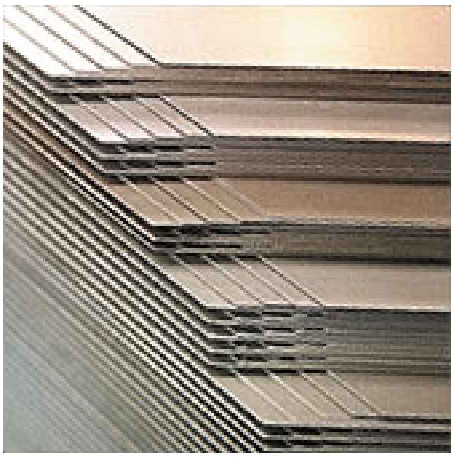
Material guarantees

ELECTRICAL PROPERTIES OF AVAILABLE GRADES IN CRGO MATERIAL

Material guarantees



Wiltan specialises in the manufacture and supply of all types of wound cores in cold rolled Grain Oriented Silicon Steel, Nickel-iron and Cobalt-iron (amorphous). We are able to manufacture and supply a comprehensive selection of core shapes and sizes, both cut and uncut to British, American and Continental specifications as well as custom designed or customer specified designs.

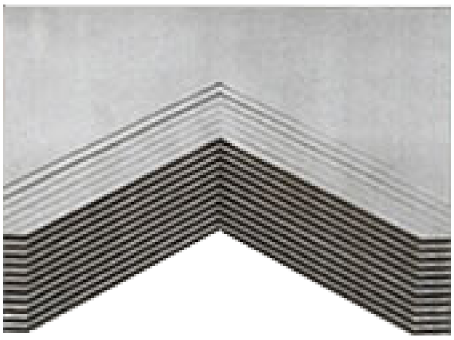
Grain Oriented Silicon Steel (GOSS / CRGO) is a 3% silicon iron, cold reduced to develop a high degree of grain orientation which gives numerous advantages when compared with laminated cores:

1. Up to 30% more flux for the same magnetising force.
2. Increased rating for a given size of transformer.
3. Better regulation.
4. Reduction in size and weight.
5. Reduced assembly time, storage and handling costs.

Normally, Wiltan silicon-steel cores are produced in three material thicknesses: 0.3mm for frequencies up to 200Hz, 0.1mm for frequencies between 200Hz and 2kHz; and 0.05mm for higher frequencies and pulse applications.

However, these are only standard thicknesses; the table below shows all the available grades and corresponding gauges:

MATERIAL GRADE BS 601	MATERIAL GRADE EN 10107	MATERIAL THICKNESS	SPECIFIC TOTAL LOSS* (50HZ)	
			W/kg @ 1.5T	W/kg @ 1.7T
23Z LASER	M075-23P	0.23mm	-	0.75
23Z	M085-23P	0.23mm		0.85
27M0H	M103-27P	0.27mm	-	1.03
30M1H	M111-30P	0.30mm	-	1.11
30M2H	M117-30P	0.30mm	-	1.17
27M4	M089-27N	0.27mm	0.89	1.40



Nickel-iron (including Mu-Metal and Permalloy) is a lower loss, higher permeability material when compared to silicon steel. Nickel-iron is preferred at higher frequencies or for high-fidelity applications up to 10kHz and is available in thicknesses of 0.2mm, 0.1mm and 0.05mm.

Cobalt-iron (amorphous) material provides the highest permeability and lowest core loss. Cobalt-iron is recommended for high frequency (up to 1MHz), low power applications such as high fidelity audio or communications. Wiltan are manufacturers and suppliers of Logicor amorphous cores; we will be happy to provide any information you may need if you contact us be email or telephone.

Non Grain Oriented Silicon Steel (NGOSS / CRNGO) is also available in a variety of formats. Please contact us for more information.

All our cores are suitable for various electronic and measuring applications and our technical staff will be happy to provide solutions to any enquiry.

Engineering section

APPLICATION OF ‘C’ CORES IN SMALL POWER TRANSFORMERS

Engineering section

To assist the Designer in the selection of core pattern, the following table gives a list of Transformers, each utilising two ‘C’ Core loops in shell configuration. The working peak flux density is taken at 1.7 Tesla throughout, and the current density chosen to produce a temperature rise of 60ºc above an ambient of 35ºc, with non-impregnated windings. The winding space is adequate for two 240V interleaved windings of round wire insulated to withstand 2,000V test.

At the smaller end of the range, Transformer design is usually limited by consideration of the voltage drop on load (regulation), and so the output values shown may not be attained. These figures may also be reduced by requirements of lower temperature rise, more insulation, or lower flux density to accommodate frequency and voltage fluctuations, etc. On the other hand, the output may be increased by a choice of higher flux density, better cooling due to winding impregnation, or better class of insulation.

An outline procedure is therefore given, showing how these designs may be modified.

The following symbols are used: -

Vp - Primary voltage (volts)
Ip - Primary current (amps)
Vs - Secondary voltage (volts)
Is - Secondary current (amps)
Rp - Primary winding resistance (ohms)
Rs - Secondary winding resistance (ohms)
N - No. of turns
Pcu - Power losses in copper (watts)
Pfe - Power losses in core (watts)
Δ - Current density (amps per mm^2)
Bm - Peak flux density (Tesla)
E - Regulation (percent)
η - Efficiency (percent)
Afe - Nett cross sectional area of core (cm^2)
p - Specific resistivity (ohms – mm^2/mm)

Procedure

a) Select design which shows power capacity more than sufficient for required Transformer. (See Table on page 43)

b) Consider the working flux density. If there is an overvoltage requirement or limitation on idling current, reduce the flux density (Bm) to a suitable value (refer to characteristic curves) and correct the power capacity figure prorata. Otherwise, for intermittent operation, or less demanding applications, consider raising Bm to 1.8 Tesla or higher.

c) If 60° temperature rise is too high, current density must be reduced. A reduction of 20% will keep the temperature rise to below 40 °C, and in most cases allow the use of Class A insulating materials. Correct the rated power, also the regulation and copper losses, for the new current density.

d) If extra insulation or higher voltage is needed, or if multiple tappings are specified, the rated power figure must be reduced to allow space for this.

e) Check that the voltage regulation is acceptable. If necessary, reduce the rated output in the proportion required to bring the regulation to the required value.

f) Read estimated efficiency η and calculate the primary current:

$$Ip = \frac{VA\ (output)}{Vp} \times \frac{100}{\eta}$$

where Ip = primary current
Vp = primary voltage

Select primary wire size, using Ip and value of current density given in table (corrected if necessary).

$$Acu = \frac{Ip}{\Delta}$$

g) Read volts per turn Vt from table, correcting for new flux density if necessary:

$$Vt\ (corrected) = Vt \times \frac{Bm}{1.7}$$

Determine the number of primary turns:

$$Np = \frac{Vp}{Vt}$$

h) From wire tables, the required primary winding space can be found and the primary resistance calculated.

i) Similar calculations for the secondary are made, making approximate corrections for the voltage drop, thus: -

No. of secondary turns

$$Ns = \frac{Vs}{Vt} \times \frac{100}{100 - E}$$

Where E = Regulation %
Vs = Secondary voltage on load

j) Having selected wire size appropriate to secondary current at density D, the resistance of the secondary winding can be estimated with the help of wire tables, or calculated by the formula: -

$$R = p \times \frac{L}{S}\ \text{ohms}$$

Where L = total length of winding wire in metres.
p = Specific resistivity of copper
(0.0175 ohms – mm^2/mm at 20°C
or 0.021 ohms-mm^2/mm at 50 °C)

S = Cross sectional area of wire in mm^2

k) Knowing primary and secondary resistances, the copper losses and regulation can be verified.

This procedure assumes a resistive load but can be used for transformers supplying reactive loads, providing consideration is given to leakage reactance. This can be minimized by the careful disposition of the windings together with a choice of lower operating flux density.

Reducing the flux density to 1.6 or 1.5 Tesla will also ease problems with inrush currents, stray magnetic fields and acoustic noise.

Example

Required 60VA Transformer 240V input, 50Hz.
48V output, 1.25A resistive load
% Regulation 10% max.
Efficiency 85% min.

a) Try pair of HWR 30/16 cores
b) Assume Bm = 1.7 Tesla
c) Class E insulation, therefore, 60ºc rise is permissible.
d) For 10% regulation, output of 70VA at 18% regulation

Suggested in table on page 43 must be reduced to $70 \times \frac{10}{8} = 38.9$VA

As this is now insufficient.

a) Try pair of HWR 30/20 cores
Output will be $85 \times \frac{10}{15} = 57$VA

Current density will reduce to $3.5 \times \frac{57}{85} = 2.35$

b) By raising Bmax to 1.8 Tesla output may be increased to $57 \times \frac{1.8}{1.7} = 60$VA

c) Iron losses will rise to 2.5 Watts/Kg. As seen from characteristic curves giving total iron loss of 1.83 Watts. Copper losses, how–ever will fall to $\frac{57}{85} \times 10.3 = 6.9$ watts, so temperature rise will be less than 60° C.

d) No extra insulation is needed, so winding space is adequate.

e) Regulation is now estimated 10%.

f) Efficiency will now be $\frac{60}{60 + 1.83 + 6.9} = 87\%$

Therefore, Primary VA = $60 \times \frac{100}{87} = 69$VA

$Ip = \frac{69}{240} = 0.29$ Amps

at $\Delta = 2.35$ amps/mm^2, wire area will be 0.123 mm^2, say, 0.4mm dia.

g) Volts per turn at 1.8 Tesla are $.216 \times \frac{1.8}{1.7} = 0.229$ volts

Therefore, No. of turns Np = $\frac{240}{0.229} = 1{,}048$ turns.

Mean length of turn = $\frac{12.3 + 21}{2} = 16.65$ cms.

Total length of wire -= 1,048 x 16.65 x 10-2 = 175 metres.
From wire tables, resistance Rp = 24 Ohms.

h) No. of turns on Secondary Ns = $\frac{48}{0.229} \times \frac{100}{90} = 233$ turns

i) Secondary wire size will be $\frac{1.25}{2.35} = 0.532$ mm^2, say 0.8mm dia.

Length of wire = 16.65 x 233 = 38.5 Metres.
From wire tables, Resistance Rs = 1.32 Ohms.

j) Total copper losses = $Ip^2\ Rp + Is^2\ Rs$
= 2.01 + 2.06 = 4.07 watts
Iron loss = 1.83 watts

Therefore, efficiency $\frac{60}{60 + 1.83 + 4.07} \times 100 = 91\%$.

TRANSFORMER DESIGN DATA HWR RANGE ‘C’ CORES @ 17,000 GAUSS, 50HZ

Core Ref. HWR	Output Rating VA	Current Density A/mm2 Δ	Mag. VA	Iron Loss Watts Pfe	Copper Loss Watts Pcu	Volts Per Turn Vt	% Regulation E	& Efficiency *n*	Mean length of Turn (cm)	
									Inner	Outer
10/8	17	5.0	3.0	0.4	7.2	0.072	38	69	7.9	14.5
10/12	26	4.8	4.5	0.6	7.5	0.11	27	76	9.1	15.8
10/16	32	4.4	6.0	0.8	7.1	0.145	24	80	10.4	17.1
10/24	40	4.0	9.0	1.2	7.16	0.218	20	82	13.0	19.7
30/8	38	4.4	4.2	0.6	9.2	0.088	26	79	8.6	17.1
30/12	53	4.0	6.4	0.9	11.4	0.13	20	81	9.8	18.4
30/16	70	3.8	8.5	1.25	11.3	0.174	18	83	11.0	19.7
30/20	85	3.5	10.6	1.55	10.3	0.216	15	86	12.3	21.0
40/12	63	3.6	7.0	1.08	13.0	0.13	18	82	9.8	20.4
40/16	80	3.4	9.0	1.35	13.2	0,175	14	84	11.0	21.7
40/20	95	3.0	11.5	1.7	12.0	0.216	12	87	12.3	23.0
40/24	120	2.9	13.5	2.05	11.5	0.26	11	89	13.6	24.3
50/14	120	3.1	11.5	1.85	18.0	0.202	12	86	11.7	24.3
50/18	150	3.0	15.5	2.4	17.0	0.26	11	88	13.0	25.6
50/24	210	2.8	20	3.2	15.0	0.348	10	91	14.9	27.5
50/32	270	2.6	27	4.2	16.0	0.464	9	93	17.4	30.0
70/12	210	2.8	15	2.45	26.0	0.216	9	88	12.3	29.0
70/18	320	2.5	22	3.65	24.5	0.326	7	92	14.2	30.9
70/24	390	2.3	29	4.9	22.0	0.382	6	94	16.1	32.8
70/32	490	2.2	39	6.5	22.0	0.58	5	94	18.7	35.3
90/16	420	2.6	27	4.65	40.0	0.346	6	91	15.4	35.8
90/24	630	2.4	40	7.0	39.4	0.52	5	93	18.0	38.2
90/32	810	2.2	54	9.4	36.4	0.695	4	94	20.9	41.1
90/44	1050	2.0	74	12.7	34..0	0.955	4	95	24.7	44.9
110/20	1000	2.0	55	10.1	50.8	0.58	4	94	19.9	45.6
110/32	1600	1.8	88	16.2	48.0	0.93	3	93	24.1	49.7
110/64	2700	1.5	176	22.2	44.0	1.28	3	95	34.5	60.0

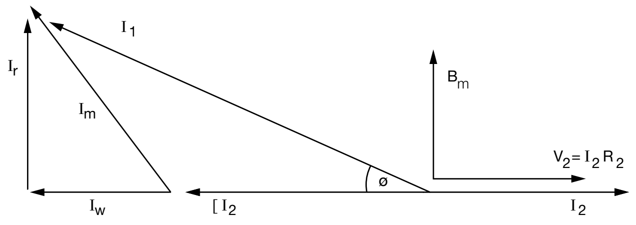
CURRENT TRANSFORMER DESIGN GUIDE

An effective design of a Ring Type C.T. may be produced first time, using the following procedure, without any previous experience.

Principles

In operation, the C.T. will induce current in its secondary winding and burden which serves to completely oppose the magnetising effect of the primary current, except for that small proportion required to magnetise the core. This core magnetising component will then be the only source of error if the secondary current is to be used as a measure of the primary current.

Making two assumptions, ie, that the C.T. has no leakings reactance and that its burden is purely resistive, the vector diagram for a one-to-one ratio CT will look like this.



Where N_2 = No of secondary Turns
V_2 = Secondary Voltage
R_b = Burden Resistance
I_l = Primary Current
I_2 = Secondary Current
I_m = Excitation Current
I_r = Reactive component of I_m
I_w = Watt loss of component I_m
e = Ratio Error

From this diagram the primary current I_1 differs from the secondary I_2 in magnitude and phase angle. The angle error θ is Sin –1 Ir/I 1 and the magnitude of $I_1 = [\,(I_2\,N_2 + I_w)^2 + I_r{}^2]^{½}$

In practice, the angle θ is so small as to allow the approximations $I_1 = I_2N_2 + I_w$ and $\theta = I_r/I_1$ radians, i.e. the current error is due to the watt loss component of the excitation current and the phase error is proportional to the reactive component I_r. The ratio error can be corrected by an amendment to the turns ratio, the secondary winding being reduced by several turns or fractions of a turn. Because of the non-linearity in the excitation characteristics, such corrections do not maintain accuracy as the current changes, and a choice must be made which gives good balance over the whole range of current. Cores can be supplied with drilled holes, enabling fractions of a turn to be wound.

The phase angle error, on the other hand, cannot be corrected, being a function of the reactive component of the excitation characteristics which vary widely over the current range and must take priority in the design of the transformer and choice of core.

The procedure is best described by considering an example, as follows: -

1. **Transformer Specification**
   Ratio 150/1
   50Hz. Burden 2.5 Va at Power Factor = 1.0
   Accuracy BS.3938, Class 0.5
   Insulation level – 11 Kv.

   Maximum Permissible Error

From 10% to 20% of rated current	Ratio error Phase displacement	1% 60 minutes
From 20% to 100% of rated current	Ratio error Phase displacement	0.75% 45 minutes
From 100% to 120% of rated current	Ratio error Phase displacement	0.5% 30 minutes

2. **Internal Diameter**
   The I.D. of the core is fixed by physical consideration of the primary conductor and insulation, plus allowance for the secondary winding and core insulation. The main insulation is invariably placed on the primary conductor

so that a 20mm dia.conductor insulated for 11Kv will have an overall diameter of about 40mm. The secondary winding and core insulation for a nominal 660 volts lead to the choice of core I.D. of 60mm. Assuming a maximum O.D. of 110mm, the mean path length will then be

$$\frac{\pi\,(60 + 110)}{2} = 267\text{mm.}$$

3. **Flux Density**

The requirements of phase displacement and angle error limit the working flux density of the core. An estimate of the flux density can be made by considering one working condition, preferably one likely to be most stringent. So considering the phase displacement at the 20% full load condition:-

I_1 = 30 amps $\qquad\qquad \theta$ = 45'

From phase diagram, $\sin\theta = \dfrac{I_r}{I_1}$

$$\therefore\ I_r = I_1 \sin\theta = 30 \times .013$$
$$= 0.4\text{A}$$

$$H_r = \frac{Ir}{Lm} = \frac{.4}{.267}$$

$$= 1.5 \text{ A/M}$$

By inspection of resolved component curves for TS grade core material on page 65 – H_r = 1.5 when Bm = 60mT.

If the flux density at 20% F. L condition is chosen at 60mT, it will rise to 300mT at full load, and other points pro-rata which can now be checked for error. If for any condition the phase displacement is excessive, a lower flux density must be chosen.

Condition (% Full Load)	120%	100%	20%	10%
Primary Current I_1 (amps)	180	150	30	15
Bmax (mT)	360	300	60	30
H_R (from curves) A/m	4.5	4.0	1.5	0.95
I_R (H_R x 0.267)	1.2	1.068	0.4	0.307
θ ($\sin^{-1} I_r/I_1$)	2.3'	2.4'	45'	58.5'
Hw (from curves) A/m	5.2	4.5	1.05	0.6
Iw (Hw x 0.267)	1.39	1.20	0.28	0.16
E ($^{Iw}/I_1$ x 100) %	0.77	0.80	0.94	1.07
1 Turn Compensation %	- 0.67	- 0.67	- 0.67	- 0.67
Compensated Error e_1 %	0.1	0.13	0.27	0.4

4. Compensation

Assuming the phase angle displacements are within allowable limits, the ratio error is calculated for each condition as shown above, and a turns ratio correction is chosen which will make them acceptable. In this case, 1 turn correction is made by reducing the secondary winding to 149 turns.

5. Cross Sectional Area

Having chosen the working flux density at full load, the required cross sectional area is calculated thus: -

Voltage across Burden at full load = 2.5 volts
Allowing secondary winding resistance 0.1 ohms
then additional voltage for internal burden = 0.1 Volts
Total secondary E.M.F. = 2.6 volts
For 149 turn secondary
Volts/Turns = $\dfrac{2.6}{149}$ = 0.0175 Volts
At rated condition Bm = 0.3 Tesla
By transformer equation $\dfrac{V}{T}$ = 0.222 x Bm x Afe

$$\therefore\ \text{Nett C.S.A. Afe} = \frac{.0175}{.0222 \times 0.3} = 2.63\ \text{cm}^2$$

Allowing 0.95 space factor, Gross C.S.A. = 2.77 cm^2

6. Final Dimensions

Before fixing the final dimensions, take account of possible core degradation during winding. If protected by a case, this will be small, but it is prudent to allow 20% extra area for a core taped, wound and impregnated.

In this example, a strip width of 20mm with a build up of 17mm gives a final core dimension of

I/D - 60mm
O/D - 94mm
Length - 20mm

USEFUL MAGNETIC FORMULAE

Area of Cores with Rectangular Cross Section Afe

$$A_{fe} = E_{min} \times D_{min} \times K$$

Mean Magnetic Path Length (L_m) for 'C' Cores

$$L_m = A_{max} + B_{max} + F_{min} + G_{min} - 1.72 \left(R + \frac{E_{max}}{2}\right)$$

Core Weight (Mfe)

$$Mfe = Afe \times Lm \times 7.65 \times 10^{-6}$$

Where

Afe = Cross Sectional Area (mm^2)
L_m = Mean Magnetic Path Length (mm)
M_{fe} = Core Weight (Kg)
A = Overall Core Width (mm)
B = Overall Core Length (mm)
D = Strip Width (mm)
E = Build Up (mm)
F = Core Window Width (mm)
G = Core Window Length (mm)
R = Inner Radius (mm)
K = Stacking Factor
= 0.95 for 0.3mm strip
= 0.92 for 0.1mm strip
= 0.88 for 0.05mm strip

Permeability

$$\mu = \frac{B}{H} \quad \text{.................................(1)}$$

$$H = \frac{I \times N}{L_m} \quad \text{................................(2)}$$

$$\mu = \mu_o \, \mu_r \quad \text{................................(3)}$$

Where B = Induction in Tesla (Webers per sq. metre)
H = Magnetising force in Amps/Metre
μ = Permeability
μo = Permeability of Free Space ($4\pi \times 10^{-7}$)
μ_r = Relative Permeability
I = Current in Amps
N = Number of turns
L_m = Magnetic Path Lengths in Metres

Modules of Complex Permeability

$$\mu = \frac{B_{max}}{H_{peak}} = \frac{B_{max}}{H_{rms} \times \sqrt{2}} \text{ for sinusoidal waveform}$$

Effective Permeability p

$$p = \frac{Bmax}{H_{rms}}$$

Transformer Equation

$$V = 4 \times F \times Bm \times N \times Afe \times f$$

Where V = Rms Voltage
F = Form Factor for Voltage Wave
B_m = Maximum Induction in Tesla
N = Number of Turns
A_{fe} = Cross-section of Iron in Metres2
f = Frequency in Hertz

For 50hz sine wave, this reduces to

$$V = 222 \times Bm \times A_{fe} \times N$$

Inductance

$$\text{Inductance in Henries} = \frac{4\pi \times N2 \times Afe \times \mu_r}{10^7 \times L_m}$$

Where N = Number of turns
Afe = Cross-sectional Area of Iron M^2
μ_r = Relative Permeability
L_m = Magnetic Path Length in Metres

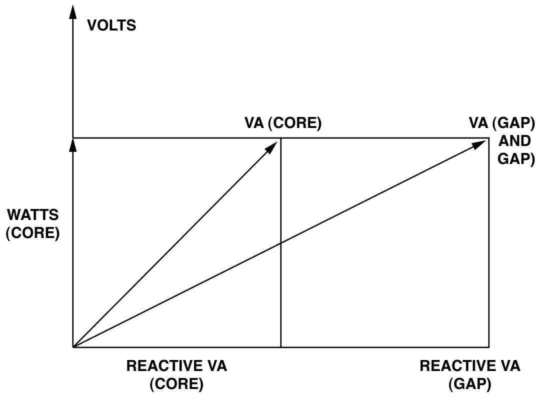
Performance curves

Performance curves

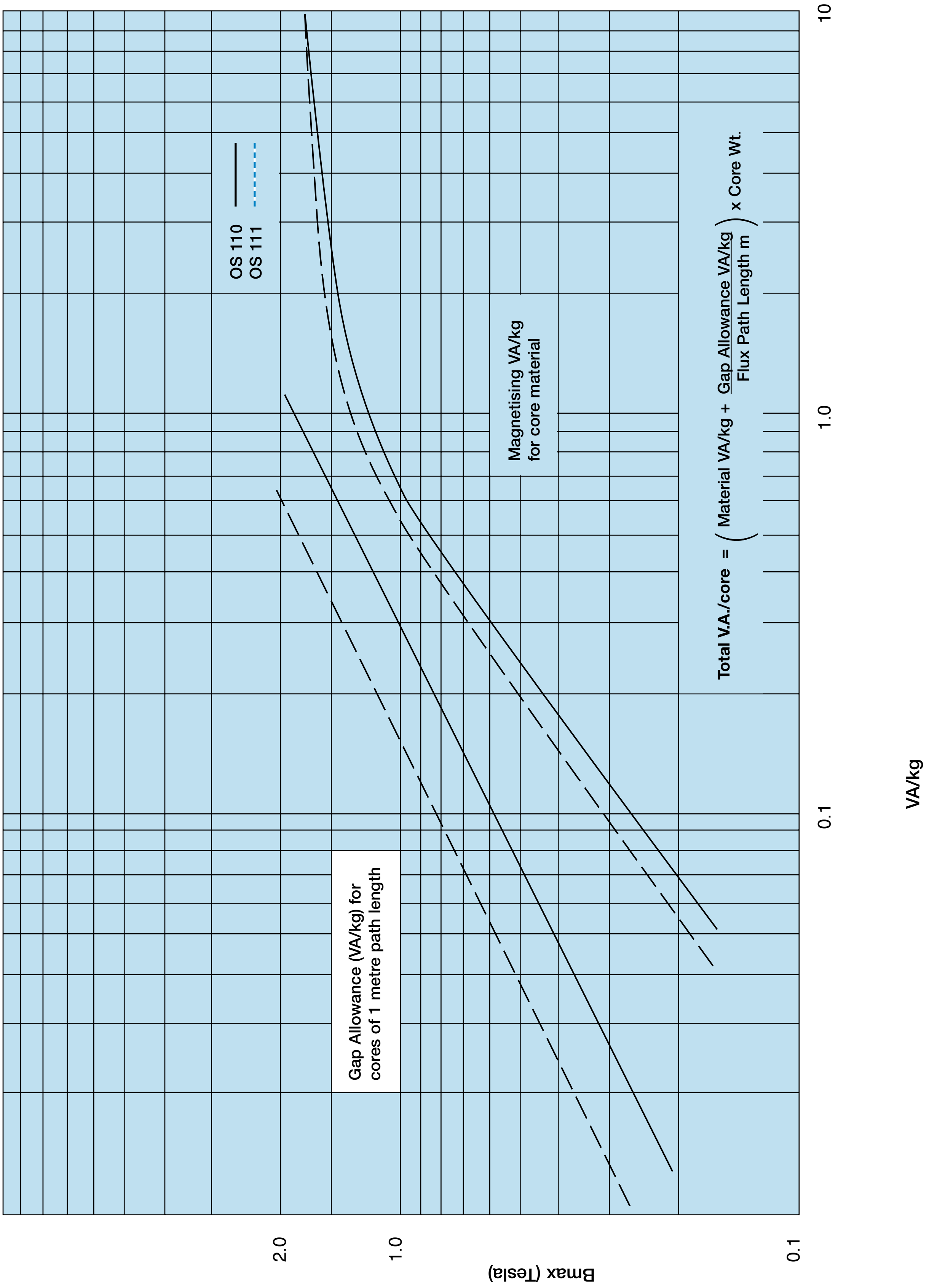
Interpretation of Loss and Magnetising VA Curves

The magnetising VA of a core is the product of the applied voltage and the total magnetising current and may be shown as a vector in phase with the current and lagging relative to the voltage. This lagging VA may be resolved into two components, the watts (in phase with the volts) and reactive VA (in quadrature). The reactive VA for the gap is the product of the voltage and the current required to produce the necessary ampere-turns to magnetise the gap and may also be shown by a vector in quadrature to the voltage. To calculate the total magnetising VA it is necessary to add arithmetically the reactive VA for the core and for the gap and add this sum vectorially to the watts.

This is true at any frequency, but at 50Hz., the magnetising VA is so nearly in quadrature that the reactive VA for the gap may be added arithmetically with negligible error. At frequencies of 400Hz. or higher this is not so and for this reason reactive and total VA curves are included in this handbook.

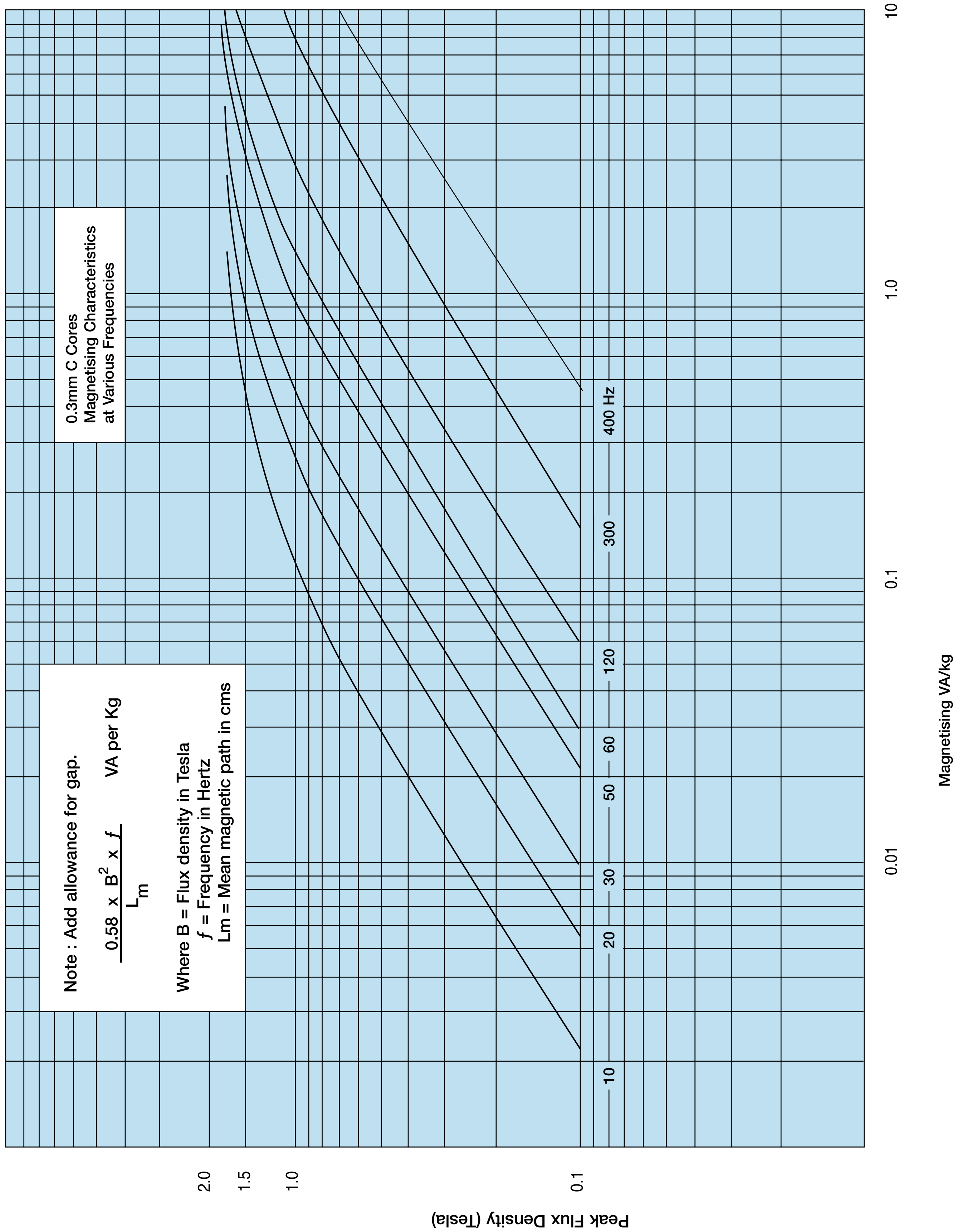


MAGNETISING CHARACTERISTICS FOR ‘C’ CORES IN 0.3mm G.O.S.S. TESTED AT 50 HZ.



$$\text{Total V.A./core} = \left(\text{Material VA/kg} + \frac{\text{Gap Allowance VA/kg}}{\text{Flux Path Length m}}\right) \times \text{Core Wt.}$$

0.3mm ‘C’ CORES - MAGNETISING CHARACTERISTICS AT VARIOUS FREQUENCIES

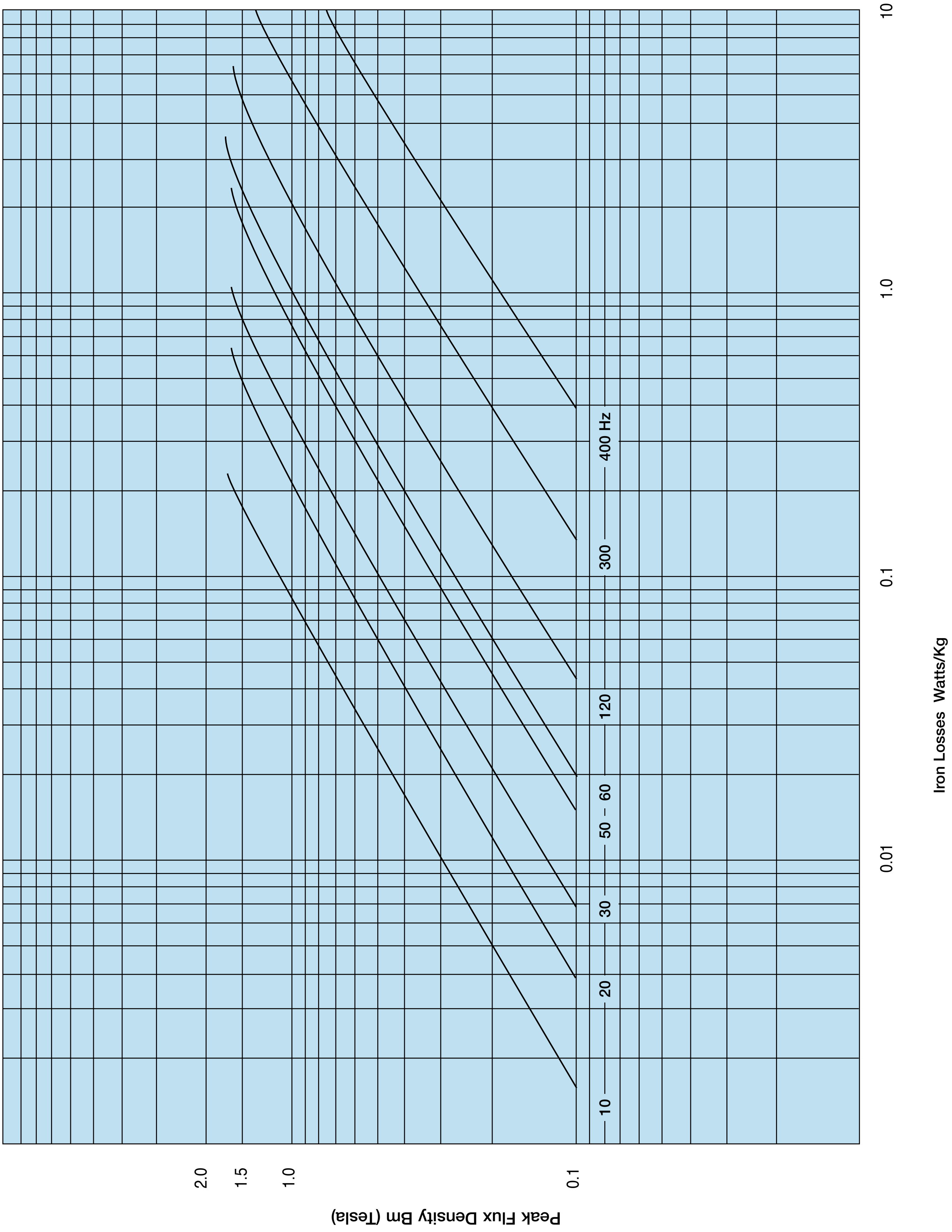


Note : Add allowance for gap.

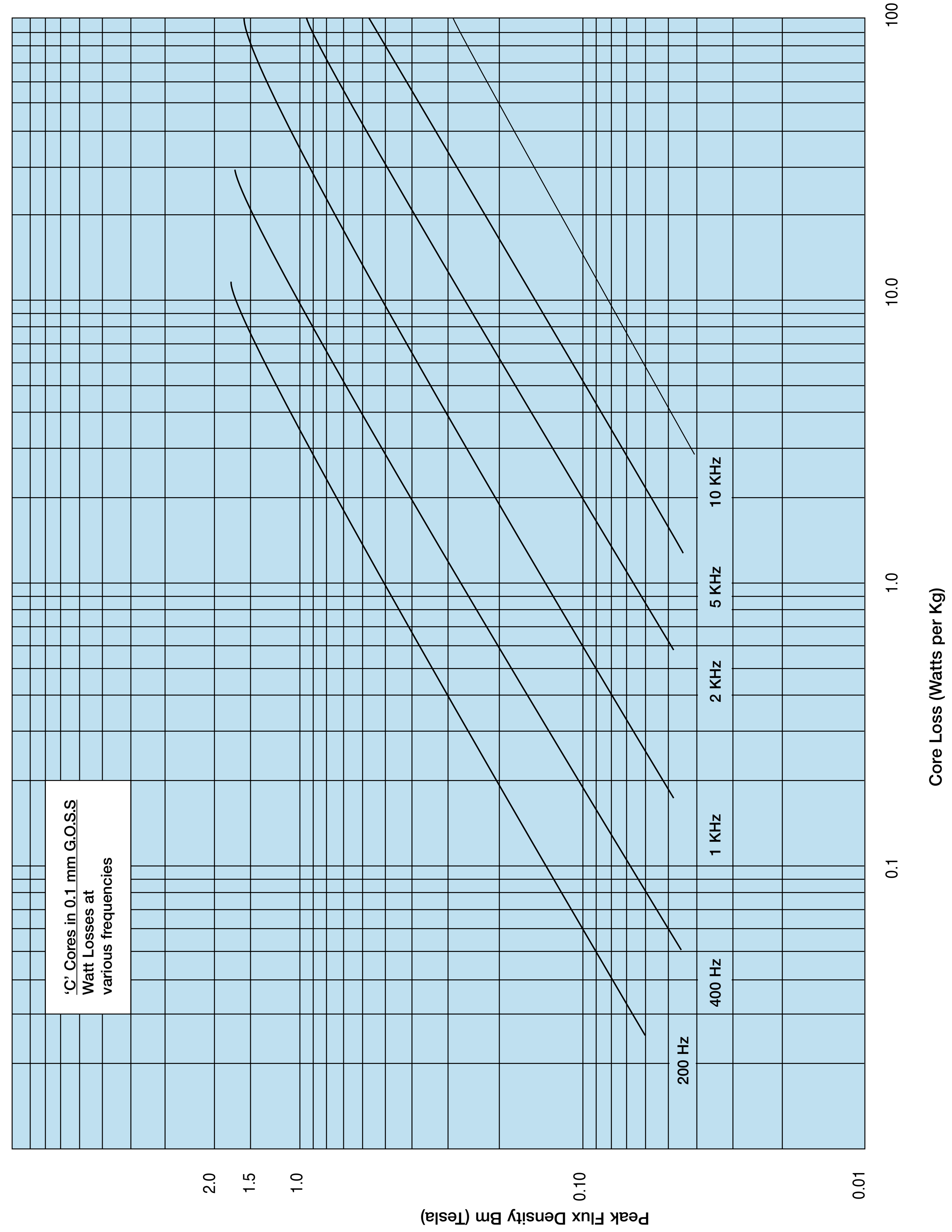
$$\frac{0.58 \times B^2 \times f}{L_m} \quad \text{VA per Kg}$$

Where B = Flux density in Tesla
f = Frequency in Hertz
Lm = Mean magnetic path in cms

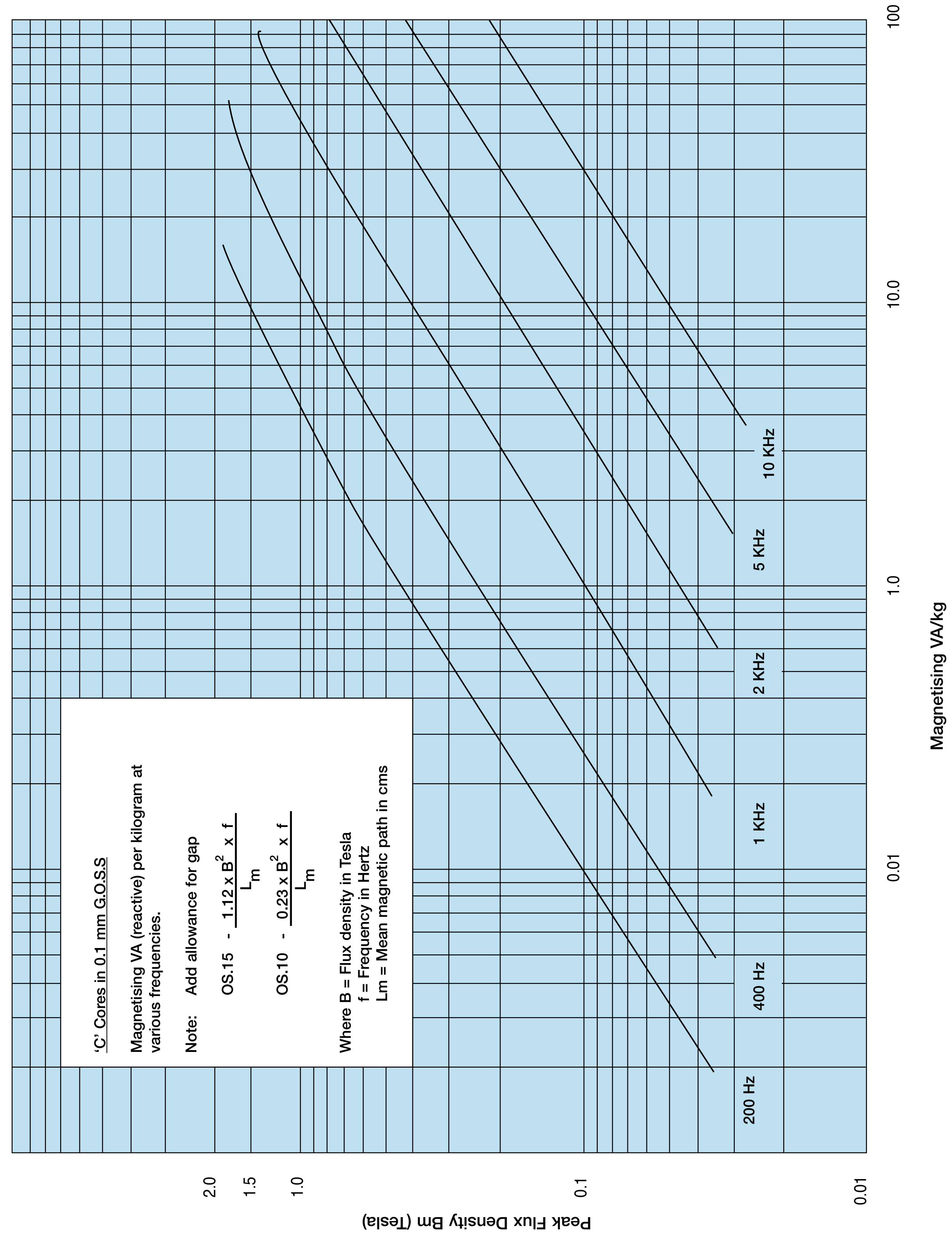
0.3mm ‘C’ CORES - LOSSES AT VARIOUS FREQUENCIES



‘C’ CORES IN 0.1mm G.O.S.S. WATT LOSSES AT VARIOUS FREQUENCIES



MAGNETISING VA/KG AT VARIOUS FREQUENCIES FOR ‘C’ CORES IN 0.1mm G.O.S.S.



‘C’ Cores in 0.1 mm G.O.S.S

Magnetising VA (reactive) per kilogram at various frequencies.

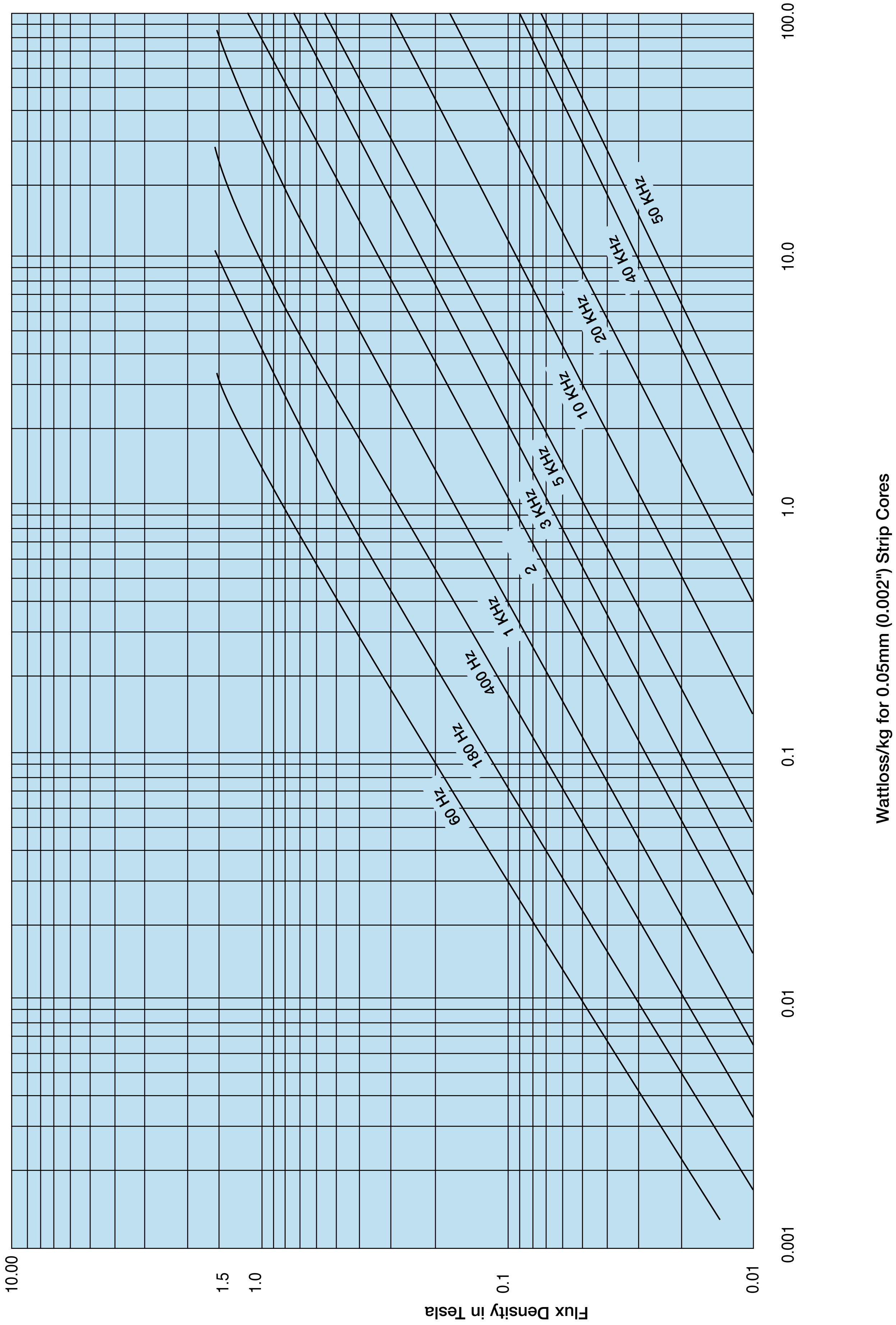
Note: Add allowance for gap

OS.15 - $\frac{1.12 \times B^2 \times f}{L_m}$

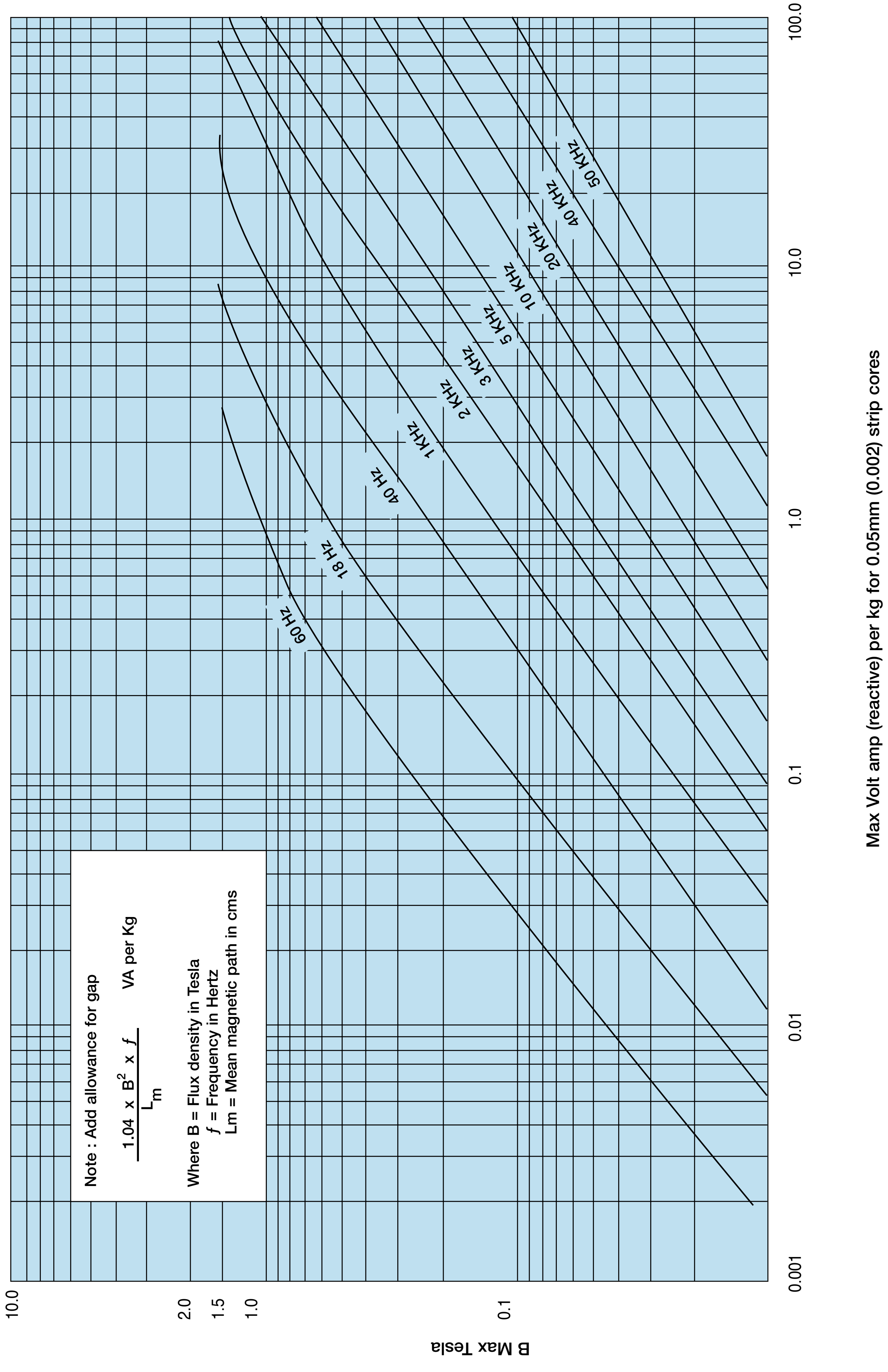
OS.10 - $\frac{0.23 \times B^2 \times f}{L_m}$

Where B = Flux density in Tesla
f = Frequency in Hertz
Lm = Mean magnetic path in cms

TOTAL IRON LOSS CHARACTERISTICS FOR CUT ‘C’ CORES IN 0.05mm (0.002") MATERIAL



TOTAL REACTIVE MAGNETISING CHARACTERISTICS FOR CUT ‘C’ CORES IN 0.05mm (0.002") MATERIAL

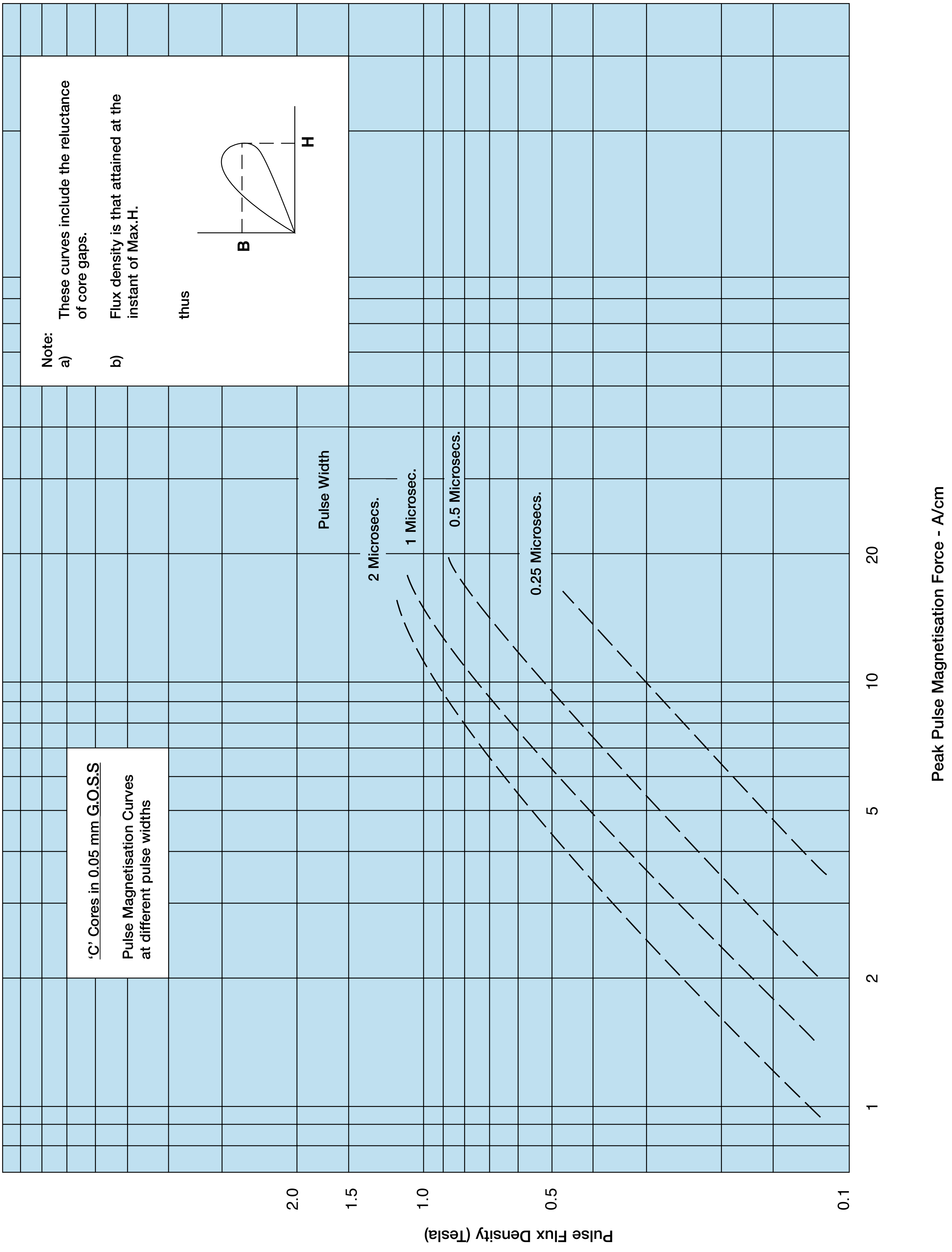


Note : Add allowance for gap

$$\frac{1.04 \times B^2 \times f}{L_m} \quad \text{VA per Kg}$$

Where B = Flux density in Tesla
f = Frequency in Hertz
Lm = Mean magnetic path in cms

‘C’ CORES IN 0.05mm G.O.S.S. PULSE MAGNETISATION CURVES AT DIFFERENT PULSE WIDTHS



‘C’ Cores in 0.05 mm G.O.S.S

Pulse Magnetisation Curves at different pulse widths

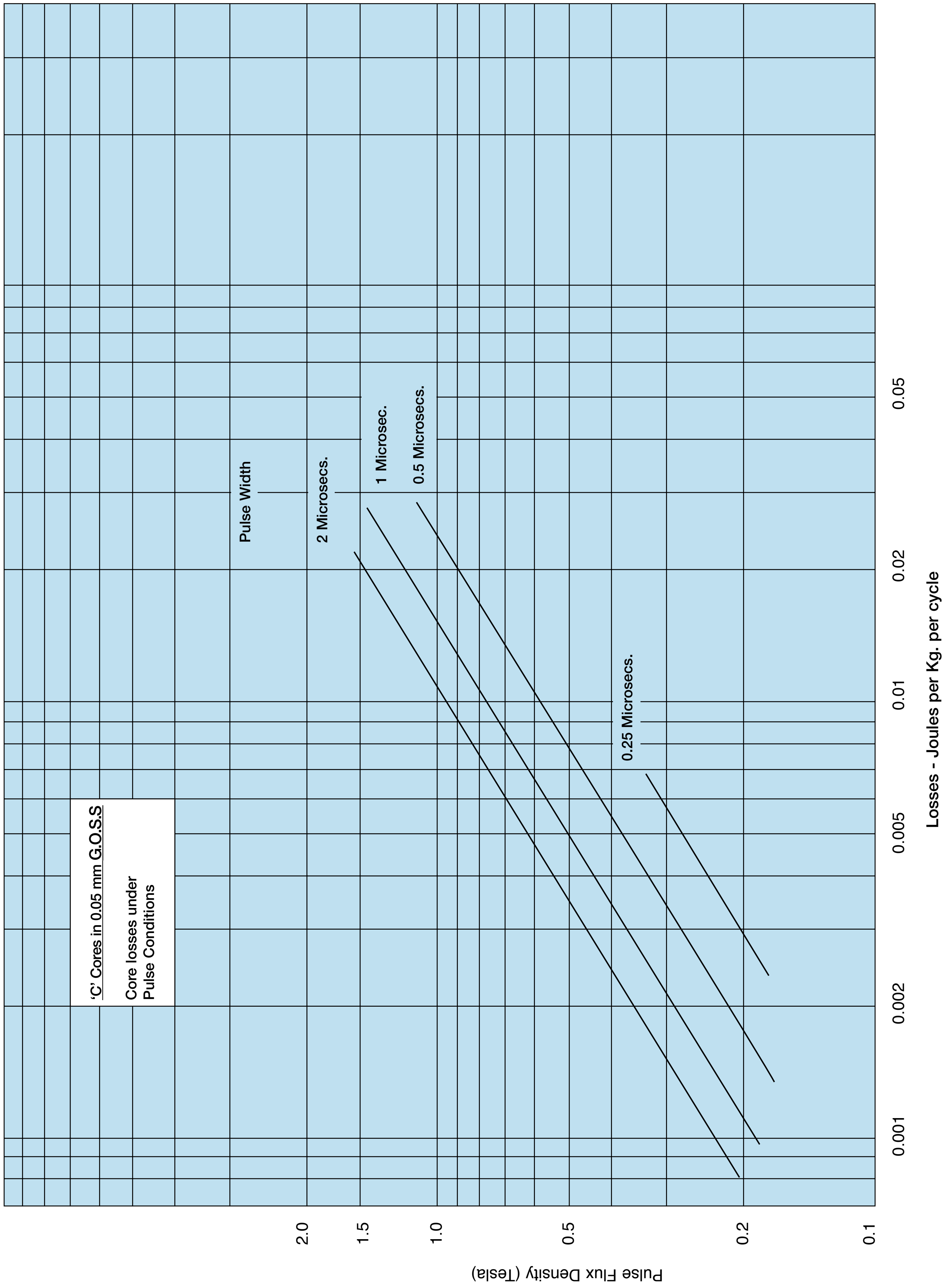
Note:

a) These curves include the reluctance of core gaps.

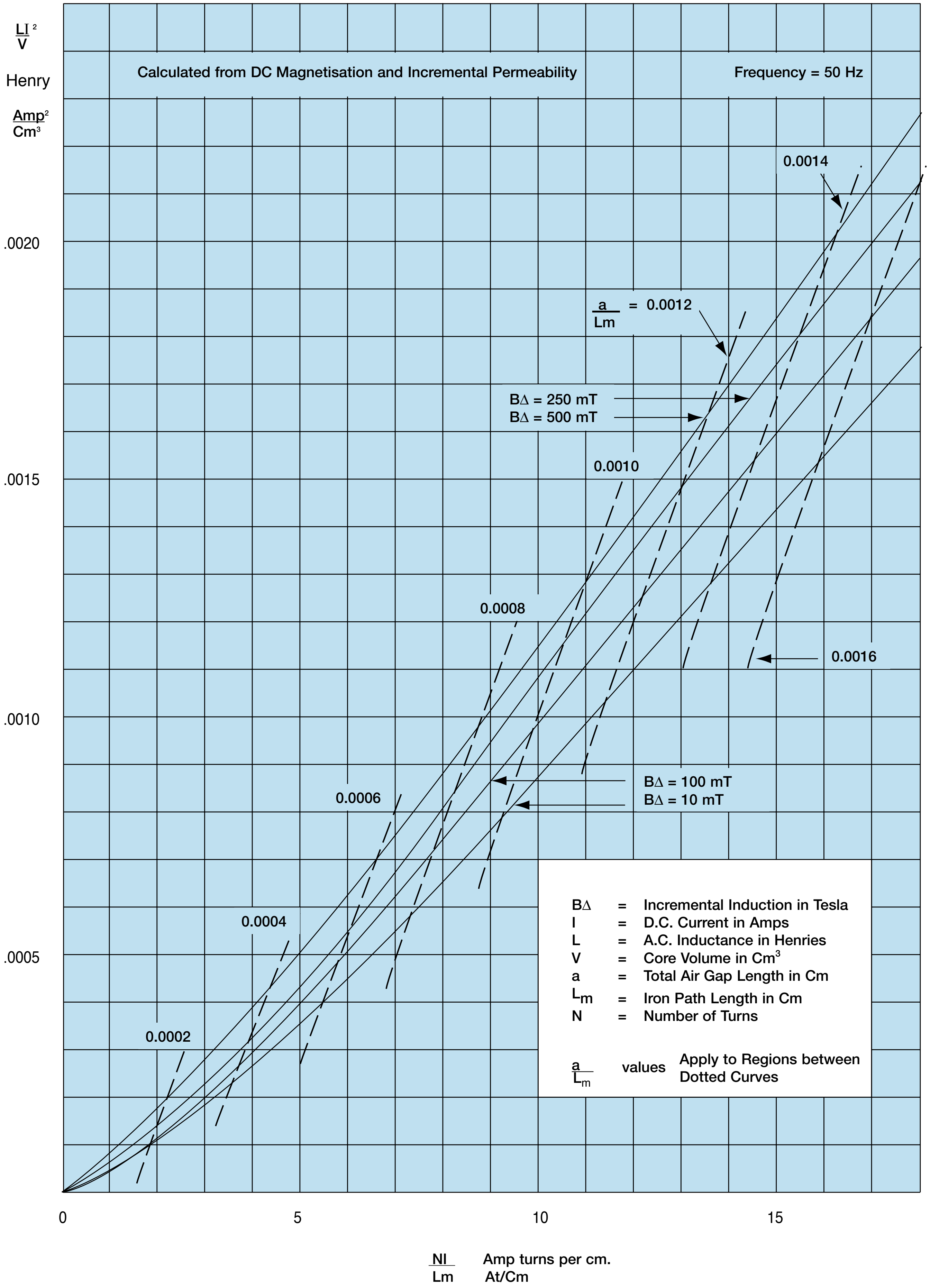
b) Flux density is that attained at the instant of Max.H.

thus

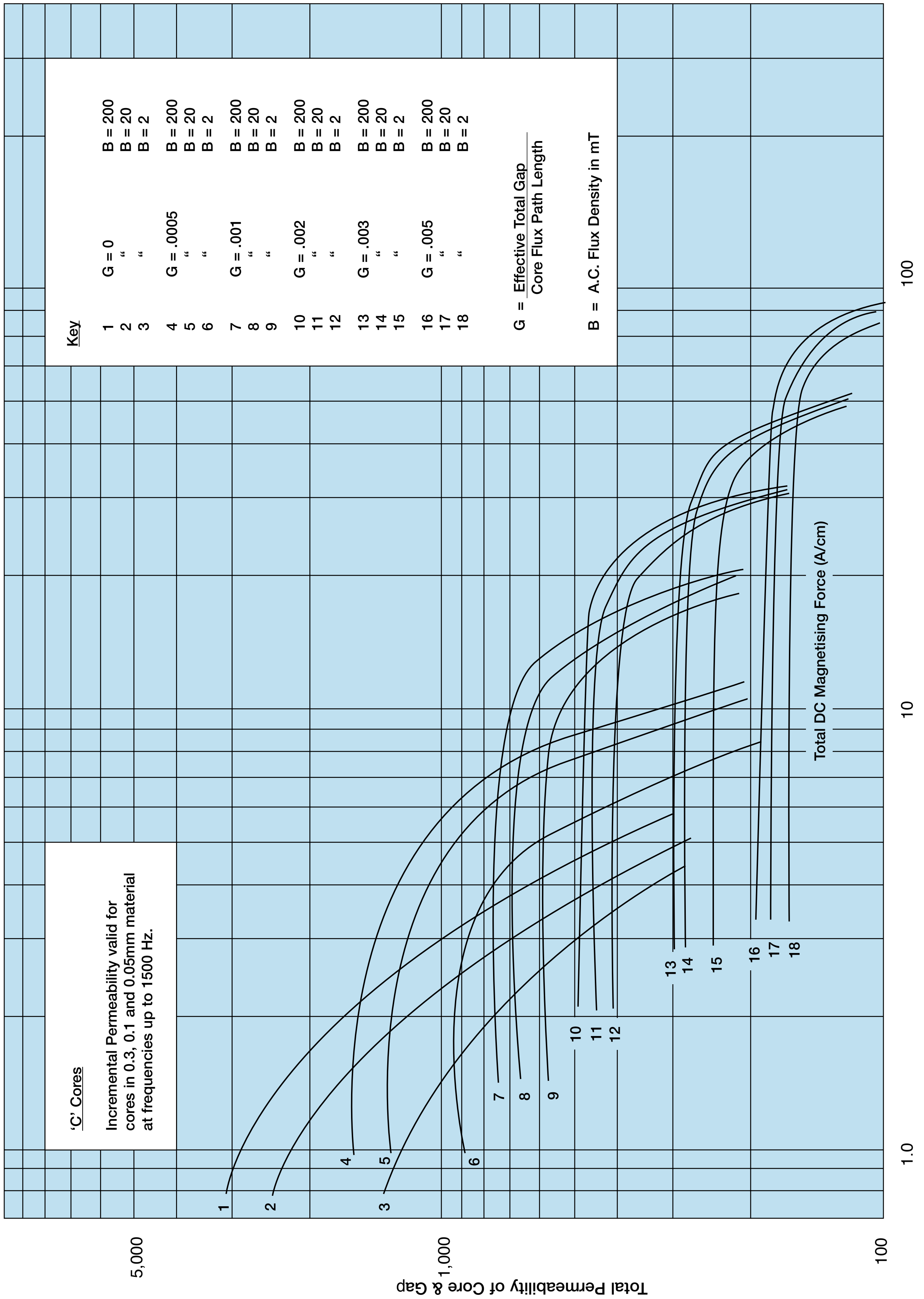
‘C’ CORES IN 0.05mm G.O.S.S. LOSSES UNDER PULSE CONDITIONS



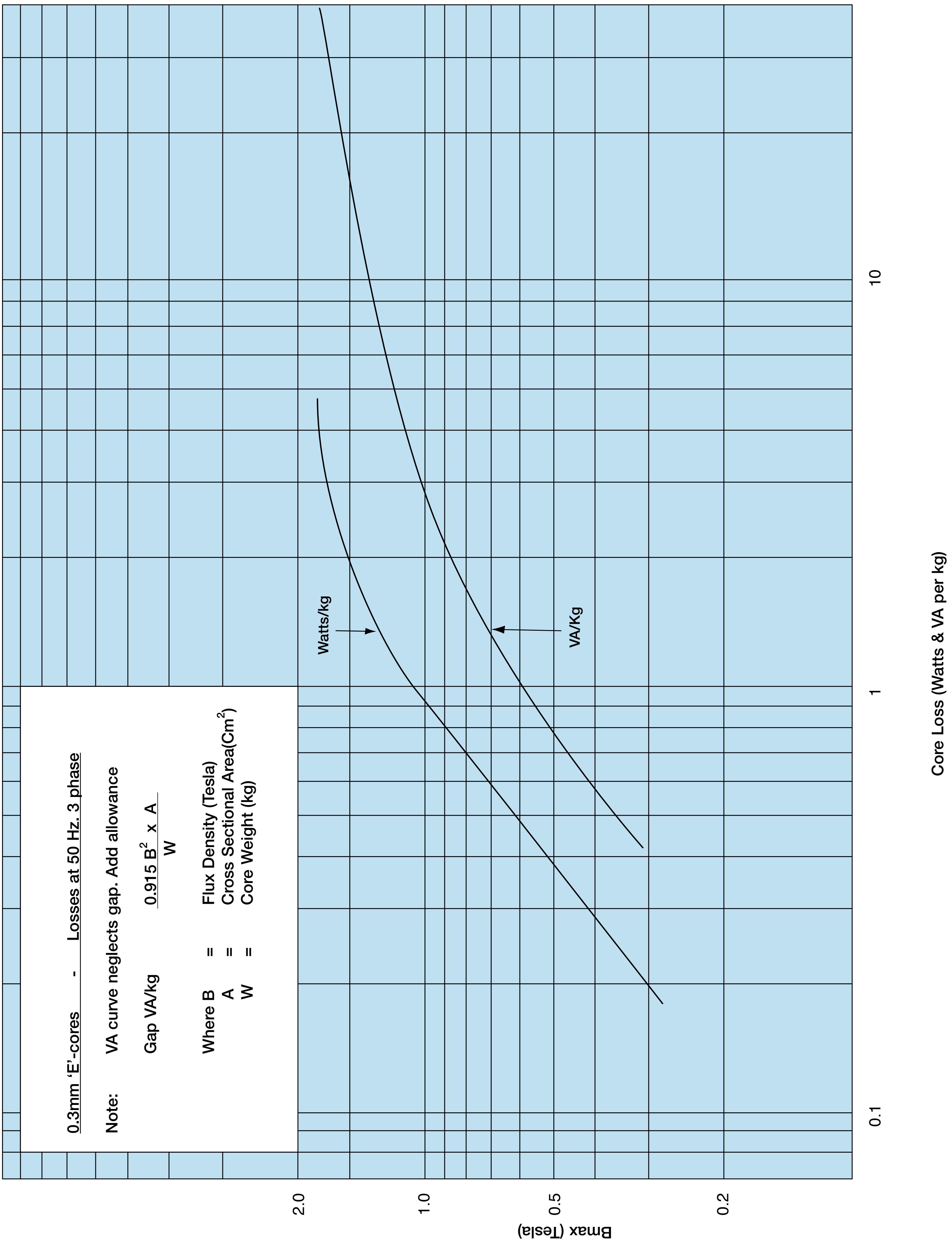
HANNA DESIGN CURVES - MATERIAL 30M5 (M097-30N)



INCREMENTAL PERMEABILITY FOR G.O.S.S. ‘C’ CORES



0.3mm G.O.S.S. 'E' - CORES - LOSSES AT 50 Hz., 3Φ



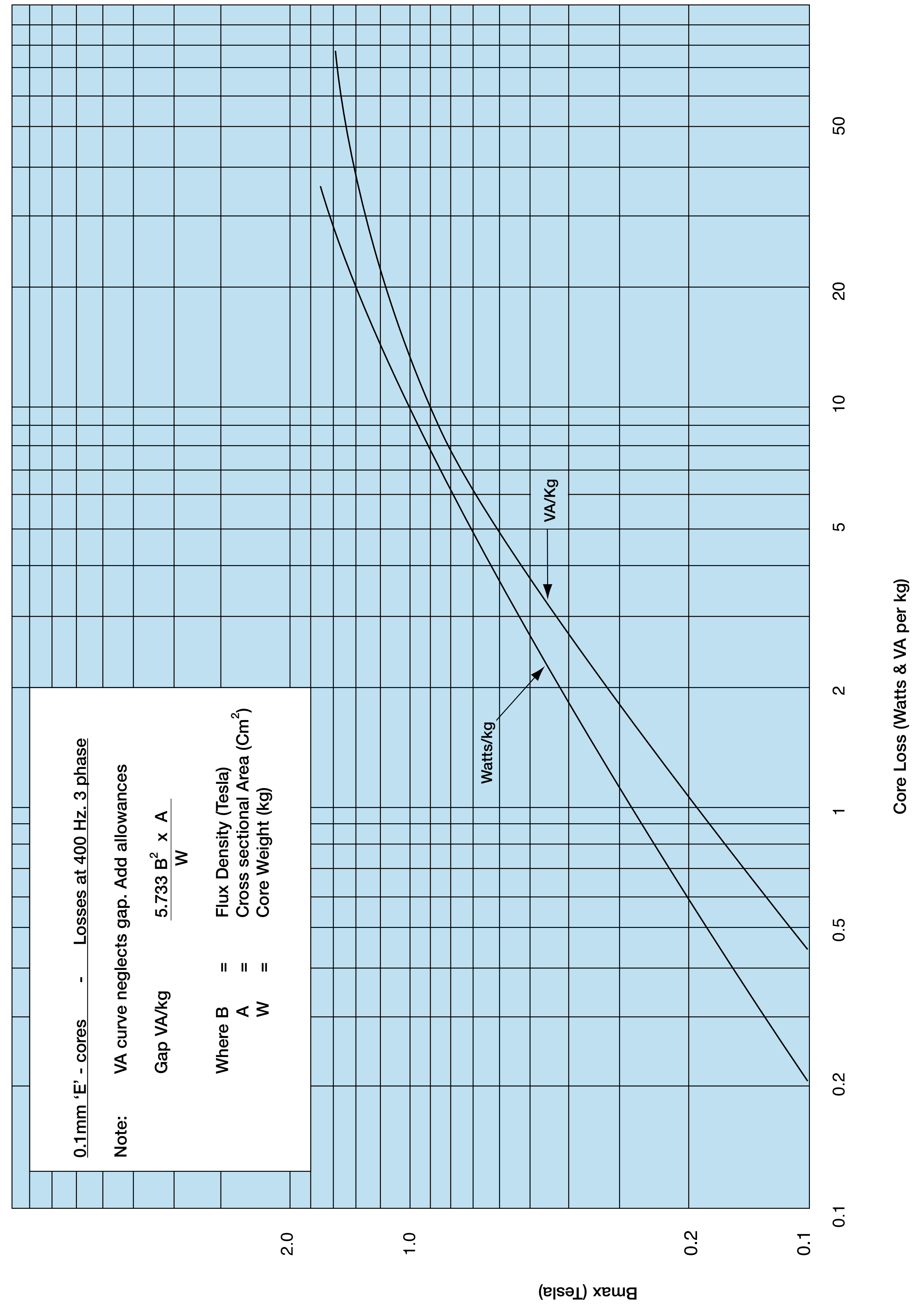
0.3mm 'E'-cores - Losses at 50 Hz. 3 phase

Note: VA curve neglects gap. Add allowance

Gap VA/kg $\frac{0.915\,B^2 \times A}{W}$

Where B = Flux Density (Tesla)
A = Cross Sectional Area(Cm^2)
W = Core Weight (kg)

0.1mm G.O.S.S. ‘E’ - CORES - LOSSES AT 400 Hz., 3Φ



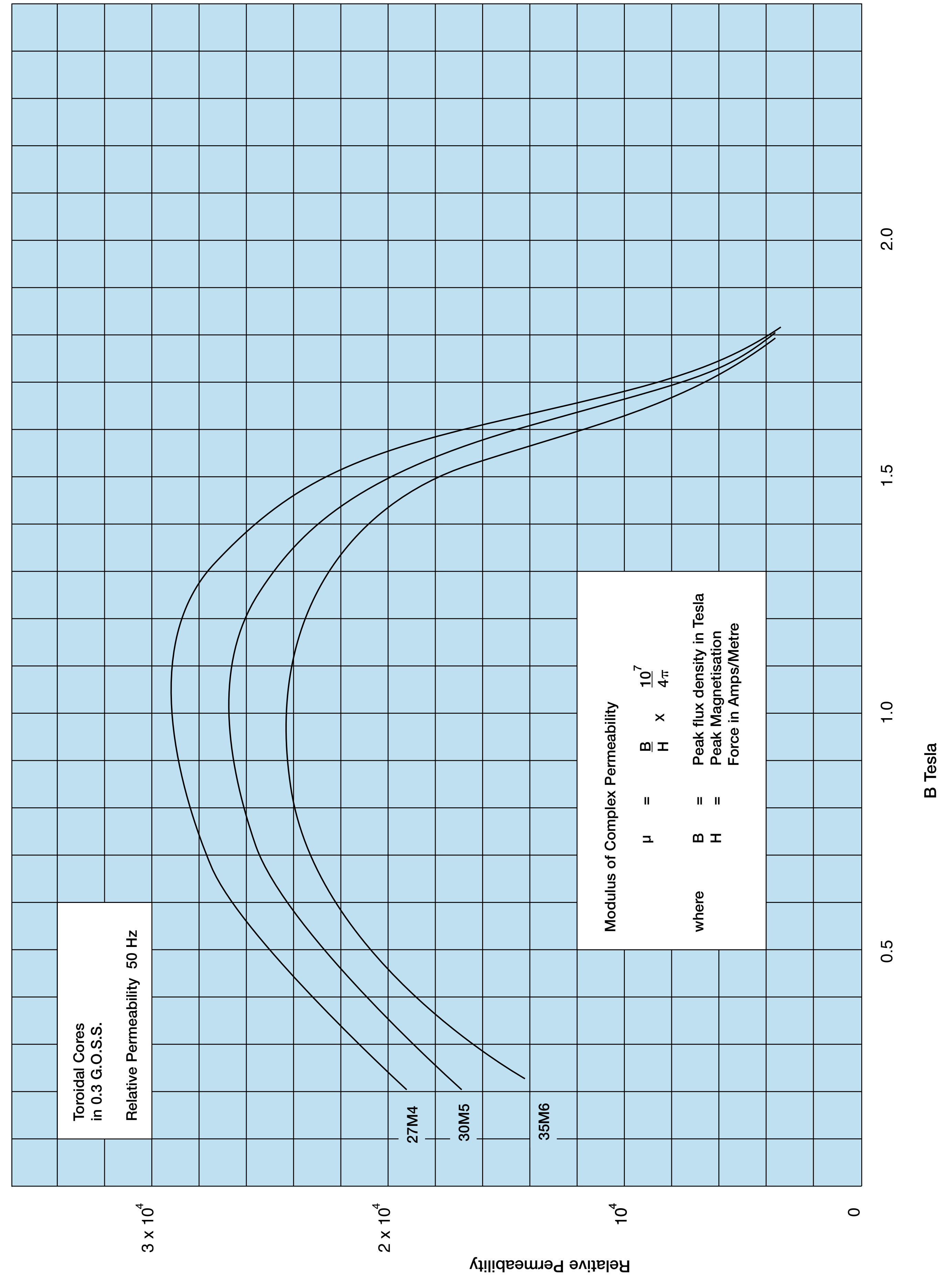
0.1mm ‘E’ - cores - Losses at 400 Hz. 3 phase

Note: VA curve neglects gap. Add allowances

Gap VA/kg $\dfrac{5.733\ B^2 \times A}{W}$

Where B = Flux Density (Tesla)
A = Cross sectional Area (Cm^2)
W = Core Weight (kg)

TOROIDAL CORES IN 0.3mm G.O.S.S. RELATIVE PERMEABILITY @ 50 Hz

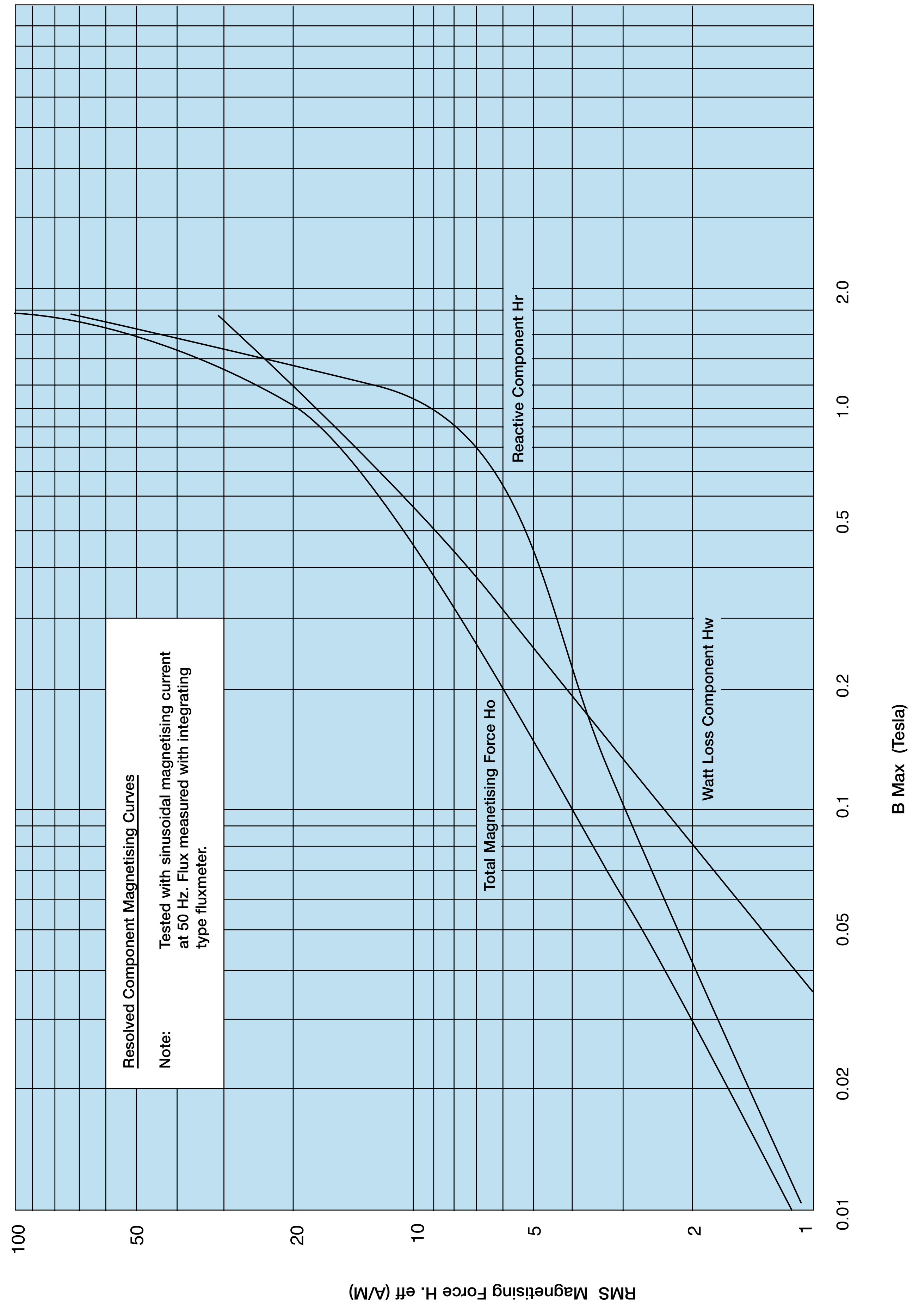


Modulus of Complex Permeability

$$\mu = \frac{B}{H} \times \frac{10^7}{4\pi}$$

where B = Peak flux density in Tesla
H = Peak Magnetisation Force in Amps/Metre

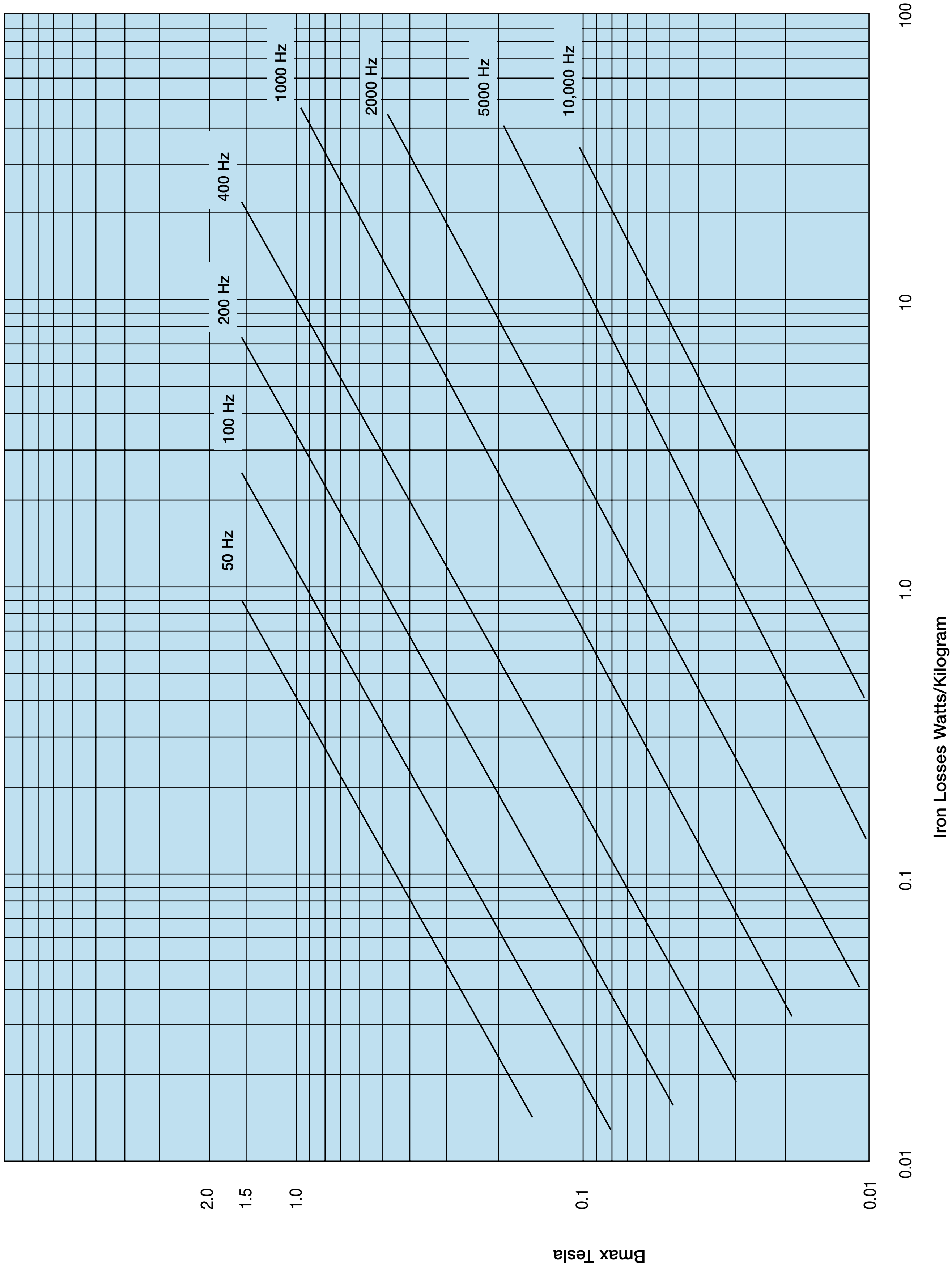
TOROIDAL CORES IN 27M4 (MO89 - 27N) MATERIAL



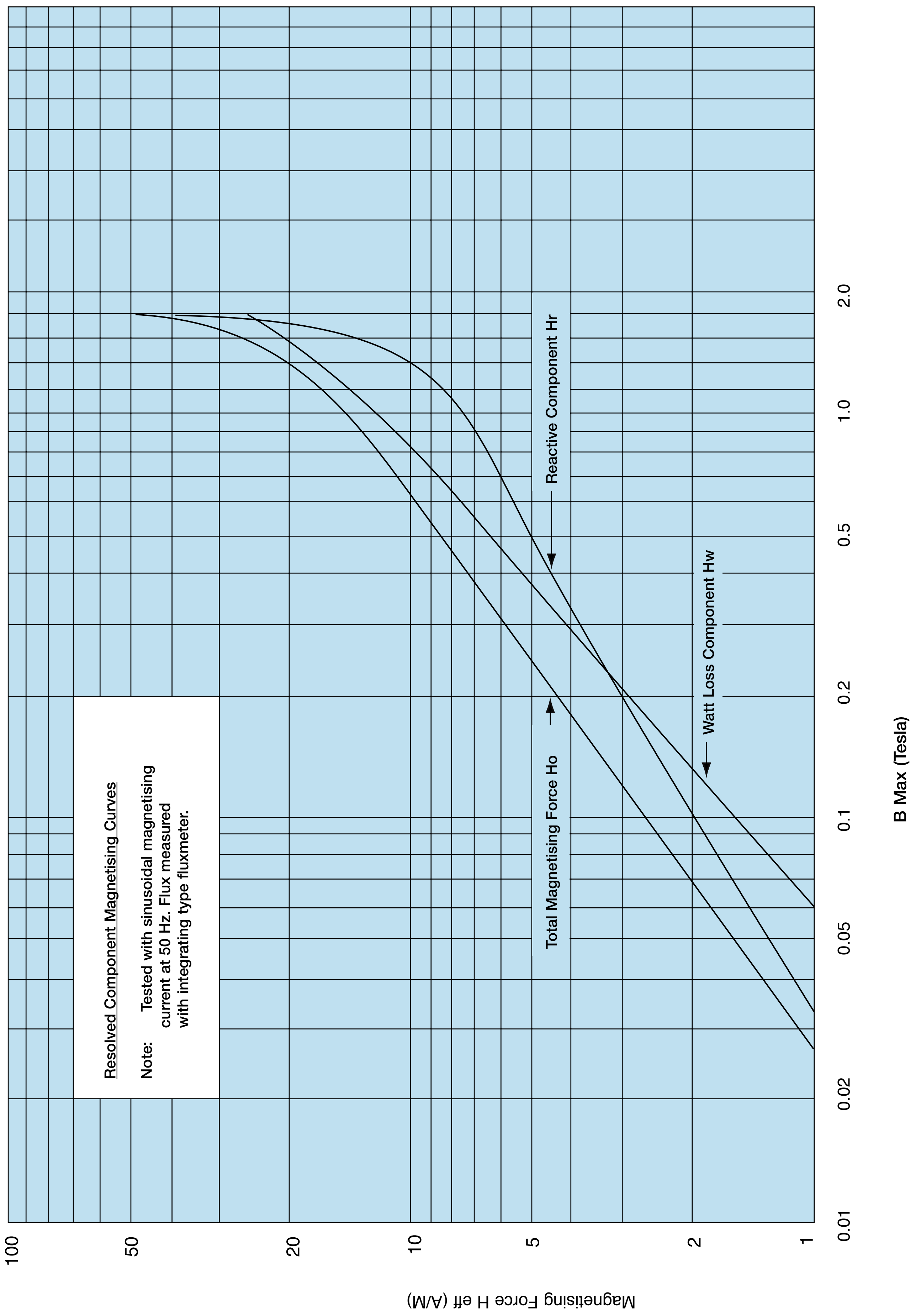
Resolved Component Magnetising Curves

Note: Tested with sinusoidal magnetising current at 50 Hz. Flux measured with integrating type fluxmeter.

TOROIDAL CORE LOSSES FOR 27M4 (M089-27N)- MATERIAL AT VARIOUS FREQUENCIES



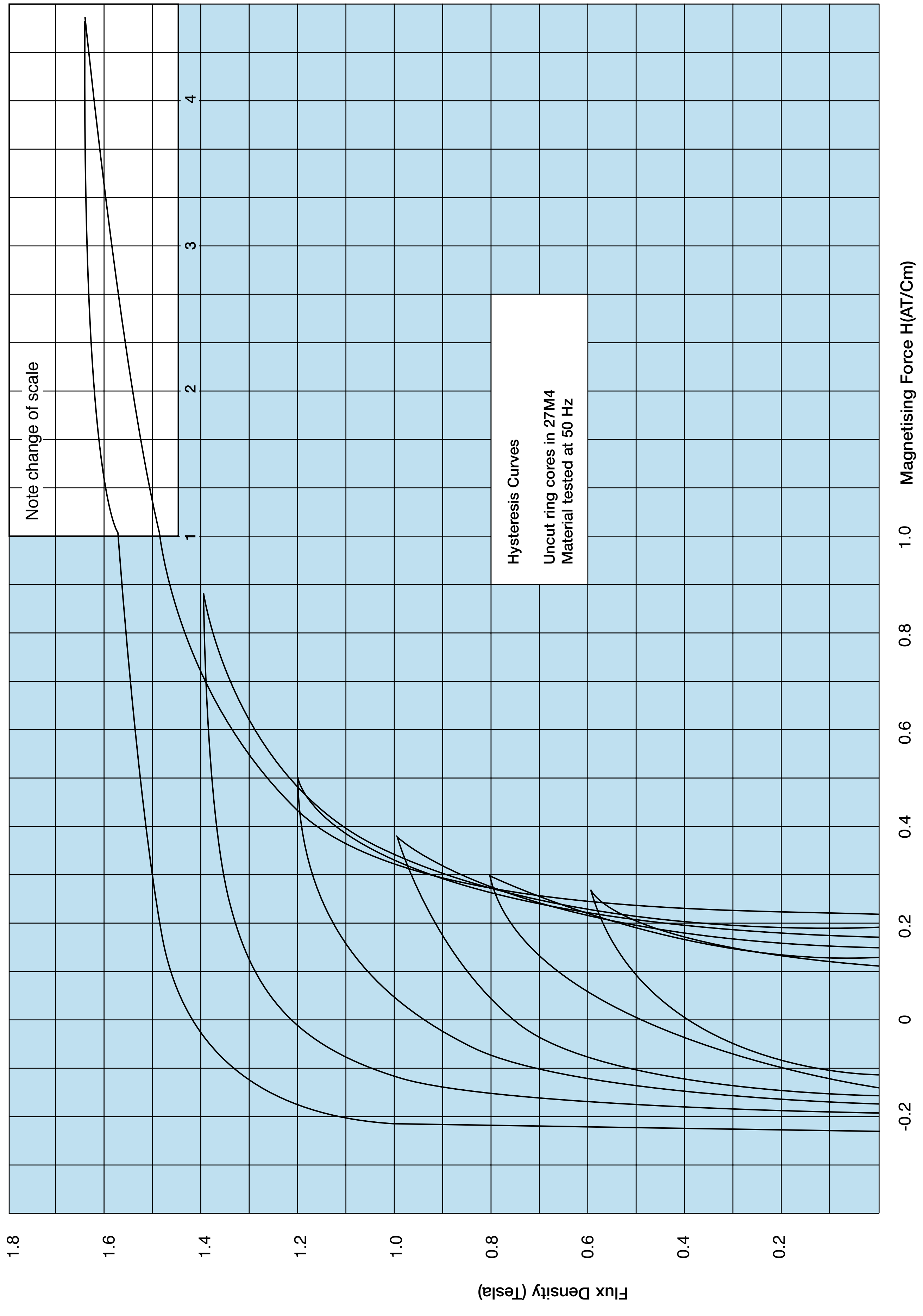
TOROIDAL CORES IN 30 MIH (MIII -30P)



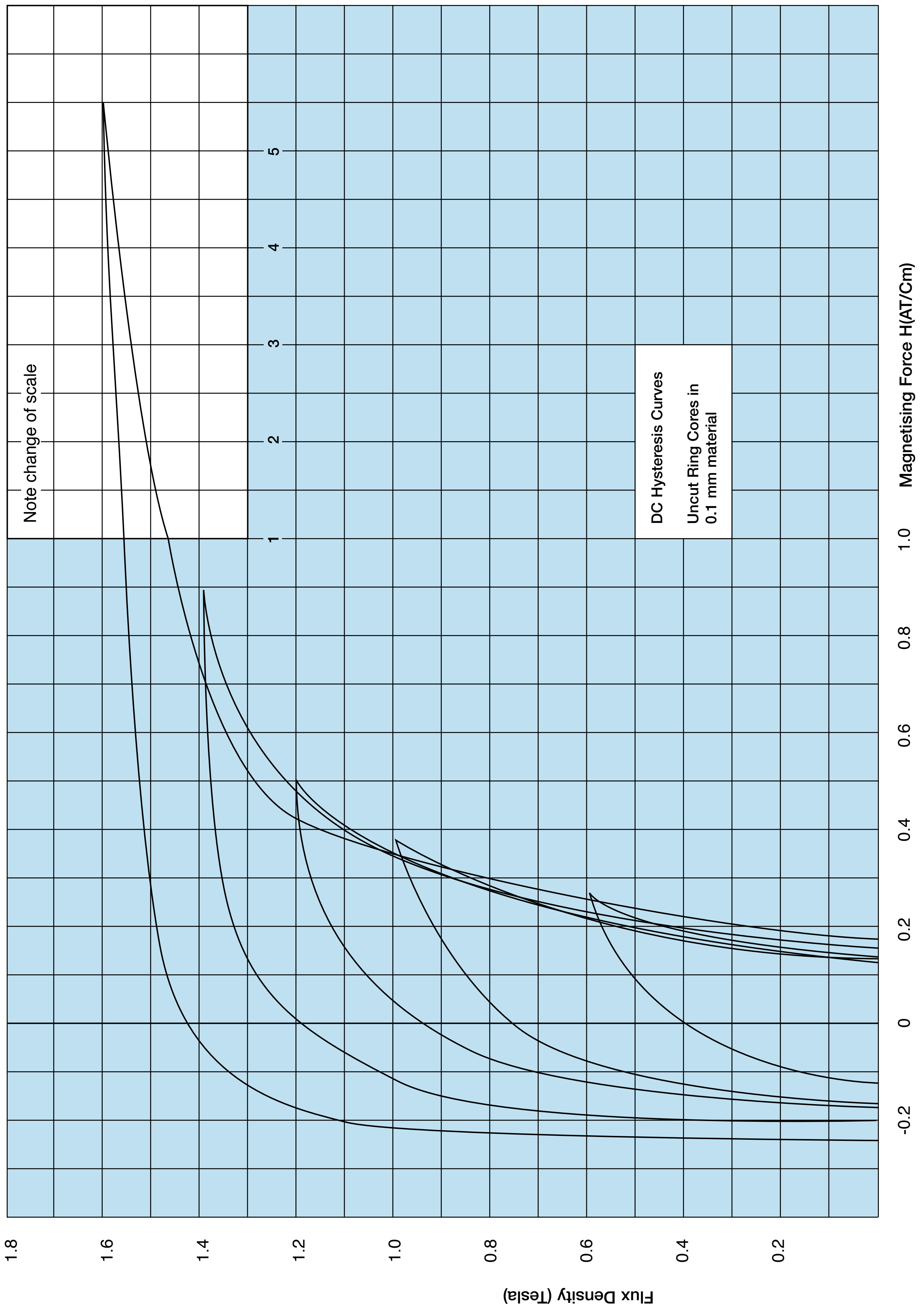
Resolved Component Magnetising Curves

Note: Tested with sinusoidal magnetising current at 50 Hz. Flux measured with integrating type fluxmeter.

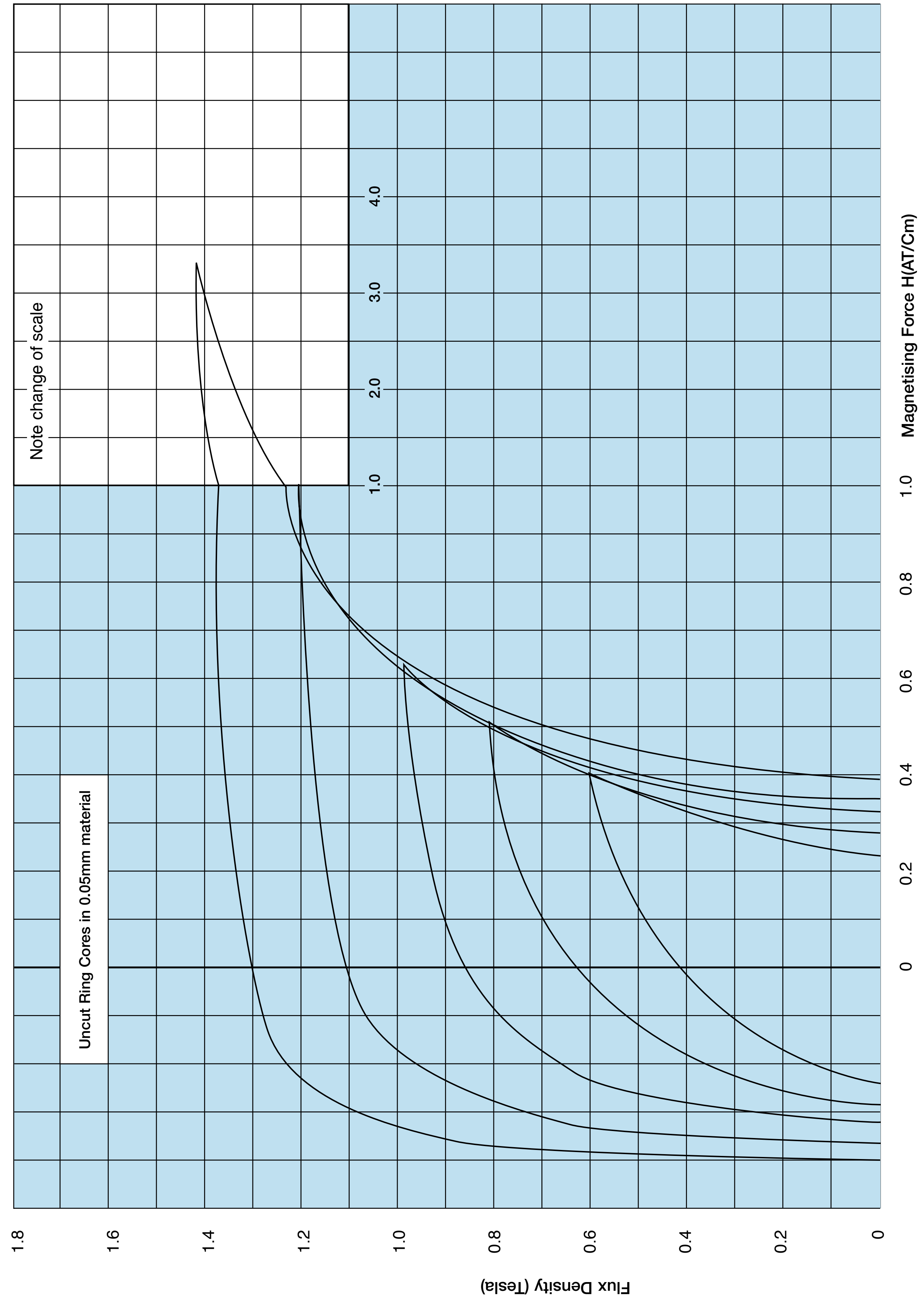
DC HYSTERESIS CURVES



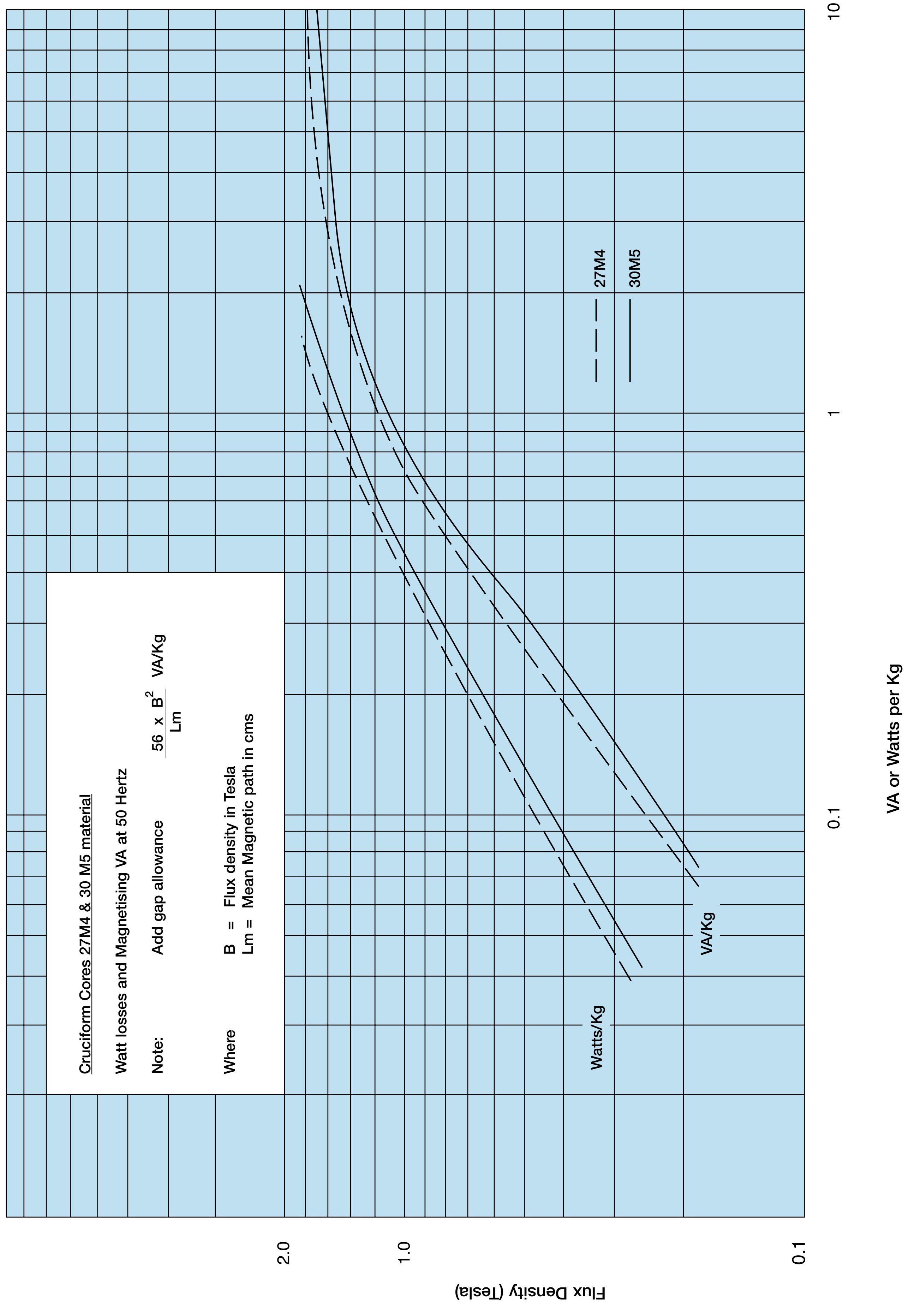
DC HYSTERESIS CURVES



DC HYSTERESIS CURVES



CRUCIFORM CORES IN 27M4 (M089-27N) AND 30M5 (M097-30N)



Cruciform Cores 27M4 & 30 M5 material

Watt losses and Magnetising VA at 50 Hertz

Note: Add gap allowance $\frac{56 \times B^2}{Lm}$ VA/Kg

Where
B = Flux density in Tesla
Lm = Mean Magnetic path in cms