0.5	48	±0.5	10	±0.5	400	d	unmagnetised	3H 717 83	40011

d/m = direction of magnetisation
d = diametrical
a = axial

Blocks

Material: see below
Direction of magnetization: ⊥ face A × B
Version: see below

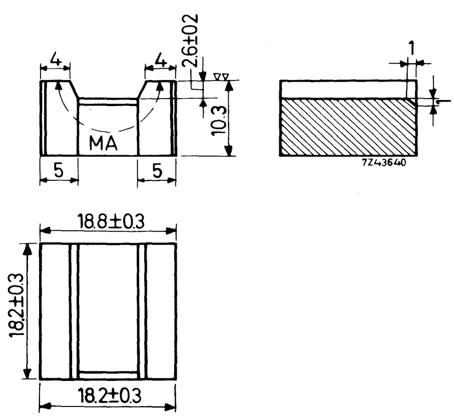


dimensions						*material*	*version*	*type number*	*catalog number*
A		*B*		*C*					
mm	*tol.*	*mm*	*tol.*	*mm*	*tol.*				
2	±0.05	2.6	±0.05	2.25	−0.03	"Ticonal"900	unmagnetised	—	4322 059 90002
4	±0.05	4	±0.05	5	±0.02	,, 900	unmagnetised	—	90011
8	−1	5	−0.4	14	−1	,, 400	magnetised	3H 717 36	40021
27	−1	20	±0.5	17	±0.05	,, 450	unmagnetised	3C 009 94	45031
21.5	±0.5	14.5	±0.5	22	+0.2	,, 500	magnetised	3C 000 59	50121
100	±1	12	±0.1	29.1	±0.05	,, 500	unmagnetised	3C 000 09	50131[1]
22	±0.3	9.1	−0.4	40	±0.1	,, 500	magnetised	3C 008 40	50141
32	±0.5	20.8	±0.5	40	±0.05	,, 500	unmagnetised	3C 005 06	50151[2]
10	±0.5	5	±0.5	50	±1	,, 500	magnetised	3C 002 02	50161
10.5	±0.2	17	±0.3	40	±0.05	,, 500	unmagnetised	3C 010 46	50171

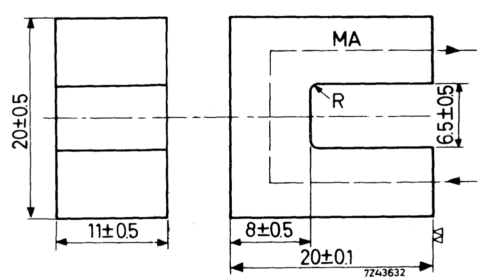
[1] with two mounting holes. [2] with one mounting hole.

Special types

Type number: 3C010.25 (unmagnetised)
Catalog number: 4322 059 10001
Material: "Reco I"
Version: unmagnetised



Type number: 3C009 72.1 (unmagnetised)
Catalog number: 4322 059 400 31
Material: "Ticonal" 400
Version: unmagnetised



DESIGN ADVISORY SERVICE

Our Application engineers offer technical assistance on the use and design of permanent magnets and complete permanent-magnet systems. Guidance is also offered on ancillary problems such as installation, handling and magnetisation. If you require more specific information than is provided here please send your enquiry to us.

When ordering new types of magnet, the following information should be given:

(1) The purpose for which the magnet is to be used should be stated.

(2) A sketch or drawing of the magnet should be provided showing the shape and the dimensions, with tolerances.

(3) The pole faces that have to be ground must be clearly indicated.

(4) The direction of the magnetic axis should be clearly shown.

(5) It should be stated whether the magnet is to be supplied magnetised or unmagnetised. (It is usual to supply magnets unmagnetised as the most efficient use of magnetic materials necessitates magnetisation in position after assembly.)

(6) The quantity required and the desired rate of delivery should be stated.

THEORY OF PERMANENT MAGNETS

The magnetic quantities are expressed in the MKSA system of units (V, A, s, m) or in the cgs system of units (Gs, Oe).

When a magnetic material is subjected to a magnetising field, the extent of the resulting magnetisation of the material will depend on the nature and immediate history of the material, and on the direction and magnitude of the magnetising field.
This dependence will be explained by describing the magnetic changes in a permanent magnet material accompanying a complete cycle of magnetisation and demagnetisation (hysteresis loop), and also the changes accompanying smaller variations in field strength (recoil line).

HYSTERESIS LOOP

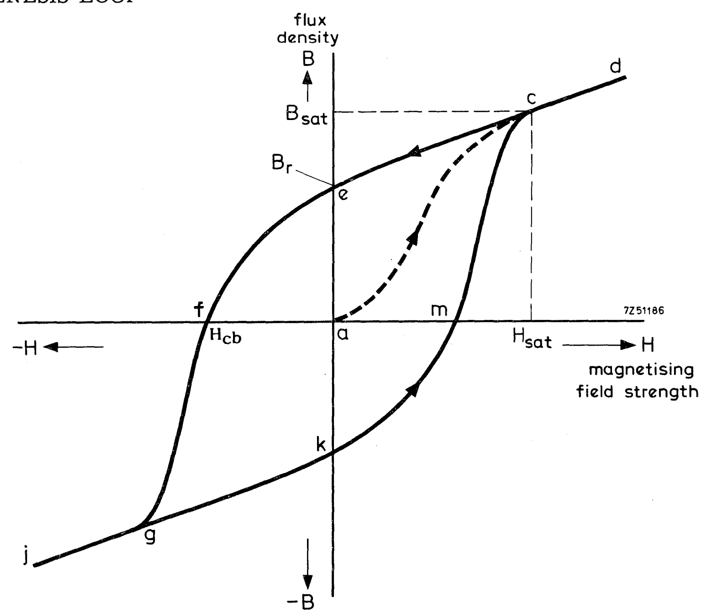


Fig.1. Hysteresis loop, variation of flux density with applied magnetising field strength.

If the material is assumed to be completely unmagnetised before the magnetising field is applied, then the state of the material can be represented by the point a on the graph of Fig.1, which shows the variation of flux density B in the material with magnetising field strength H applied to the material. If H is increased steadily from zero, the corresponding values of B will increase in accordance with the "virgin magnetising curve" ac. If H is increased further, B will increase linearly, the slope of the straight line being constant. Point c corresponds to the magnetic saturation of the material. The material no longer contributes to the increase in flux density, the further increase in B being attributable entirely to the relationship between the magnetising field strength and the flux density of the free space coincident with the magnetic material ($\frac{dB}{dH} = \mu_0$). The point c is defined as the point of magnetic saturation.

Saturation field strength H_{sat}

This is the minimum field strength that has to be expended to reach the region of magnetic saturation. Here we have

$\frac{dB}{dH} = \mu_0$, provided $H \geqq H_{sat}$.

μ_0 = 1 gauss/oersted or $4\pi.10^{-7}$ Vs/Am.

Saturation induction B_{sat}

This is the value of the induction corresponding to H_{sat}.

If after saturation has been reached, H is steadily reduced, the value of B corresponds to the curve ce. When H is zero, flux density corresponding to ae resides in the material. This residual flux density is termed the remanence B_r of the material.

Remanence B_r

This is the induction of a magnet remaining in a closed magnetic circuit if after attaining of the saturation state the field strength returns to zero (point of intersection of the hysteresis loop with the B-axis).
The units for the induction are Vs/cm^2 or gauss.
1 gauss = 10^{-8} Vs/cm^2
= 10^{-4} Vs/m^2

When the magnetising field is reversed and is increased steadily in the opposite direction, the flux density decreases along the "demagnetisation curve" ef. At f, the flux density is zero, and the corresponding field strength is defined as the coercive force H_{cb} of the material.

Demagnetisation curve

The operating range of permanent magnets lies in the second quadrant of the hysteresis loop. This part is the demagnetisation curve.

Coercive force (coercivity) H_{cb}

This is the magnetic field strength at which the induction of a magnet previously magnetised up to saturation becomes zero (point of intersection of the demagnetisation curve with the H-axis).
The units for the field strength are A/m, A/cm or oersted.

1 oersted = 0.796 A/cm = 79.6 A/m
1 A/cm = 1.26 oersted

Permanent magnets have a high coercive force, i.e. broad hysteresis loops, while magnetically soft materials have a small coercive force. The difference may be greater than three powers of ten.

As the magnetising field strength is increased beyond H_{cb}, the flux density increases in the opposite direction along the curve fg. The point g is reached which corresponds to magnetic saturation in the opposite sense to that occurring at c.

Any further increase in the magnetising field gives rise to increases in B corresponding to the straight line gj. This again represents the linear relationship between the flux density in the free space coincident with the material and the magnetising field strength.

If after saturation in the negative direction is reached, the magnetising field is reduced to zero, the flux density follows the curve gk. If the magnetising force is again reversed, the flux density follows the curve kmc, so that the loop cefgkmc is completed.

The area of the hysteresis loop indicates the energy expended in completing the magnetisation cycle. The slope of the hysteresis loop at any point is defined as the differential permeability of the material at that point.

The initial slope of the virgin magnetisation curve gives the initial permeability of the material. The slope of curve when saturation is reached is the permeability of the vacuum in the magnetic material.

Differential permeability

(Absolute) differential permeability	μ'_d	$= \frac{dB}{dH}$ at points lying on the hysteresis loop (in Vs/Am or Gs/Oe)
(Relative) differential permeability	μ_d	$= \frac{1}{\mu_0}\frac{dB}{dH}$ at points lying on the hysteresis loop (dimensionless)
Initial permeability	$\mu_{d\,o}$	$= \mu_d$ at origin of virgin magnetisation curve
(Absolute) permeability of vacuum, magnetic constant	μ_0	$= 4\pi.10^{-7}$ Vs/Am $= 1$ Gs/Oe

INTRINSIC HYSTERESIS LOOP

The flux density plotted in Fig.1 is the algebraic sum of the intrinsic flux density B_i of the material and the flux density B_o of the space that the material occupies.

$$B = B_i + B_o = B_i + \mu_0 H$$

B_i is also called magnetic polarisation.
If B_i is plotted against H, the effect of B_o is excluded, and the resultant loop is shown in Fig.2 together with the B-H loop.

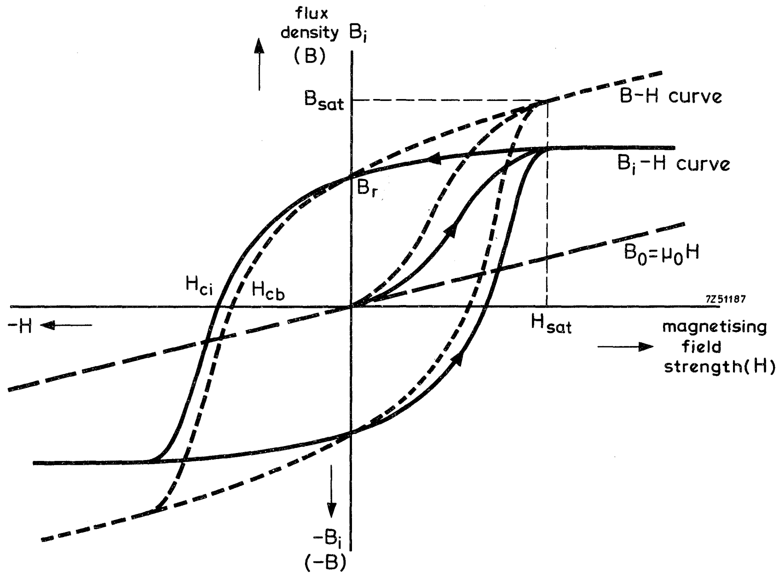


Fig.2. Comparison of variations of flux density and intrinsic flux density with applied magnetising field strength.

At saturation, the intrinsic hysteresis curve is horizontal. For zero applied field, the intrinsic flux density equals the flux density, and equals the remanence of the material. The magnetising field required to remove the intrinsic flux density is shown by the intersection of the curve and the horizontal axis. This field strength - the intrinsic coercive force H_{ci} - is greater than the coercive force H_{cb}. The difference between H_{cb} and H_{ci}, however, depends on the shape of loop: if the loop cuts the horizontal axis at a small angle, the difference will be significant; if the loop cuts at an angle approaching 90^o, it will be negligible.

Intrinsic coercive force H_{ci}

This is the magnetic field strength at which the intrinsic flux density (magnetic polarisation) of a magnet previously magnetised up to saturation becomes zero (point of intersection of the intrinsic demagnetisation curve with the H-axis).

DEMAGNETISATION CURVE

Complete hysteresis loops are important when considering soft magnetic materials, but with hard or permanent magnetic materials, it is the second (or fourth) quadrant that is of importance to the designer. The second quadrant shows the response of the magnetised material to demagnetising forces, and is therefore called the demagnetisation curve.

A typical normal demagnetisation curve for permanent magnetic materials is shown in Fig.3. Also shown in Fig.3 is a curve indicating the variation of the product BH with B. The product BH indicates the energy available in the material for a given value of B. It can be seen that a maximum value of BH-product exists, and this is designated $(BH)_{max}$. This maximum corresponds to a flux density of B_d and demagnetising field strength H_d and these, in general, represent the ideal operating point for the most efficient use of the material under static conditions.

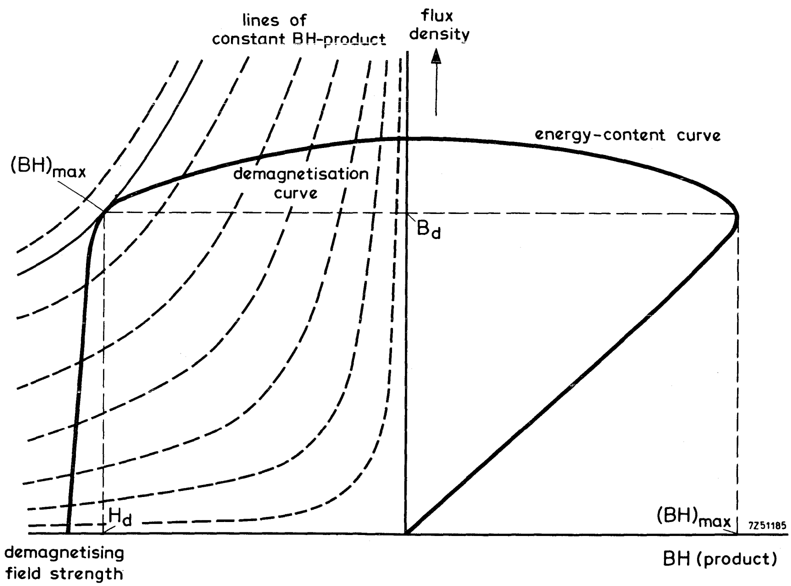


Fig.3. Demagnetisation curve with contours of constant BH-product, and energy-product curve.

Maximum energy product $(BH)_{max}$.

This is the maximum product of the flux density and field strength of a permanent magnet attained on the demagnetisation curve. The maximum energy in the field external to the magnetic material, per unit volume of the permanent magnet, is:

$$\frac{(BH)_{max}}{2}$$

The units of $(BH)_{max}$ are mWs/cm^3 or gauss-oersted

$1\ mWs/cm^3 = 1.26 \times 10^5$ gauss-oersted

1 gauss-oersted $= 8 \times 10^{-6}\ mWs/cm^3$

The values of B and H at $(BH)_{max}$ are designated B_d and H_d.

Energy content can also be represented by contour lines of constant BH-product superimposed on the demagnetisation curves. The maximum energy product of a material occurs at the point on the demagnetisation curve where a contour line would just touch it.

RECOIL LINE

The demagnetisation curve of a permanent magnetic material is a smooth curve indicating the decrease in flux density with a steadily increasing demagnetising field. If a constant demagnetising field is applied to the magnetic material, the corresponding value of flux density can be obtained from the curve. However, under practical conditions, the demagnetising field will probably not be constant. Small variations can be caused by small local magnetic fields, and large variations can occur in motors and generators (which are subject to varying armature reaction and can even have their armatures removed completely). It is therefore necessary to study the effects of such variations in the demagnetising field.

If a demagnetising field of strength H_1 is applied to magnetic material which has been saturated, the flux density will fall from its remanence value B_r to some value B_1 which corresponds to the point A_1 on the demagnetisation curve of Fig.4.

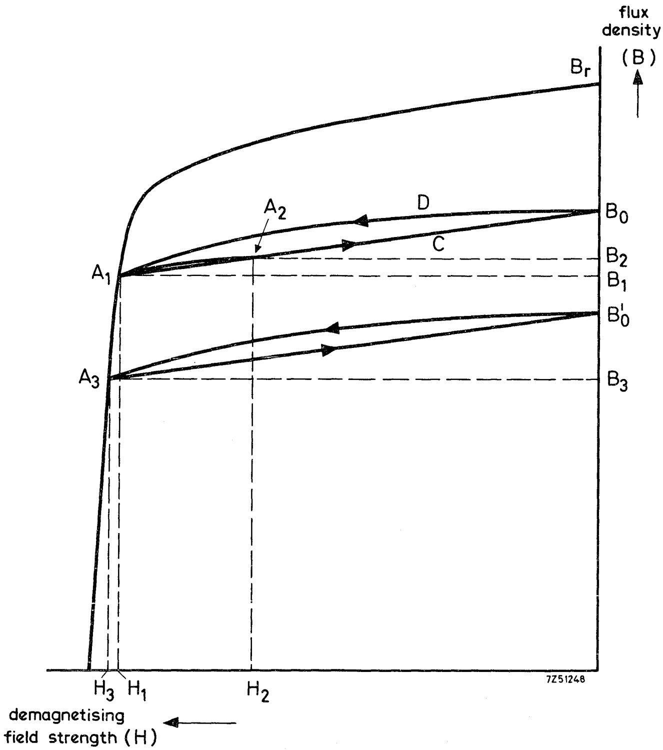


Fig.4. Recoil lines.

If H is reduced to zero, the flux density does not follow the demagnetisation curve back to the starting point, but follows a path A_1CB_0 which leaves the demagnetisation curve abruptly. If H_1 is now restored, the flux density follows the path B_0DA_1 which ends in A_1, but which deviates from the path A_1CB_0.

The loop $A_1CB_0DA_1$ so formed constitutes a minor hysteresis loop of the material. If the demagnetising field strength H_1 is only reduced to some value H_2 instead of being removed completely, and is then restored, another minor hysteresis loop is formed ($A_1A_2A_1$). For permanent magnetic materials, these minor hysteresis loops are very slender, and can be considered to form the straight line joining A_1 and B_0. This line is called a recoil line. The slope of the recoil line is the recoil permeability. It can be shown that the slope of a recoil line is approximately equal to the slope of the demagnetisation curve at its intersection with the vertical axis.

Recoil line

Actually a very narrow hysteresis loop which touches the demagnetisation curve, if at all; it is traversed during a limited variation of the demagnetising field strength in a permanent magnet.

Recoil permeability or reversible permeability μ_{rec} or μ_{rev}

The relative permeability corresponding to the slope of the recoil line.

$$\mu_{rec} = \frac{1}{\mu_0} \frac{\Delta B}{\Delta H_{rec}}$$

If the demagnetising field strength H_1 is increased to some value H_3, the operating point will move along the demagnetisation curve to the point A_3 corresponding to a flux density of B_3. Reduction of the demagnetising field strength to H_1 does not restore the working point to A_1, but moves it along another recoil line $A_3B'_0$, parallel to A_1B_0. Any reduction in H_3 will only cause the working point to move along the recoil line: the point A_1 can only be regained by resaturating the material and then applying the demagnetising field strength H_1.

The effects of increases in the demagnetising field when the operating conditions of the material correspond to a point on the demagnetisation curve are thus irreversible (except by the expedient of resaturation), so in designs where a high degree of magnetic stability is required it is usual to operate on a recoil line. A demagnetising field greater than that likely to be encountered in normal use is applied, and this is then reduced to the normal working value (stabilisation). Fluctuations in the demagnetising field will then only cause fluctuations of the working point along a recoil line.

TEMPERATURE COEFFICIENT

To characterise the behaviour of the material of a permanent magnet with changes in temperature the temperature coefficient of the remanence or of the coercive force is indicated in percent per degree

$$TC\ B_r = \frac{1}{B_r} \frac{dB_r}{dT} \times 100\ \%/\text{deg C}$$

$$TC\ H_{cb} = \frac{1}{H_{cb}} \frac{dH_{cb}}{dT} \times 100\ \%/\text{deg C}$$

CURIE TEMPERATURE AND TRANSITION TEMPERATURE

At the Curie temperature the material becomes practically non-magnetic, and the magnetism can only be restored by renewed magnetisation below this temperature. At the transition temperature the crystal structure is changed (e.g. formation of mixed crystals); this also leads to irreversible changes of the magnetisation, but these cannot be nullified by renewed magnetisation. The limit for the practical application of permanent magnet materials is in specific cases set by whichever of these temperatures is the lower.

MAGNETIC CIRCUIT DESIGN

Dimensions of magnet

The principal object of magnet circuit design is to provide efficiently a specified magnetic field in a given load (or air gap). The design of the circuit is governed by the required field strength, the dimensions of the air gap, the flux leakage from the surfaces of the magnet and the reluctance of the assembly.

In the simple circuit of Fig.5, A_g and L_g are the area (assumed equal to that of the pole pieces) and length of the air gap respectively, and A_m and L_m are the area and length of the magnet necessary to produce the required gap field strength H_g.

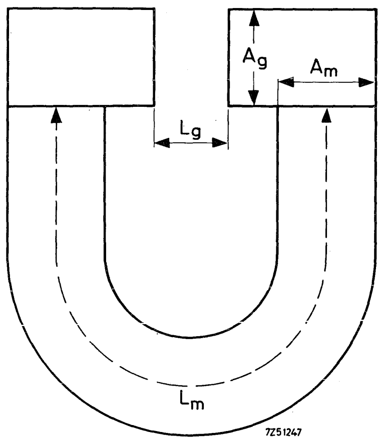


Fig.5. Simple magnetic circuit

If, initially, flux leakage is neglected, then all lines of flux in the magnet cross the air gap. Therefore the total flux in the gap equals the total flux in the magnet. By definition, total flux equals the product of flux density and area. Thus:

$$B_mA_m = B_gA_g,$$

where B_g and B_m are the flux densities in the gap and magnet respectively. Since for an air gap, $B_g = \mu_0H_g$, this equation can be written:

$$B_mA_m = \mu_0H_gA_g. \qquad (1)$$

NOTE: When B is expressed in gausses and H in oersteds, then μ_0 = 1 gauss/oersted; when B is expressed in Vs/m^2 and H in A/m, the $\mu_0 = 4\pi.10^{-7}$ Vs/Am.

Magnetic flux is produced by magnetomotive force, and the ratio between m.m.f. and flux is termed the reluctance of the magnetic circuit. (This relationship is the magnetic analogy of Ohm's Law, flux, m.m.f., and reluctance corresponding to current, voltage, and resistance respectively.) In the cgs system the m.m.f.

between two points is the work done in moving unit magnetic pole between two points. It is thus the product of the force exerted on unit pole (that is, the field strength) and the distance through which the pole moves. In Fig.5 the m.m.f. across the air gap is thus the product of the field strength H_g in the gap and the length L_g of the gap. The m.m.f. across the magnet is similarly the product of the field strength H_m in the magnet and the length L_m of the magnet. If there is no leakage from the surfaces of the magnet these values of m.m.f. are equal. Therefore:

$$H_m L_m = H_g L_g. \qquad (2)$$

Equations (1) and (2) give the formulas for the design of magnetic circuits, assuming no flux losses. In practice, a loss or leakage factor must be introduced into each equation. The practical design equations thus become:

$$B_m A_m = p\mu_0 H_g A_g \qquad (3)$$

and

$$H_m L_m = q H_g L_g \qquad (4)$$

where p and q represent the loss or leakage factors.

Leakage factor

The total flux in a magnetic circuit is made up of the useful flux and the leakage flux. A certain amount of leakage can never be avoided completely, and it becomes appreciable particularly in a magnetic circuit with small magnetic conductance of the air gap. In the calculation of a magnet the leakage is taken into account by the leakage factor

$$p = \frac{\text{total flux required}}{\text{useful flux in air gap}}$$

The leakage factor p in the equation (3) varies widely from one application to another. It will be a minimum when the magnet is as close to the working gap as possible. The precise calculation of p is extremely difficult, and an acceptable estimate must be based on experience. As a guide, some typical leakage factors are given in the following table.

Application	approximate leakage factor
Loudspeaker with "Ticonal" centrepole magnet 19 mm ($^3/4$ in) speech coil up to 6.5 kGs	2
Loudspeaker with "Ticonal" centrepole magnet 25 mm (1 in) speech coil up to 8 kGs	2
Loudspeaker with ferroxdure ring magnet 36 mm ($1\frac{1}{2}$ in) speech coil up to 15 kGs	2

Application	approximate leakage factor
Loudspeaker with ferroxdure ring magnet 61 mm ($2\frac{1}{2}$ in) speech coil up to 14.5 kGs	2
Loudspeaker with "Ticonal" ring magnet 25 mm (1 in) speech coil up to 12 kGs	3
Loudspeaker with "Ticonal" ring magnet 25 mm (1 in) speech coil up to 16 kGs	6
Loudspeaker with "Ticonal" ring magnet 36 mm ($1\frac{1}{2}$ in) speech coil up to 16 kGs	5
Moving coil meter using "Ticonal" rectangular magnets	3
Moving coil meter using "Ticonal" semicircular magnets	2
Moving coil meter using "Ticonal" internal core magnet	1.5
Motors using ferroxdure segments	1.1
Motors and generators, "Ticonal" two-pole type	2
Motors and generators, "Ticonal" four-pole type	4

The loss factor q in equation (4) is attributable to unwanted reluctances in series with the useful air gap. Compensation for these can generally be effected by assuming a value of q of about 1.1 (thus increasing the required length of magnet by 10%).

Equations (3) and (4) can be rewritten as:

$$A_m = \frac{p \mu_0 H_g}{B_m} \cdot A_g, \qquad (5)$$

and

$$L_m = \frac{q H_g}{H_m} \cdot L_g. \qquad (6)$$

The product of equations (5) and (6) gives:

$$V_m = \frac{pq \mu_0 H_g{}^2 V_g}{B_m H_m}, \qquad (7)$$

where V_m and V_g are the volumes of the magnet and gap respectively.

For a given magnetic material, and therefore a given demagnetisation curve, an infinite number of combinations of length and area of magnet can be chosen for a given volume by varying the point $B_m H_m$ on the demagnetisation curve. However, the minimum volume of material will be given when the product $B_m H_m$ is a maximum. Thus the most efficient use of the material is obtained by operating at the design points B_d and H_d, corresponding to maximum BH-product, $(BH)_{max}$.

Thus for greatest efficiency, the design equations become;

$$A_m = \frac{p\mu_0 H_g}{B_d} \cdot A_g, \tag{8}$$

and

$$L_m = \frac{q H_g}{H_d} \cdot L_g, \tag{9}$$

Equations (3) and (4) can be combined to give:

$$B_m = \left\{ \frac{p}{q} \cdot \frac{A_g}{A_m} \cdot \frac{L_m}{L_g} \right\} \cdot \mu_0 H_m, \tag{10}$$

which can be represented as the straight line OP_1 (load line), superimposed on the demagnetisation curve in Fig.6, having a slope

$$\text{cotg}\ \alpha = \frac{B_m}{H_m} = pA_g L_m \mu_0 / q A_m L_g. \tag{11}$$

The intersection of the load line and the demagnetisation curve, P_1, is the working point which, if the design is for maximum efficiency, will be the point having the coordinates B_m, H_m = B_d, H_d.
However, operation on the demagnetisation curve does not give maximum stability: for highly stable operation the working point should lie on a recoil line.

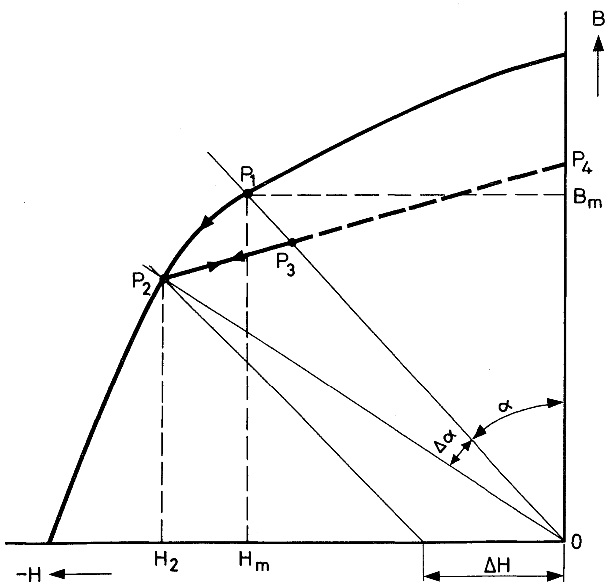


Fig.6. Demagnetisation curve with load line and recoil line.

VARIABLE WORKING POINT AND STABILISATION

If the dimensions of a magnet and its air gap are given, the working point on the demagnetisation curve is fixed. However changes in the dimensions of the air gap bring about changes in the slope of the load line (see equation 11), but the occurrence of an additional magnetic field (ΔH in Fig.6) causes the load line to be shifted to a parallel position, so that the working point moves, for example, to P_2 on the demagnetisation curve. If the change is reversed again, the working point returns along the recoil line; the new working point then lies at P_3, the point of intersection of this line with the old load line. (The slope of the recoil line equals $\mu_0 . \mu_{rec}$.)
For adequate stabilisation, a stabilising demagnetising force should be applied to the magnet greater than the maximum demagnetising influences likely to be encountered during normal operation.

Note: As long as the change from P_1 to P_2 takes place along the straight part of the demagnetisation curve, the working point P_3 will not differ appreciably from P_1.
It is therefore sometimes worth while to let the load line not pass through the point of $(BH)_{max}$ but to choose a smaller angle α, in order to remain always within the straight-line region of the curve. Especially with permanent magnets which will be magnetised outside their system or which may be taken out of their system it is then necessary to investigate whether, after assembly, the new working point will still lie on the straight part of the demagnetisation curve.

Changes in the induction will also take place on account of temperature changes below the Curie or transition temperatures, and are determined by the temperature coefficient. Such a change of the induction with temperature is only reversible within a certain temperature region. The irreversible changes may become particularly great if the working point on account of the temperature changes moves down beyond the knee of the demagnetisation curve. For this reason it is often advisable to arrange for the working point, by means of appropriate dimensioning of the system, to lie sufficiently far above the knee.

SYMBOLS

A_g = cross sectional area of the air gap perpendicular to the lines of flux

A_m = cross sectional area of permanent magnet perpendicular to direction of magnetisation

B = (magnetic) flux density/(magnetic) induction/normal induction

B_d = flux density at the point $(BH)_{max}$ on the demagnetisation curve

B_g = flux density (induction) in the air gap

$(BH)_{max}$ = maximum energy product/peak energy product

B_i = intrinsic flux density, intrinsic induction

B_m = flux density (induction) in the magnet

B_r = residual flux density, residual induction, remanence

B_{sat}, B_s = saturation flux density/saturation induction

F_m = magnetomotive force/magnetic potential difference

H = magnetising force/magnetising field strength/magnetic intensity

H_{cb} = coercive force/coercivity

H_{ci} = intrinsic coercive force/intrinsic coercivity

H_d = demagnetising force at $(BH)_{max}$ on the demagnetisation curve

H_g = magnetising force (field strength) in the air gap

H_m = demagnetising force (field strength) in the magnet

H_{sat}, H_s = magnetising force required for saturation/saturation field strength

L_g = length of the air gap parallel to the lines of flux

L_m = effective magnetic length of magnet

N = total number of turns

P = permeance

P_c = core loss

P_e = eddy current loss

P_h = hysteresis loss

R_m = reluctance

μ = permeability/normal permeability

μ_d = differential permeability

μ_{d_o} = initial permeability

μ_{rec}, μ_{rev} = recoil permeability/reversible permeability

μ_Δ = incremental permeability

$\emptyset$ = magnetic flux/total flux

APPLICATIONS OF PERMANENT MAGNETS

CLASSIFICATION ACCORDING TO MAGNETIC FUNCTION

As a rule, permanent magnets function as energy transducers which transfer energy from one kind into another, without permanently losing energy of their own. In keeping with this, permanent magnets may be classified as follows.

Magnets for the transfer of

- electrical energy into mechanical
  such as in motors, meters, loudspeakers, beam deflectors, mass spectrometers;
- mechanical energy into electrical
  such as in generators, alternators, cycle dynamos, microphones, phonographic pick-ups, electric stringed instruments, magnetic detectors;
- mechanical energy into other mechanical energy
  such as for attraction and repulsion, holding and lifting (e.g. in industrial and household appliances, separators, chucks, thermostats, toys, etc.);
- mechanical energy into heat
  such as in hysteresis-torque and eddy-current instruments, e.g. speedometers, brakes of watt-hour meters, balances, etc.
- A fifth group of magnets accomplish special effects such as the Hall effect, magnetic resistance and nuclear magnetic resonance.

EXAMPLES OF INDUSTRIAL USE

There is practically no industrial sector in which some means equipped with permanent magnets is not used. A few examples:

The ceramics industry	- separators.
Shipbuilding	- welding terminals.
Navigation	- attachment of rust-preventing anodes.
Typography	- magnetic cylinders for iron/rubber blocks.
Mining	- separators; non-skid cable wheels.
Rolling mills	- conveyors; plate lifters.
Office machines	- paper guides and holders.
Cattle raising	- garbage separation.
Foods and allied products	- separators.
Oil trade	- filling machines.
Machining	- chucks.
Miscellaneous	- clocks and watches.

ENUMERATION OF APPLICATIONS

Electrotechnical

Measurement and control

Galvanometers
Ammeters
Voltmeters
Fluxmeters
Photometers
Tachometers
Speedometers
Kilowatt-hour meters
Recording instruments
Vibrographs
Oscillographs
Cardiographs
Seismographs
Pressure gauges

Switchgear

Spark extinguishers

Motors and generators

Alternators
Magnets for IC engines
Cycle dynamos
Hand dynamos
Hysteresis motors
Synchronous motors
Clock motors
D.C. shunt motors
Screenwiper motors
Fan motors
Toy motors
Aeronautic motors and generators
Gyroscopes
Electrodynamic tachometers
Pulse generators

Electro-acoustics and communications

Tone generators
Telephones
Hearing aids
Cutting heads
Pick ups
Stringed instruments
Tape recorders
Dictaphones
Magnetrons
UHF directional isolators

Radio and TV

Loudspeakers
Transformers
Vibratory convertors
Picture tubes
Focusing units

Applied physics

Scientific

Magnetostrictive devices
Resonance measurements
Resistance modification

Industrial

Compass compensation
Material selection
Hardness testing
Film-thickness measurement
Crack detection
Polarity indicators
Water softening

General

Compasses
Coin check in vending machines
Replacement of springs
Magnetizing yokes

Mechanical

Measurement and control

- Flow meters
- Level indicators
- Maximum thermometers
- Thermocouples
- Eddy-current brakes
- Valves

Consumer goods

- Visual demonstration
- Calendars
- Card-index systems
- Guides of many kinds
- Lamp holders
- Inspection lamps

Switchgear and connectors

- Switches
- Microscopy
- Buttons
- Couplings
- Pumps
- Calorimeters
- Mixers
- Drives through a wall
- Frictionless drives
- Centrifugal couplings
- Polarized contacts

Industrial

- Holding devices
- Plate lifters
- Conveyors
- Drain plugs
- Filters
- Separators
- Floor cleaners
- Indicating boards
- Frictional brakes
- Hammers
- Screwdrivers
- Refrigerators

Miscellaneous

Accessories

- Cigarette holders
- Name plates
- Parking plates
- Soap holders
- Tin openers

Medical

- Extraction of steel splinters
- Blood testing
- Prothesis

Toys

- Toys of all kinds
- Draughtsmen
- Chessmen

Sundries

- Magnetic drags
- Veterinary uses (cow's stomach)

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PERMANENT MAGNET MATERIALS

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Printed in Holland

32-570-BE