Soft magnetic materials of TOHO ZINC

*Dust core ?

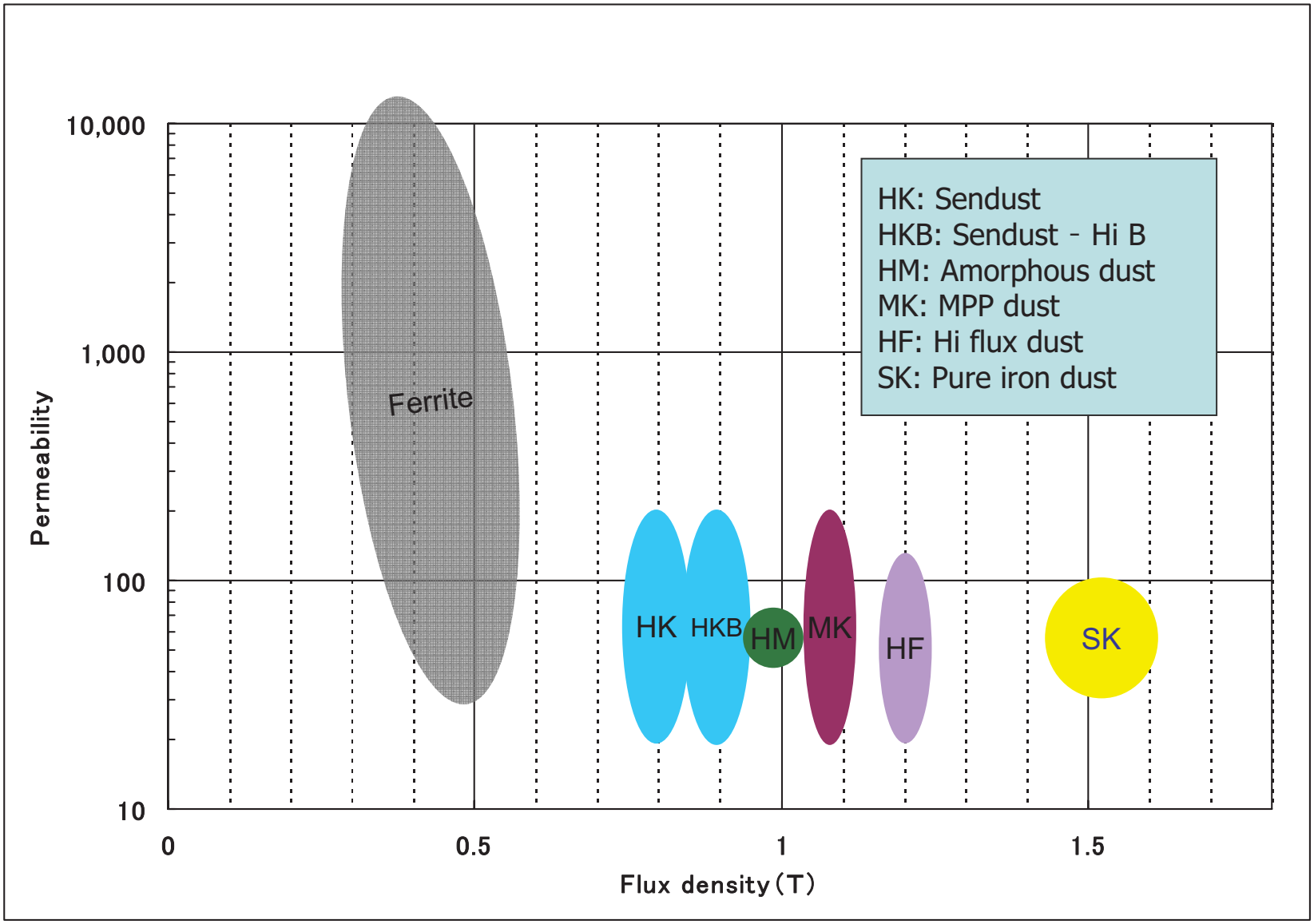
*Use dust core efficiently

Toho Technical Center
TOHO ZINC CO., LTD.

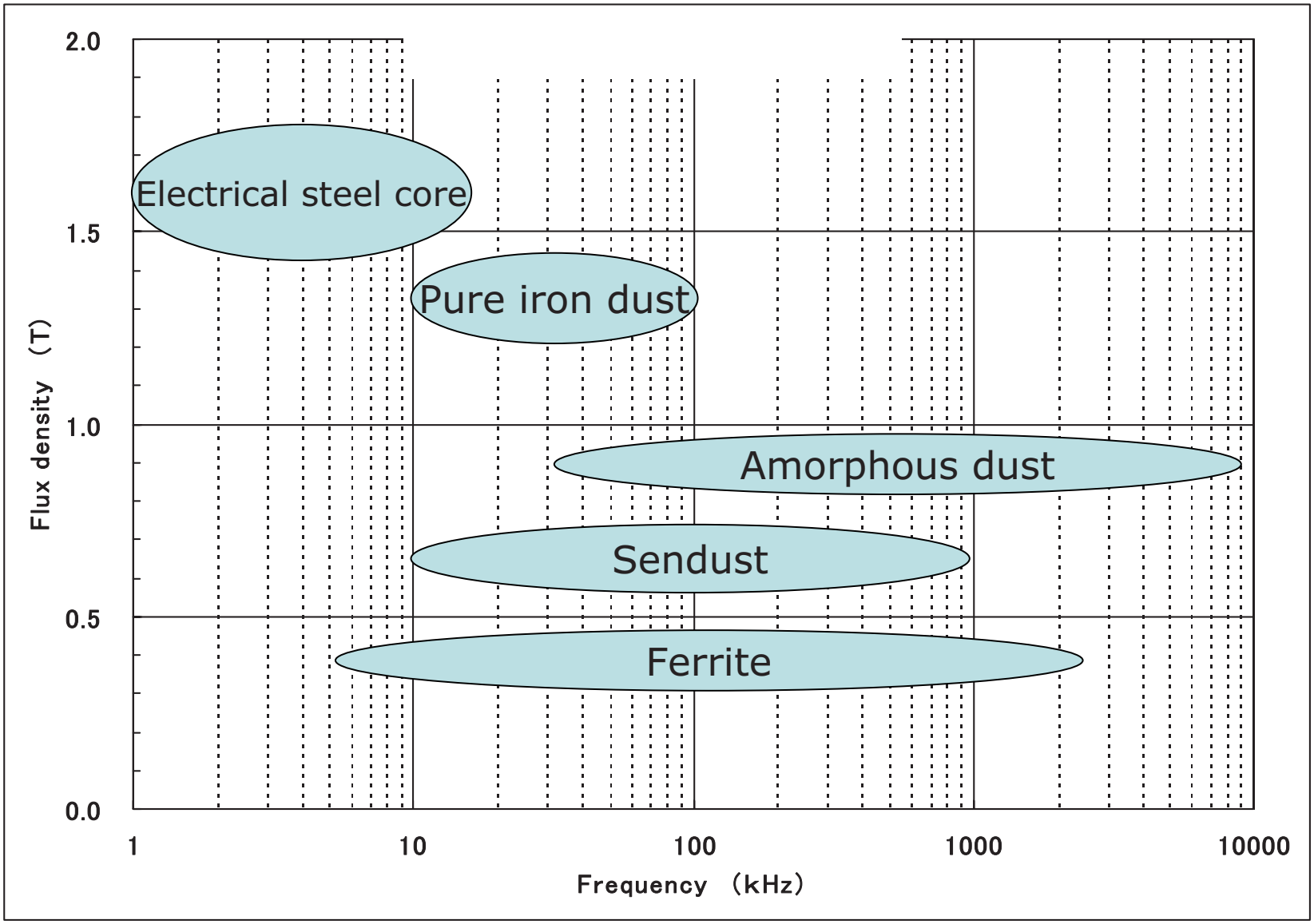
Typical soft magnetic materials

Type	Item	Typical composition	Permeability	Saturate magnetic flux density (T)	Frequency (kHz)
Metal dust	Iron dust	Fe	60	1.7	100
	Senduxt	Fe-10Si-5Al	60 / 120	0.7	2000
	Hi flux	Fe-50Ni	60 / 120	1.2	1000
	MPP	Fe-78Ni-2Mo	60 / 150	1.5	2000
	Si steel	Fe-6.5Si	60 / 120	1.3	200
	Carbonyl	Fe(CO)5	5 / 35	1.5	10000
	Amorphous dust	Fe-Si-B, etc.	60	1.2	2000
Ferrite	Mn-Zn Ferrite	MnFe3O4	1500 / 15000	0.4	1000
	Ni-Zn Ferrite	NiFe3O4	150 / 2000	0.5	5000
Metal sheet	Si steel sheet	Fe-3Si, Fe-6.5Si	100 / 20000	1.5	50
	Amorphous tape	Fe-Si-B, etc.	1000 / 20000	1.2	1000
	Finemet	Fe-Cu-Nb-B-Si, etc.	500 / 20000	1.3	2000

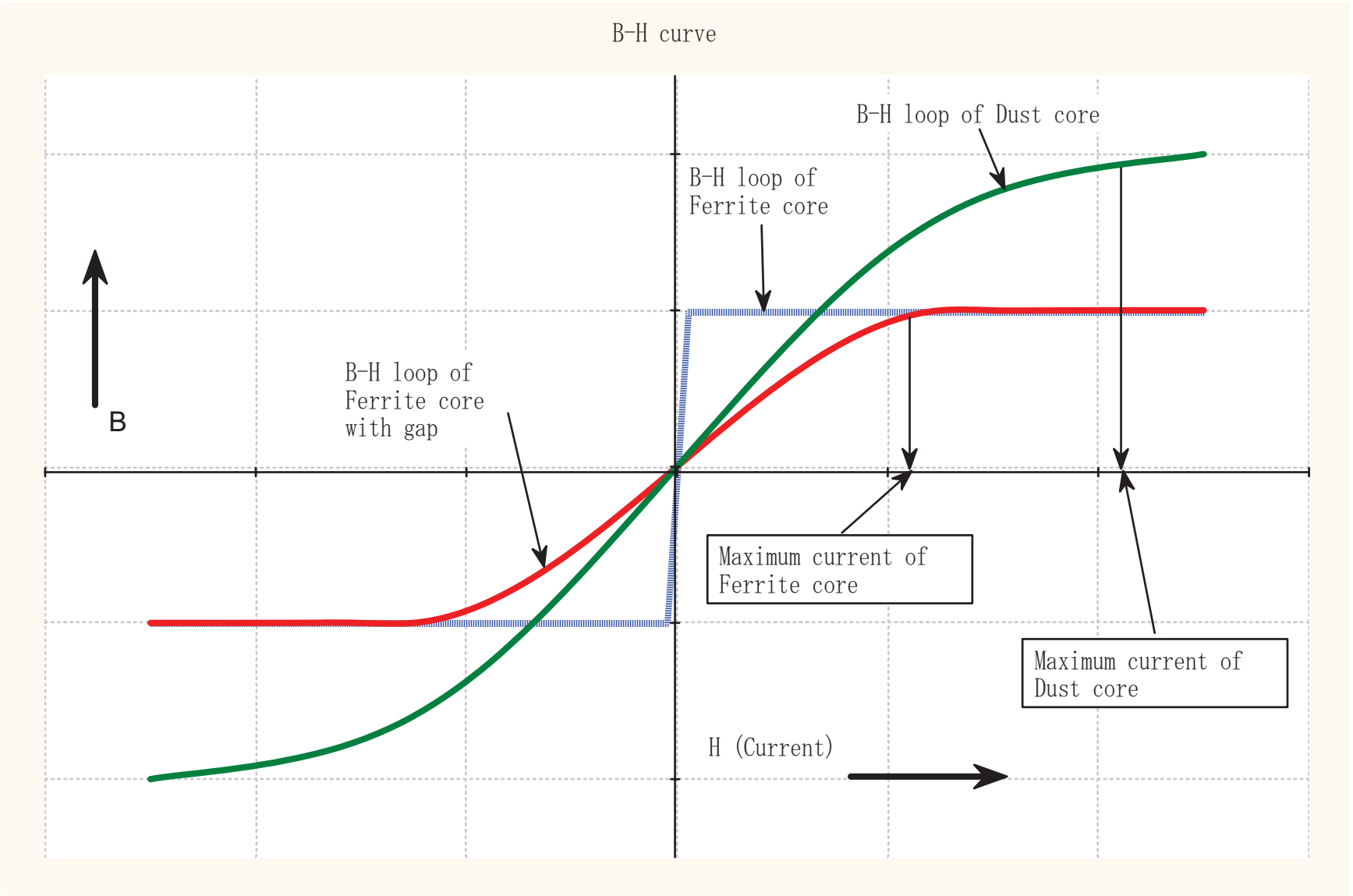
Comparison of dust core and ferrite



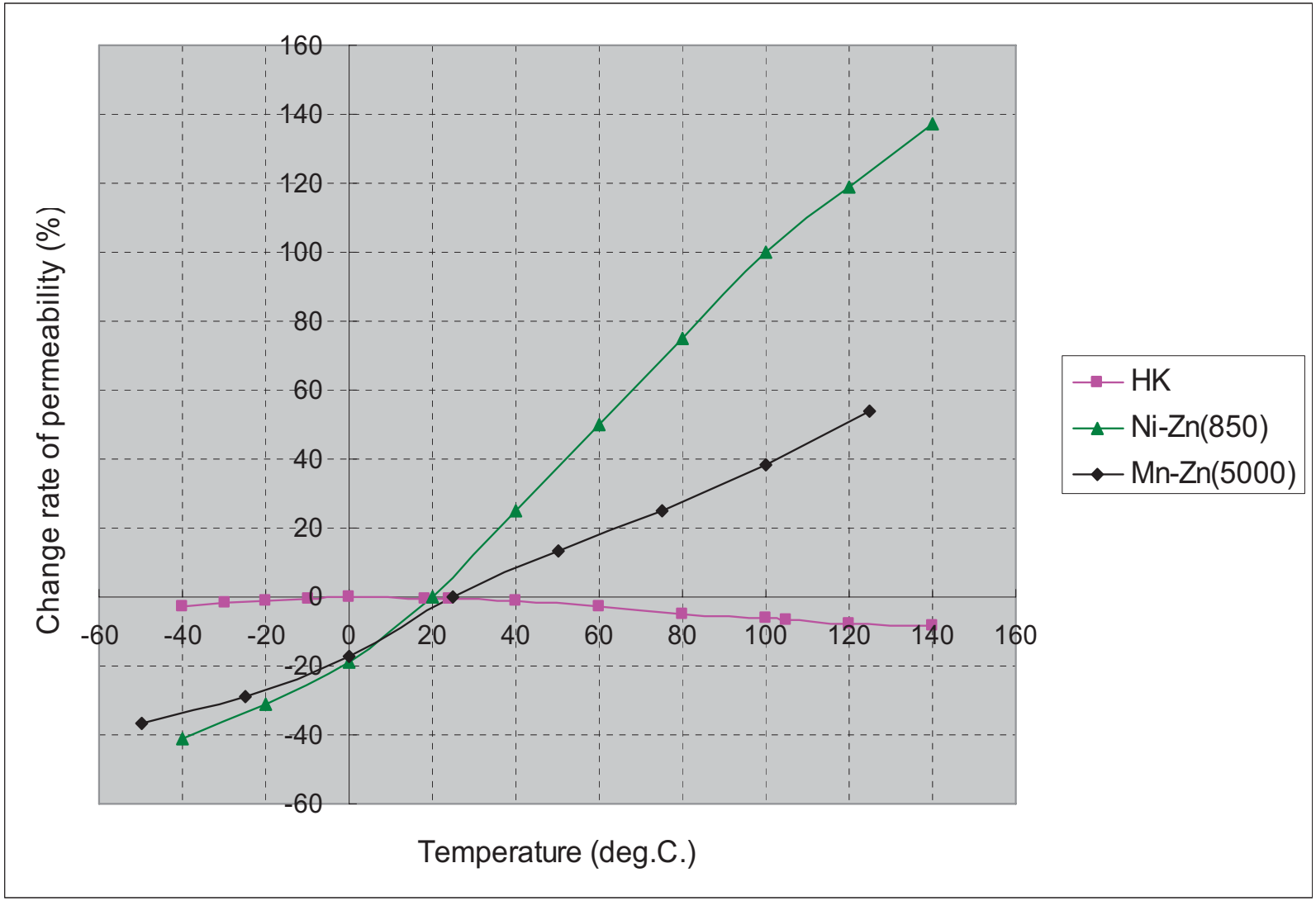
Frequency chracteristic



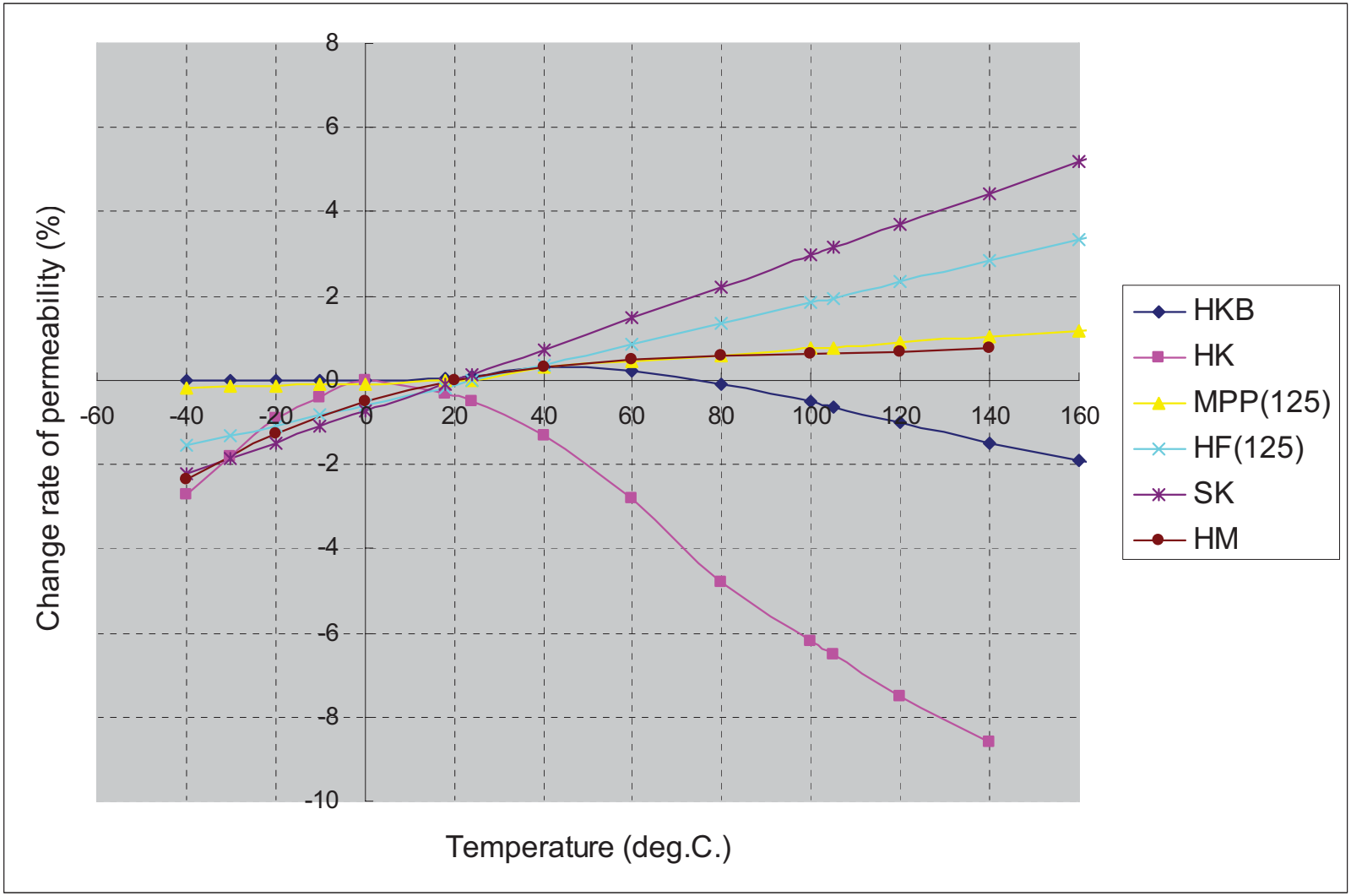
DC Bias characteristic of dust core and Ferrite core



Temperature characteristic (1)

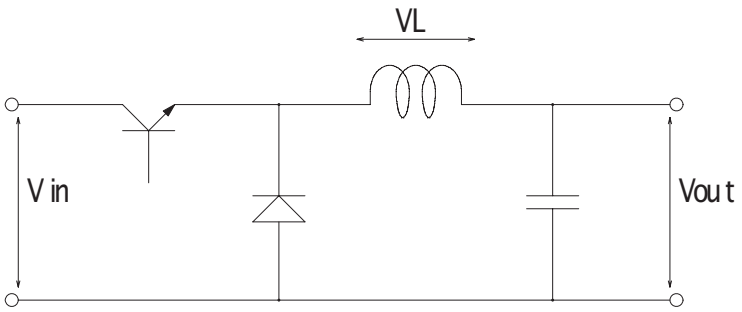


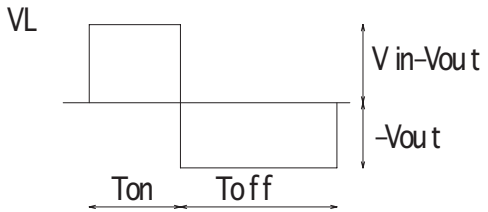
Temperature characteristic (2)



Example of a core loss calculation

$$Conditions \ : Vin = 25V, Vout = 5V, f = 100\,kHz, Ton = 2\mu S$$





$$Winding \ : \text{HK12S core, 50Turns}$$

$$N = 50\,(Turns), Ae = 0.275\,cm^2, Ve = 1.37\,cc$$

Then,

$$\Delta B = \frac{(Vin - Vout) \cdot Ton}{Ae \cdot N}$$

$$\Delta B = \frac{(25-5) \cdot 2 \cdot 10^{-6}}{0.275 \cdot 10^{-4} \cdot 50} = 0.0291\,(T) = 29.1(mT)$$

$$P = C \cdot B^a \cdot f^b = C \cdot (\Delta B/2)^a \cdot f^b$$

$$P = 2.848 \cdot 10^{-5} \cdot 14.55^{2.0950} \cdot 100^{1.5980} = 12.2(mW/cc)$$

$$Pfe = 12.2 \times 1.37 = 16.7(mW)$$

Approximate formula and parameter for a core loss calculation

$$P\ [mW/cc] = C \cdot B\ [mT]^{a} \cdot F\ [kHz]^{b}$$

Materials	*a*	*b*	*C*
SK	1.9897	1.4332	6.375E-04
HK	2.0950	1.5980	2.848E-05
HKL	2.1252	1.5449	4.177E-05
HKS	2.1167	1.6161	2.098E-05
HKH	2.0967	1.5817	2.527E-05
HKBL	1.9782	1.4878	1.344E-04
HKBS	2.0075	1.5256	8.381E-05
HKBH	1.9992	1.4845	1.068E-04
HM	2.0148	1.7221	1.828E-05
MPP(60)	2.1917	1.5341	2.434E-05
MPP(90)	2.1899	1.5322	2.823E-05
MPP(120)	2.2103	1.5706	2.147E-05
HF(60)	2.0323	1.5530	1.234E-04
HF(125)	2.1168	1.5695	4.805E-05

Example of an inductance calculation under DC Bias

Winding : HK12S core, 50 Turns

$$\mathrm{Le} = 4.99\mathrm{cm}, \mathrm{Ae} = 0.275\mathrm{cm}^2$$

DCBias: DC5A

Then,

$$H = \frac{I \cdot N}{Le}$$

$$H = \frac{5 \cdot 50}{4.99 \cdot 10^{-2}} = 5010(AT/m)$$

$$\mu e = a \cdot \mathrm{x}^5 + b \cdot \mathrm{x}^4 + c \cdot \mathrm{x}^3 + d \cdot \mathrm{x}^2 + e \cdot \mathrm{x} + f \qquad \mathrm{x} : (AT/m)$$

$$\mu e = 3.143 \cdot 10^{-18} \cdot 5010^5 - 9.825 \cdot 10^{-14} \cdot 5010^4 + 1.078 \cdot 10^{-9} \cdot 5010^3 - 4.062 \cdot 10^{-6} \cdot 5010^2$$
$$- 0.00872 \cdot 5010 + 99.8$$
$$= 37.7$$

$$L = \frac{4\pi \cdot 10^{-7} \cdot N^2 \cdot Ae \cdot \mu e}{Le}$$

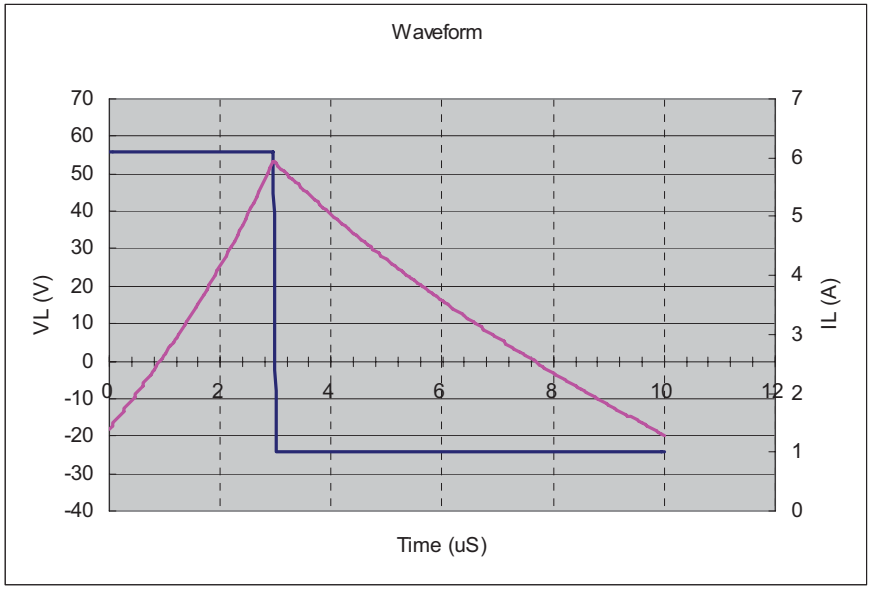
$$L = \frac{4\pi \cdot 10^{-7} \cdot 50^2 \cdot 0.275 \cdot 10^{-4} \cdot 37.7}{4.99 \cdot 10^{-2}} = 65.2 \cdot 10^{-6}(H) = 65.2(\mu H) \quad at\ DC5A$$

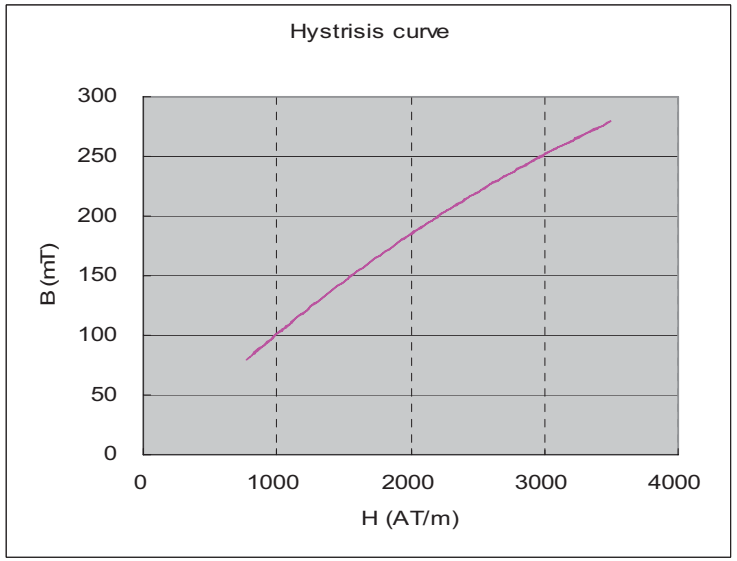
Approximate formula and parameter for an inductance calculation under DC Bias

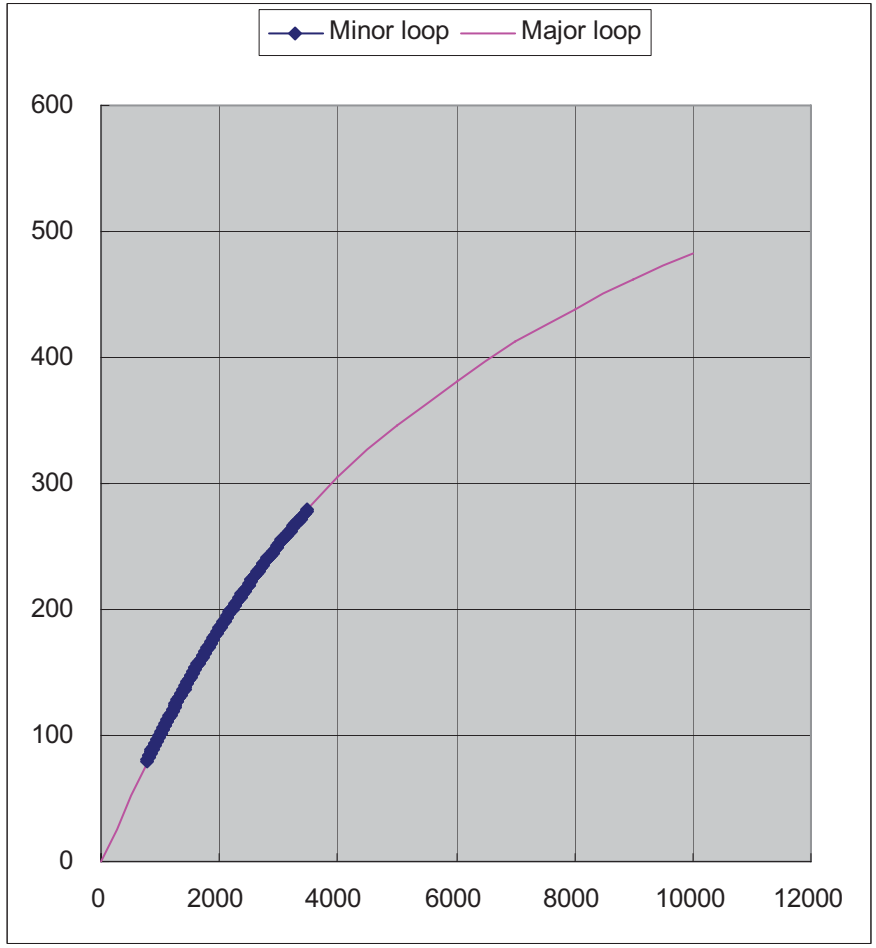
$$\mu e = a \cdot x^5 + b \cdot x^4 + c \cdot x^3 + d \cdot x^2 + e \cdot x + f \qquad x : [AT/m]$$

Materials	*a*	*b*	*c*	*d*	*e*	*f*
SK	4.620E-18	-1.400E-13	1.529E-09	-6.725E-06	0.0031	72.9
HK	3.143E-18	-9.825E-14	1.078E-09	-4.062E-06	-0.0087	99.8
HKL	1.552E-18	-4.485E-14	4.376E-10	-1.226E-06	-0.0064	58.7
HKS	3.380E-18	-9.769E-14	9.567E-10	-2.782E-06	-0.0112	86.7
HKH	3.055E-18	-9.065E-14	8.962E-10	-2.147E-06	-0.0181	115.1
HKBL	9.266E-19	-2.699E-14	2.669E-10	-7.292E-07	-0.0053	55.4
HKBS	2.405E-18	-7.382E-14	8.040E-10	-3.144E-06	-0.0055	83.2
HKBH	2.728E-18	-8.196E-14	8.372E-10	-2.371E-06	-0.0148	114.1
HM	3.353E-16	-3.614E-12	1.409E-8	-2.167E-05	-0.002	60.9
MPP(60)	1.293E-19	-5.001E-15	9.834E-11	-8.939E-07	-0.0008	59.4
MPP(90)	1.696E-18	-5.479E-14	6.573E-10	-3.067E-06	-0.0041	87.2
MPP(120)	6.825E-18	-2.060E-13	2.188E-09	-8.293E-06	-0.0092	124.2
HF(60)	-3.570E-20	1.600E-15	-1.610E-11	-1.240E-07	-0.0002	55.4
HF(125)	3.922E-19	-2.362E-14	5.116E-10	-4.381E-06	0.0039	112.5

Wave form simulation from approximate formula of DC Bias

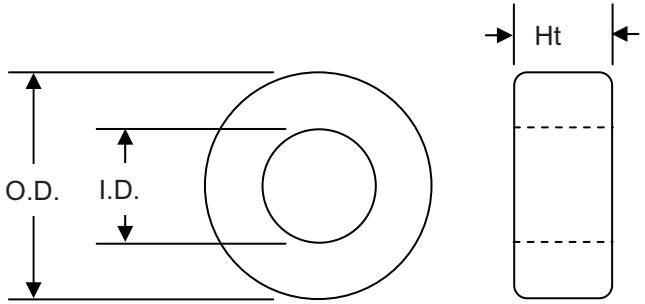






Core parameter table (1)

＜Toroidal core＞

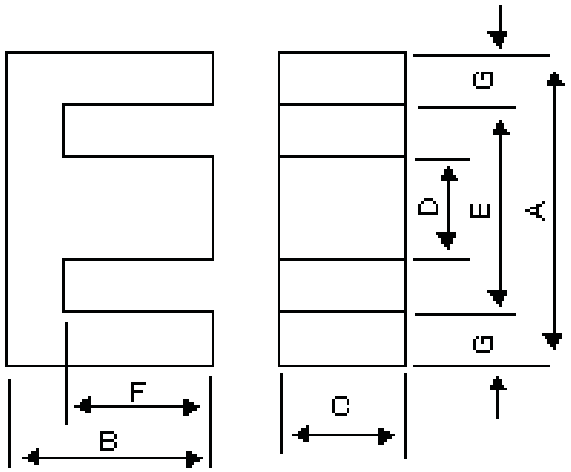


HK core

Size	O.D. mm	I.D. mm	Ht mm	Ae cm^2	Le cm	Volume cc	AL value nH
03S	6.3	3.5	2.5	0.034	1.45	0.05	29
04S	8.2	4.3	2.5	0.047	1.83	0.09	31
05S	10.3	5.1	4.0	0.100	2.23	0.22	54
08S	13.4	7.7	5.4	0.150	3.15	0.47	60
10S	17.3	10.2	6.7	0.232	4.13	0.96	70
12S	20.8	12.4	6.7	0.275	4.99	1.37	69
14S	27.2	14.6	7.3	0.445	6.16	2.74	91
14D	27.2	14.6	11.9	0.726	6.16	4.47	148
20D	33.6	19.8	12.2	0.822	8.01	6.58	129
28D	44.0	27.5	15.0	1.215	10.83	13.16	143
36D	57.1	35.3	15.0	1.604	13.97	22.41	146

Core parameter table (2)

<EE, EERL core>

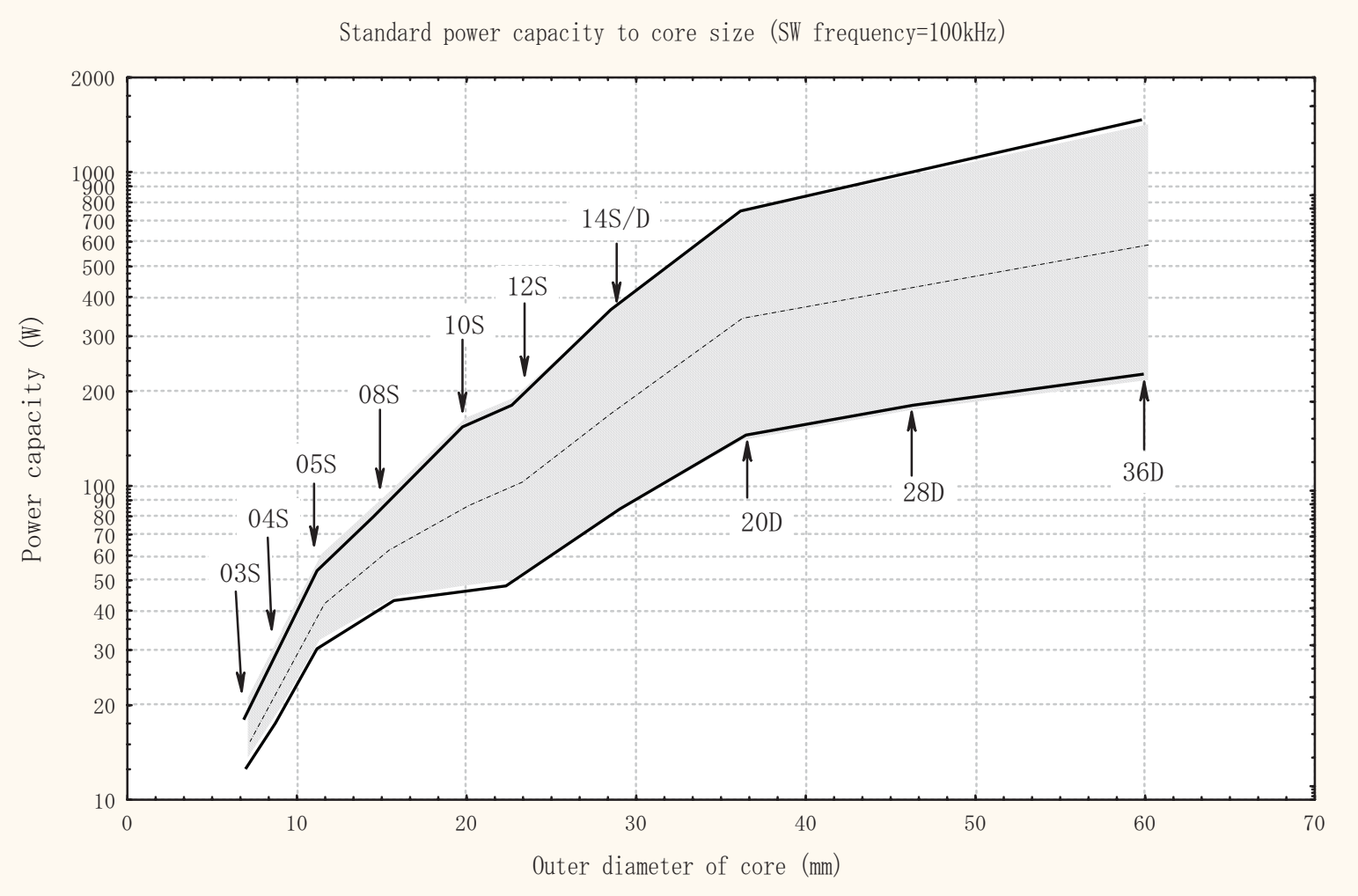


HK core

Size	A mm	B mm	C mm	D mm	E mm	F mm	G mm	Ae cm^2	Le cm	Volume cc	AL value nH
16EE	16.0	7.1	5.0	4.1	11.8	5.2	2.1	0.209	3.40	0.71	77
25EE	24.6	9.8	6.0	6.0	16.0	5.5	4.3	0.445	4.35	1.94	129
30EE	30.2	13.4	11.0	10.8	20.0	8.1	5.1	1.165	5.78	6.73	253
35EE	35.3	15.0	10.0	10.1	24.5	9.1	5.1	1.070	6.81	7.29	197
42EE	42.0	21.0	19.8	11.9	29.5	15.5	5.5	2.323	9.79	22.74	300
25EER	25.5	9.2	7.5	7.5	19.8	6.2	2.9	0.432	5.00	2.16	100
28EERL	28.0	17.0	11.4	9.9	21.1	12.5	3.4	0.847	7.83	6.63	120
35EERL	35.0	20.7	11.4	11.4	25.4	14.7	3.4	1.084	9.45	10.24	140
49EER	49.0	20.9	17.2	17.2	36.2	12.4	6.3	2.290	9.72	22.26	290

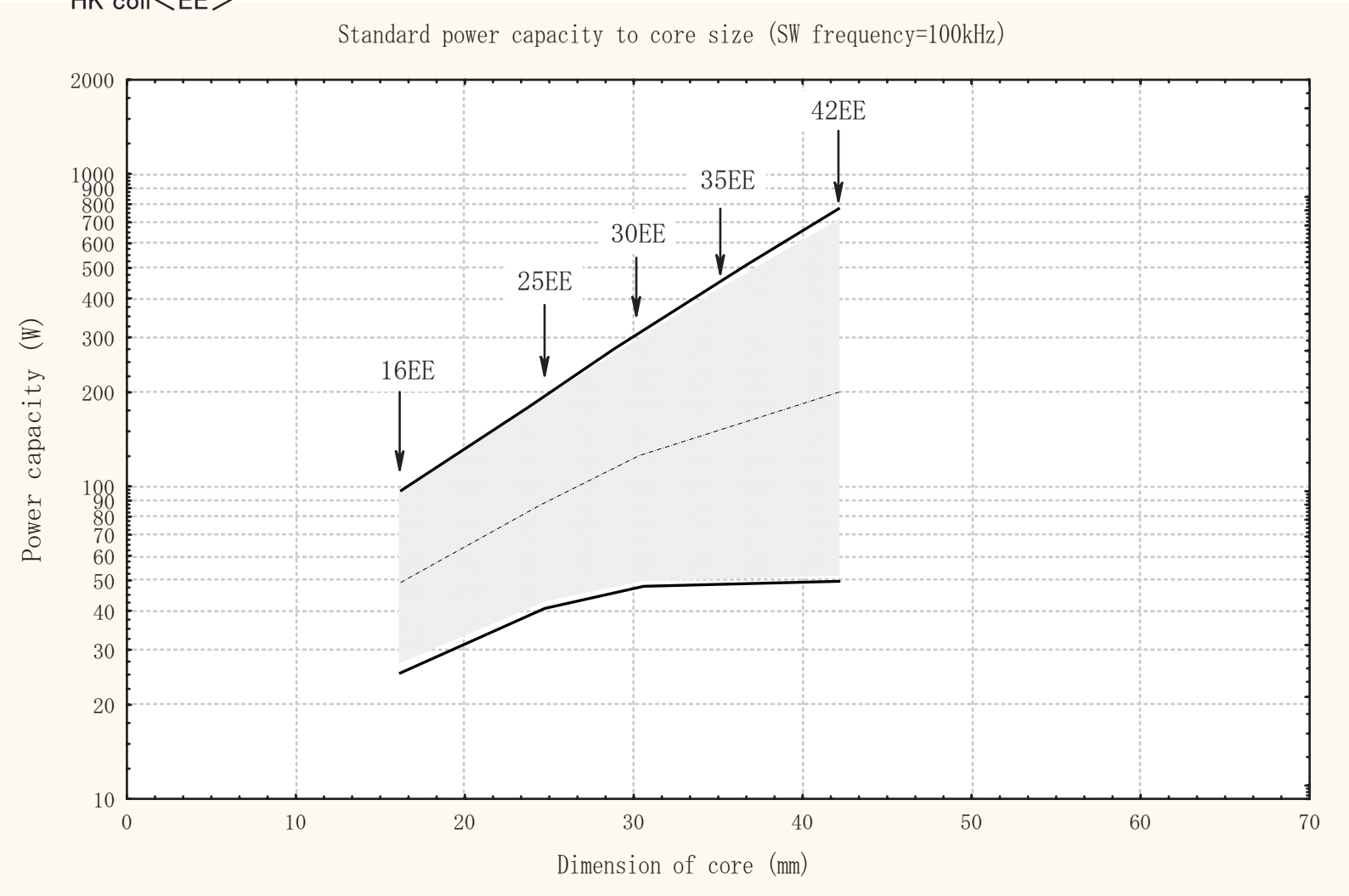
Standard power capacity to core size (1)

HK coil＜Toroidal＞



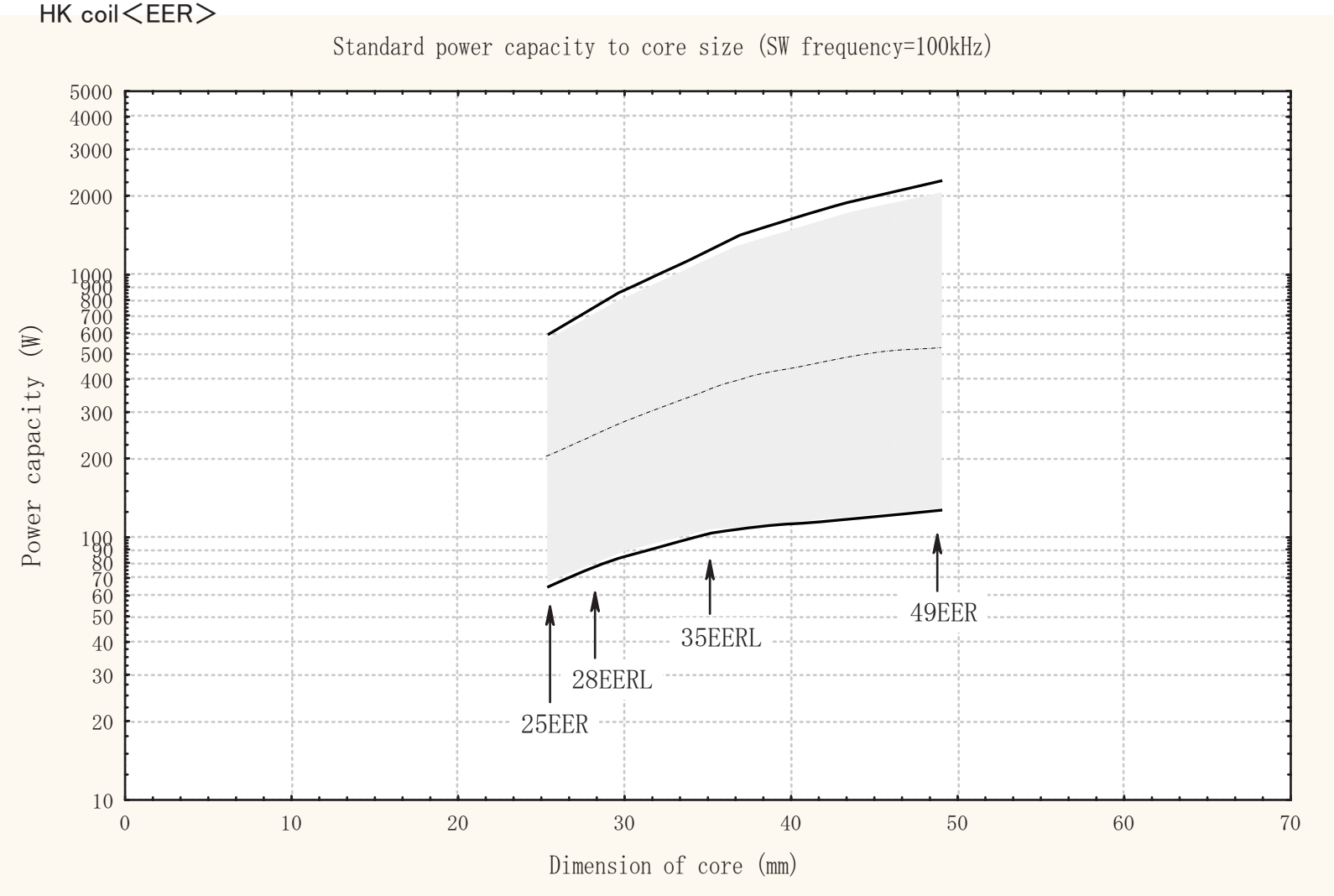
Standard power capacity to core size (2)

HK coil＜EE＞

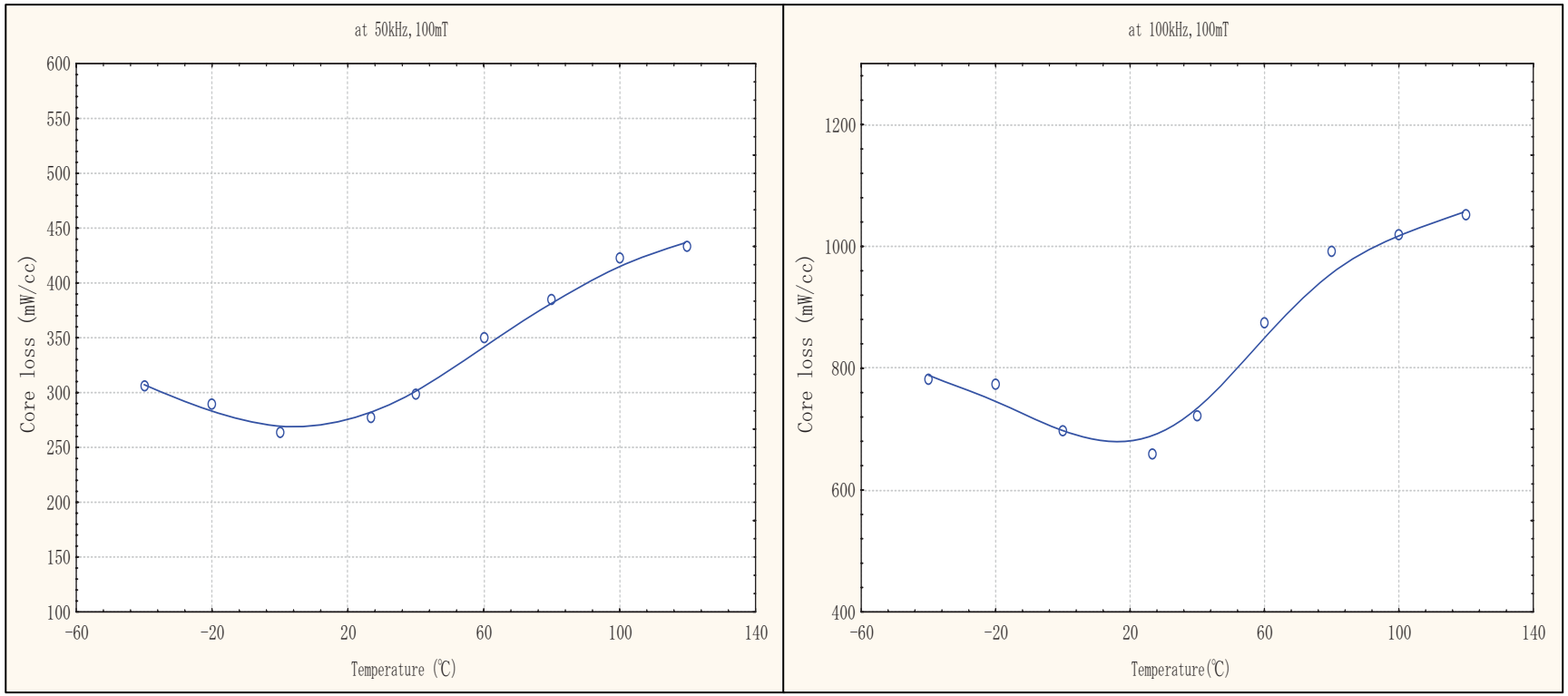


Standard power capacity to core size (3)

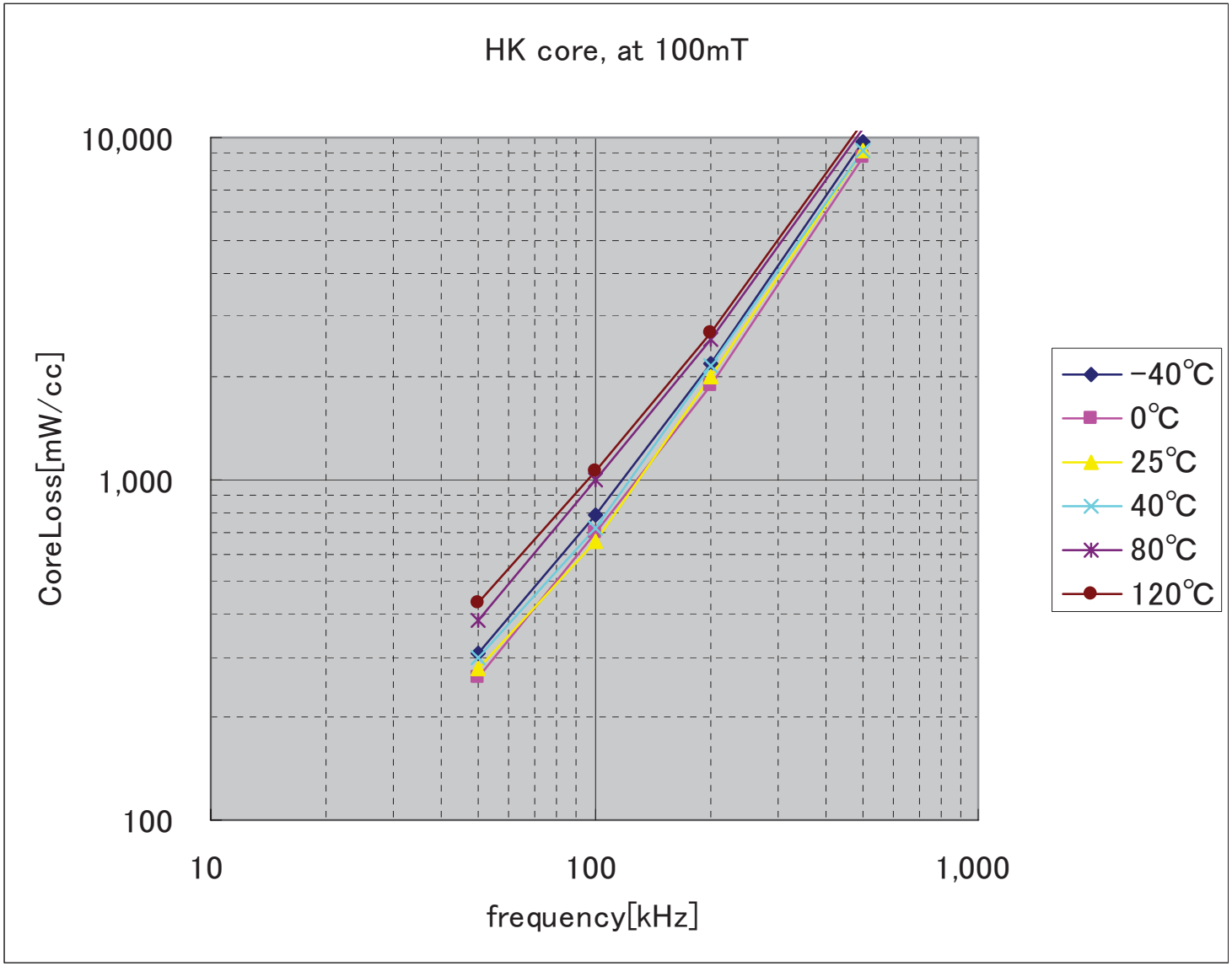
HK coil＜EER＞



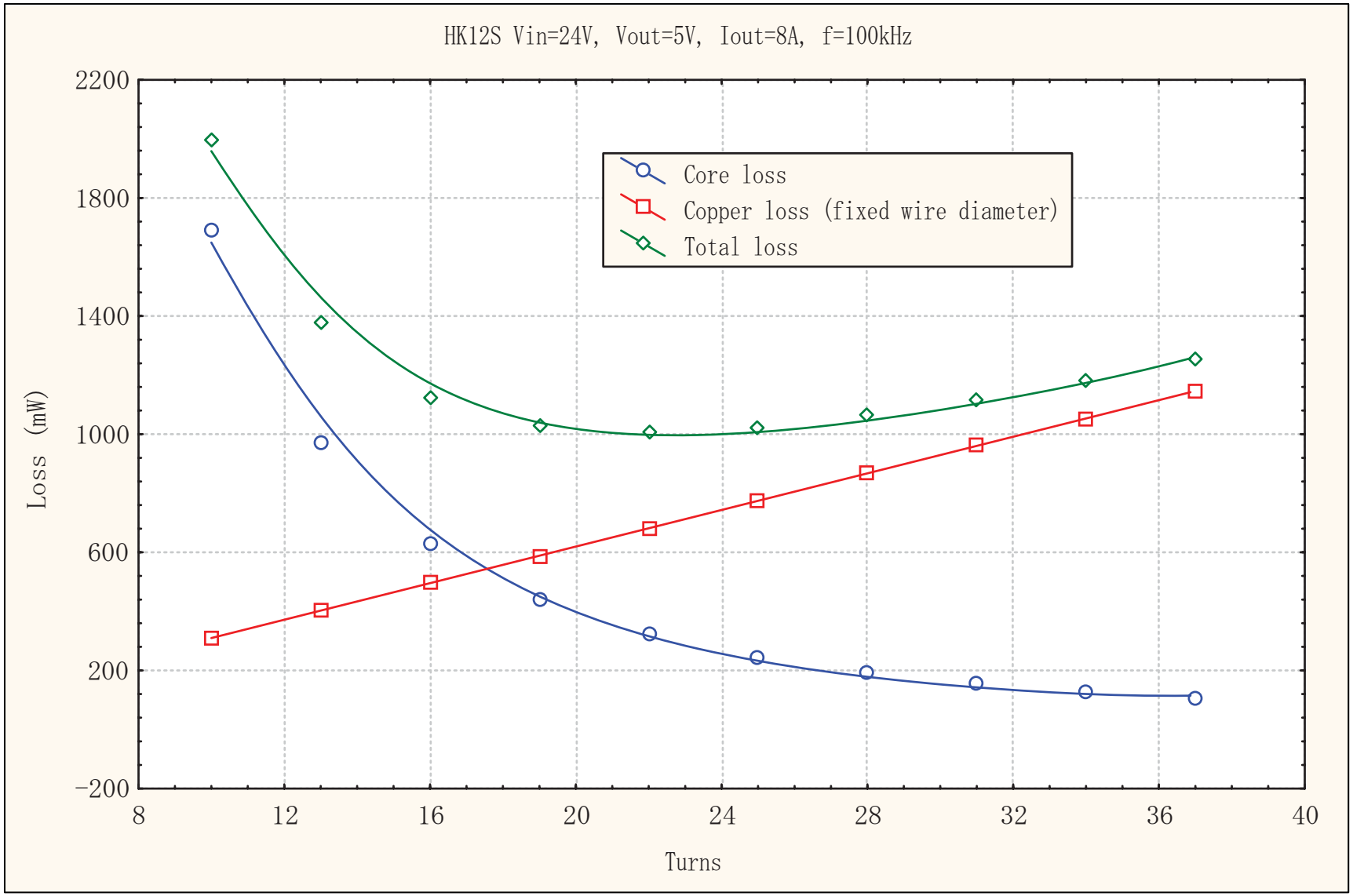
Temperature characteristic of core loss (1)



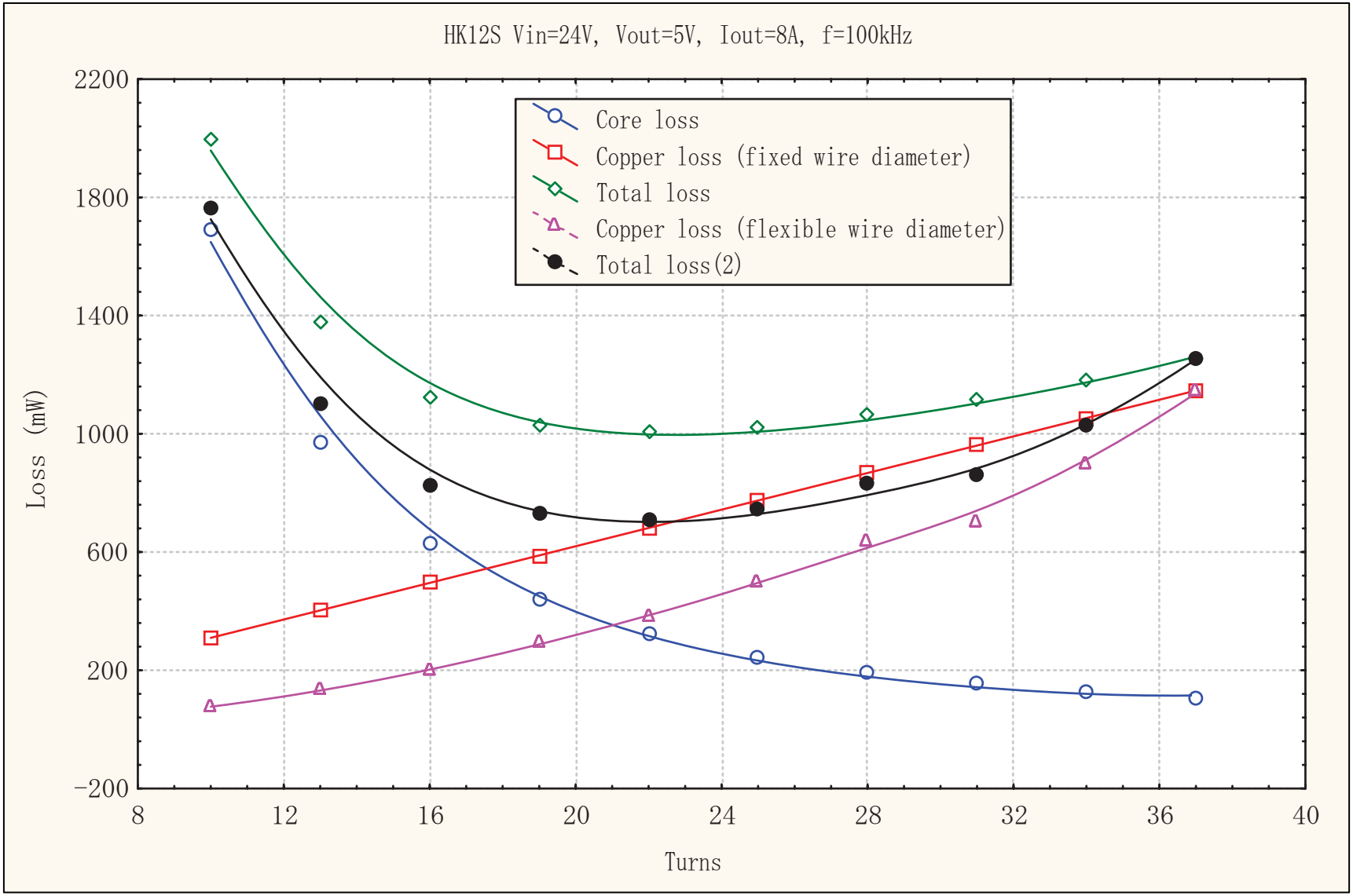
Temperature characteristic of core loss (2)



Winding tuning for loss reduction (1)



Winding tuning for loss reduction (2)



ＨＫ Core材質選定的要點

○他勵式

・先從高透磁率的鐵芯來選擇（ＨＫＨ→ＨＫＳ→ＨＫＬ）

・如果直流重畳特性無法滿足則選擇使用ＨＫＢ

○自勵式

・先選擇ＨＫＢ

・如果頻率還有空間的話,Loss大時就嘗試選擇低Loss種類（ＨＫＨ、ＨＫＳ、ＨＫＬ）