VDM Metals

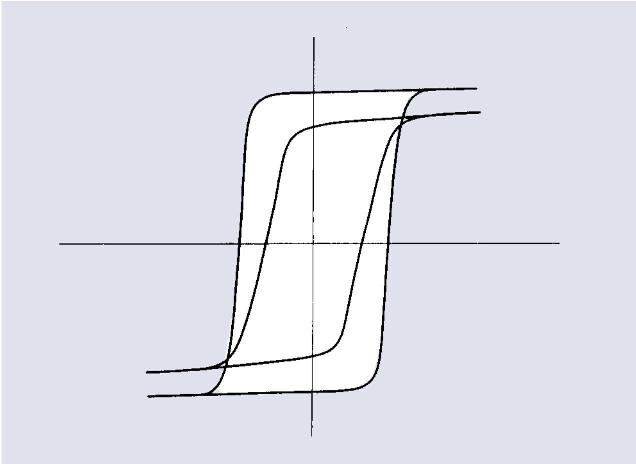
VDM® Magnifer 50

Material Data Sheet No. 9002
August 2002 Edition

Magnifer® 50

Magnifer 50 is a soft-magnetic nickel-iron alloy with about 48 % Ni. It has a saturation induction of 1.55 T and high permeability. Magnifer 50 exhibits the highest saturation induction obtainable with a nickel-iron alloy.

Typical applications of Magnifer 50 are:
- LF power transduters
- Rotor and stator laminations
- Chokes
- Relay parts
- Integrating current transformers for earth-leakage circuit breakers
- Stepping motors
- Magnetic valves
- Shieldings



Magnetic properties
Magnifer 50 is produced in three variants to satisfy the requirements of different applications:

Magnifer 50 RG
After final heat treatment, Magnifer 50 RG exhibits a virtually isotropic, relatively fine-grained structure.

Magnifer 50 TG
By contrast, after final heat treatment Magnifer 50 TG exhibits a very coarse-grained, anisotropic structure with a grain diameter of a few millimetres. A typical feature of this structure is that the permeability values are particularly high, both in the direction of rolling of the strip and to some extent in transverse direction. The favourable magnetic properties of Magnifer 50 TG can be obtained at relatively low annealing temperatures.

Magnifer 50 T
After final annealing, Magnifer 50 T exhibits a pronounced cubic texture, resulting in an almost rectangular hysteresis loop with remanence of about 1.5 T. The ratio of remanence to saturation induction is then higher than 0.95.

Table 1 lists limiting values for individual grades of the three variants. Besides these three main variants there are futher derived qualities.

Magnifer 50 RG-S
Special variations with specific magnetic properties lying between those of Magnifer 50 RG and Magnifer 50 TG can be manufactured if required, with due consideration of the subsequent conditions of further treatment.

Magnifer 50 MG
Strip of greater thickness (> 0.35 mm to approx. 3.2 mm) and bulk material in the other mill product forms are supplied in the quality Magnifer 50 MH.

Magnifer 50 MH-BSo
The variant Magnifer 50 MH-BSo is distinguished by increased corrosion resistance in a cyclic damp heat test. It is used e.g. for stamped parts with thicknesses > 0.5 mm.

Figures 1 to 12 show the magnetic properties of Magnifer 50 RG, Magnifer 50 TG and Magnifer 50 T in relation to various parameters. From these the user can take the most important data required for dimensioning.

The properties shown in these diagrams are characteristic of the alloy in the heat-treated condition. The various heat treatments are described in the following sections. Variations in these heat treatments will result in changes in the properties of the alloy. The main factors in this respect are annealing temperature and furnace atmosphere.

Alloy	Grade	Designation acc. to DIN	Strip thickness (mm)	Permeability[1)] μ_4	$\mu_{max.}$	Coercive force[2)] H_c (A/m)	Induction (mT) at H_{eff} = 160 mA/cm	Core loss (W/kg)
Magnifer® 50 RG	MF 3	F 3 DIN 41301	0.10; 0.20 0.35	≥ 4.000 ≥ 4.000	≥ 60.000 ≥ 40.000		≥ 650 ≥ 500	V_{10} = 0.25
	MF 6		0.10; 0.20 0.35	≥ 6.000 ≥ 6.000	≥ 70.000 ≥ 45.000		≥ 800 ≥ 600	
	MF 10		0.10; 0.20 0.35	≥ 10.000 ≥ 10.000	≥ 80.000 ≥ 50.000		≥ 1000 ≥ 700	
	MH 8	RNi8, RNi 12 DIN 17405	Bulk material			≤ 8		
Magnifer® 50 TG	MG 6		0.10; 0.20 0.35	≥ 6.000 ≥ 6.000	≥ 70.000 ≥ 50.000		≥ 800 ≥ 650	
	MG 10		0.15 0.35	≥ 10.000 ≥ 10.000	≥ 80.000 ≥ 55.000		≥ 1000 ≥ 750	
Magnifer® 50 T	MT		0.05; 0.10	Rectangular $B_R / B_M \geq 0.95$				V_{15} = 0.8

1) Measured with 22 x 14.5 x 10 (mm) toroidal tape-wound cores.

2) Static measurement after magnetization to saturation.

Table 1 – Magnetic properties of Magnifer 50.

Heat treatment

Heavily worked stock may need to be soft-annealed before carrying out any further deformation. This annealing is best performed at between 800 °C and 1000 °C. The annealing time – not longer than 1 hour – can be kept shorter the higher the temperature is.

Temperature and annealing time are guided by the desired final condition, which is adjusted in accordance with subsequent working operations. Annealing should be carried out in hydrogen, cracked ammonia or a clean inert gas atmosphere.

Final annealing for obtaining optimum magnetic properties

The magnetic properties quoted in this Data Sheet are obtainable only after a special final annealing treatment. Annealing must take place in dry hydrogen or cracked ammonia (dew point < -40 °C). The appropriate annealing temperature for Magnifer 50 RG and Magnifer 50 TG is between 1050 and 1250 °C, with an annealing time of 2 to 8 hours.

After this final annealing, the stock must be furnace-cooled to about 450 °C over a period of 5 to 7 hours. Further cooling is then not critical.

Final annealing of Magnifer 50 T is usually carried out at temperatures around 1000 °C. The required data for annealing temperature, holding time and cooling are quoted for each individual batch delivered. The final annealing of parts produced from Magnifer 50 T should preferably be carried out in our factory.

After the final heat treatment, the parts must not be subjected to further mechanical stress, as any plastic deformation results in a considerable loss of magnetic properties.

Chemical composition

Ni	Mn	Si	C	Fe
48	0.4	0.15	0.02	balance

Table 2 – Chemical composition (%)

Standards and material numbers

DIN 17745 DIN 41301	1.3926; 1.3927 1.3922	Ni 48 F3	DIN 17405 DIN 17405	1.3926 1.3927	RNi12 RNi8

Table 3 – Standards and material numbers applicable to Magnifer 50.

Physical properties

Saturation induction	1.55 T	15 500 G	Density	8.25 g/cm³	0.298 lb/in.³
Curie temperature	470 °C	880 °F	Thermal conductivity	15 W/K/m	60 (BTU in.) (ft h °F)
Saturation magnetostriction	$+ 25 \cdot 10^{-6}$	$+ 25 \cdot 10^{-6}$	Mean coefficient of thermal expansion (20 – 100 °)	$8 \cdot 10^{-6} K^{-1}$	$4.6 \cdot 10^{-6}$/°F
Electrical resistivity	0.45 Ωmm²/m	280 ohm circ mil/ft			

Table 4 – Typical physical properties of Magnifer 50.

Mechanical properties

		cold rolled (about 50 %)	*deep drawable soft annealed	after final anneal
Tensile strength R_m	(N/mm²)	750	560	530
	(ksi)	110	80	75
Yield stress $R_{p\,0.2}$	(N/mm²)	700	290	220
	(ksi)	100	40	30
Elongation A_5	(%)	4	> 40	> 40
Hardness	HV5	220	130 – 180	100 – 120
	HRB	97	63 – 90	55 – 69
*The required condition, deep drawable or soft annealed, should be stated when ordering.				

Table 5 – Typical mechanical properties of Magnifer 50.

Fabrication

Working

The conventional processes can be used. Fabrication data may be obtained from the table of mechanical properties. In the "deep drawable" condition, the minimum Erichsen depth is 8 for sheets of 1 mm thickness. The magnetic final annealed condition is only the final condition in the fabrication of certain parts. It is not suitable as the initial condition for any working operation, as the magnetic properties would be drastically impaired. The cold-rolled state is the most suitable for stamping.

Machining

The cold-worked condition is best suited for machining operations. The behaviour of the alloy is similar to that of stainless steels. Low cutting speeds, cooling cutting oils, and carbide or high-speed tools are necessary. The latter must be kept sharp. After machining is completed, residual oil, grease or dirt films must be entirely removed before annealing the parts.

Welding

The best process is usually resistance spot welding, although in principle other processes are also applicable. We are pleased to advice on the best process in specific cases.

Corrosion resistance

Corrosion resistance in a humid atmosphere is low. Higher corrosion resistance can be obtained with the quality Magnifer 50 MH-BSo.

Forms supplied

Mill products

Strip, ribbon, sheet, bar and wire.

Fabricated parts

Toroidal tape-wound cores, core sheets, relay parts and other stamped and bent parts.

Inductive components

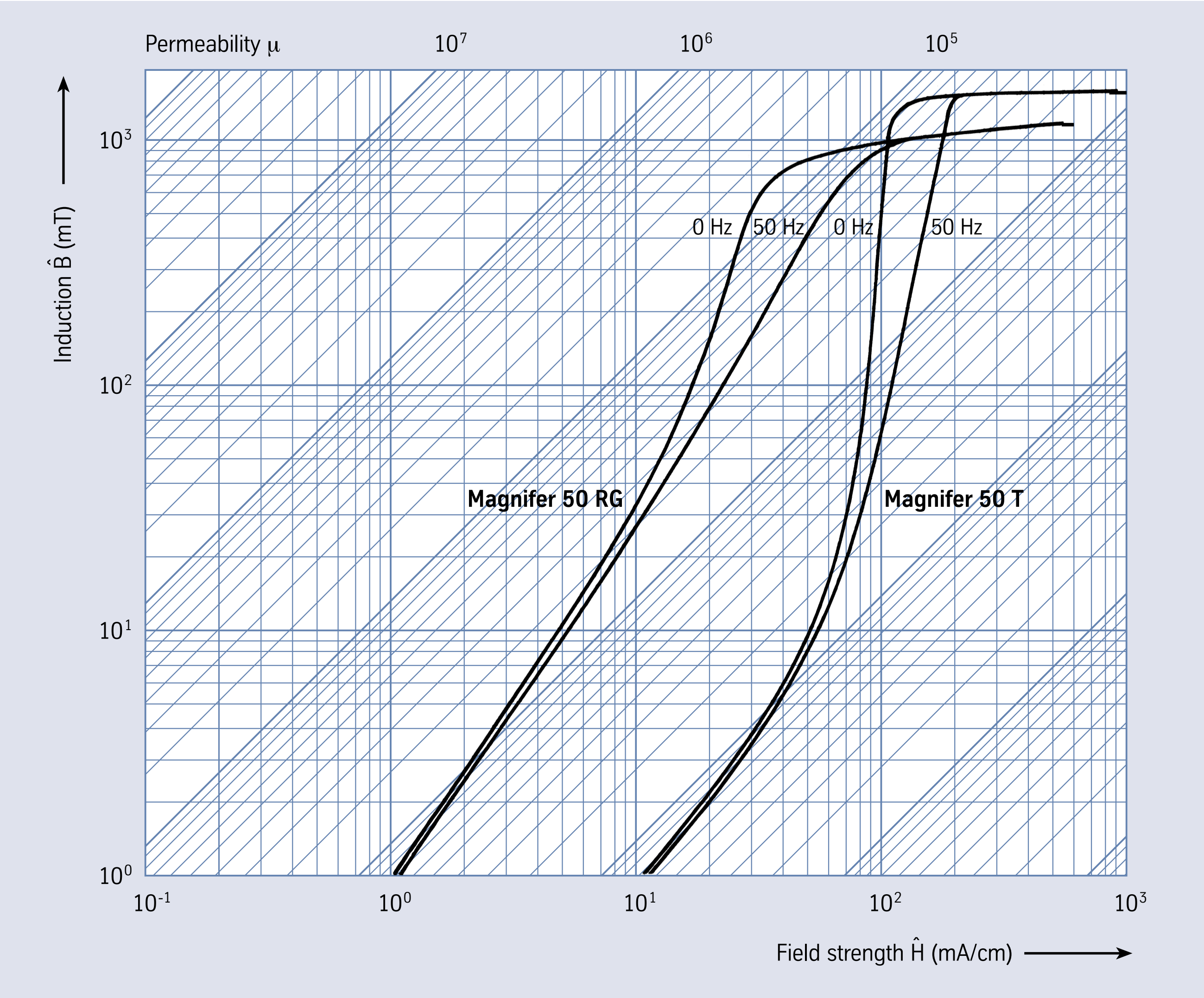


Fig. 1 – Typical induction/magnetic field-strength curves of Magnifer 50 RG and Magnifer 50 T, measured using toroidal tape-wound cores of 0.2 mm strip thickness.

Magnifer® 50

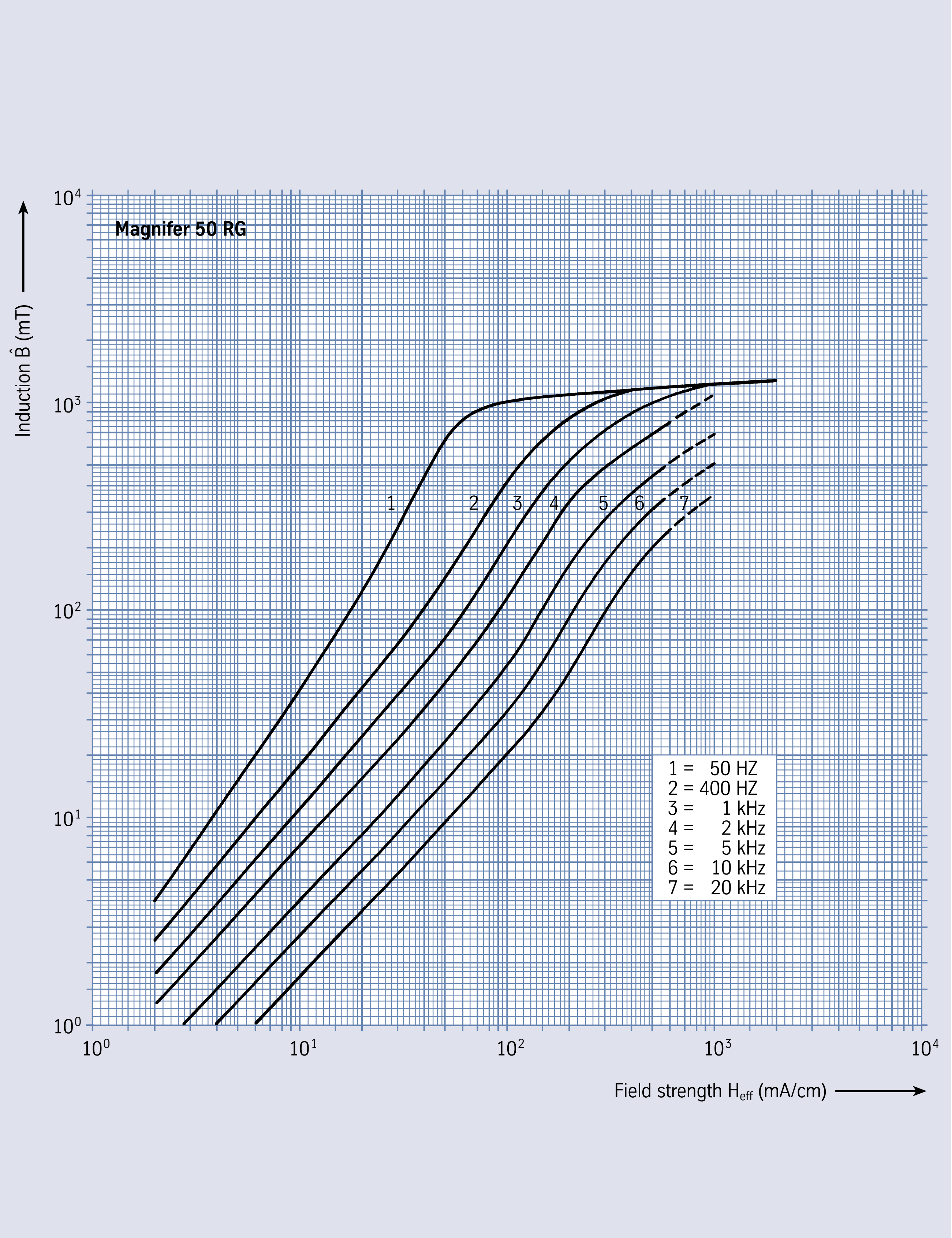


Fig. 2 – Typical induction/magnetic field-strength curves of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.2 mm strip thickness at various frequencies.

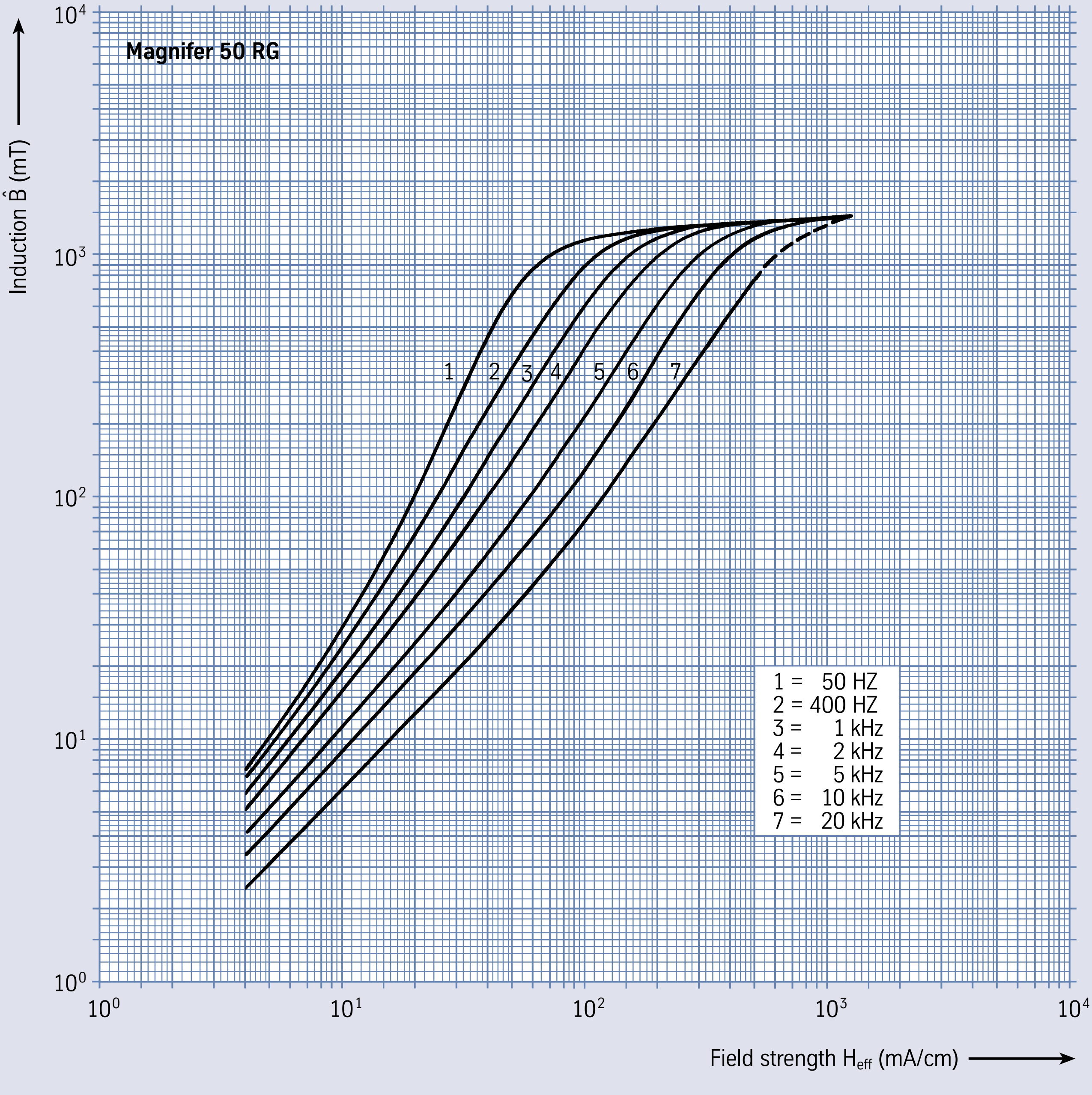


Fig. 3 – Typical induction/magnetic field-strength curves of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.05 mm strip thickness at various frequencies.

Magnifer® 50

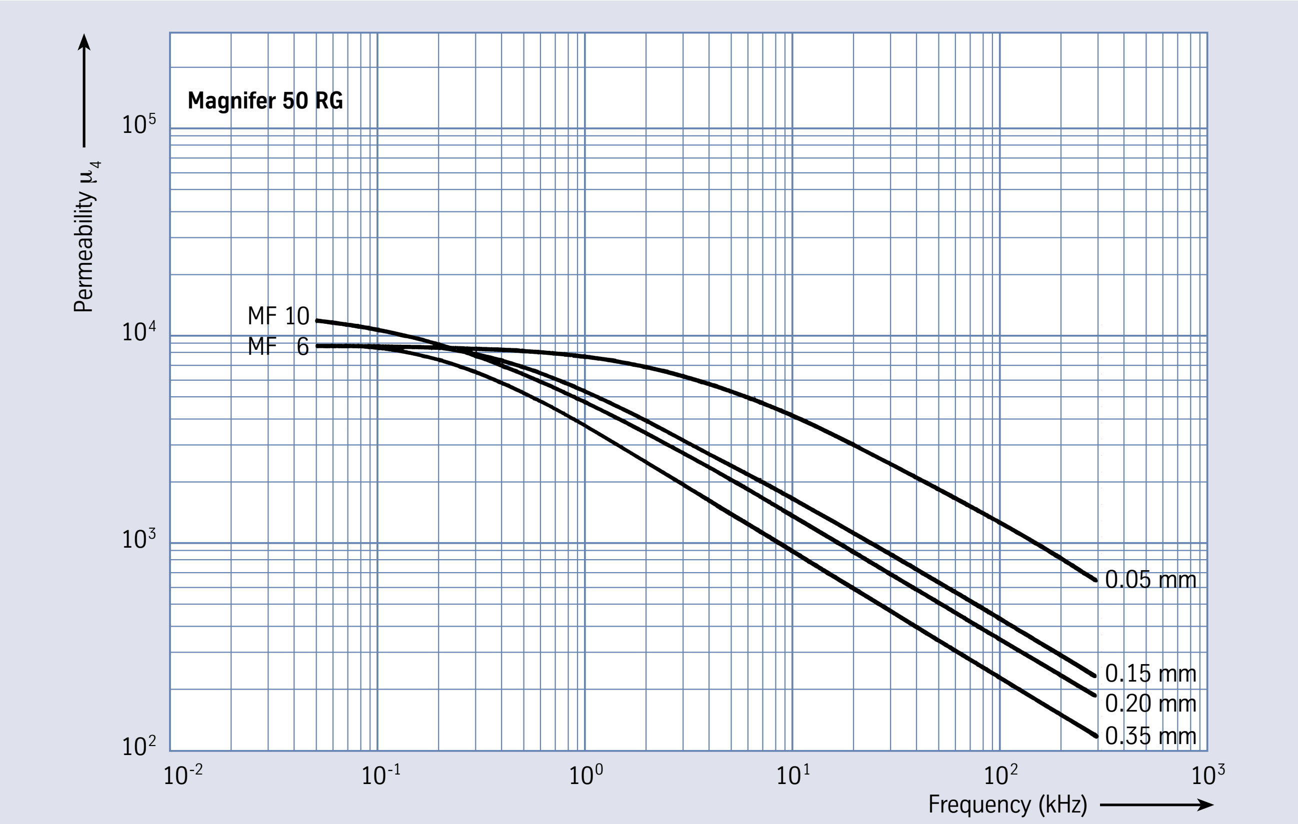


Fig. 4 – Initial permeability of Magnifer 50 RG at 4 mA/cm in relation to frequency, measured using toroidal tape-wound cores of various strip thicknesses.

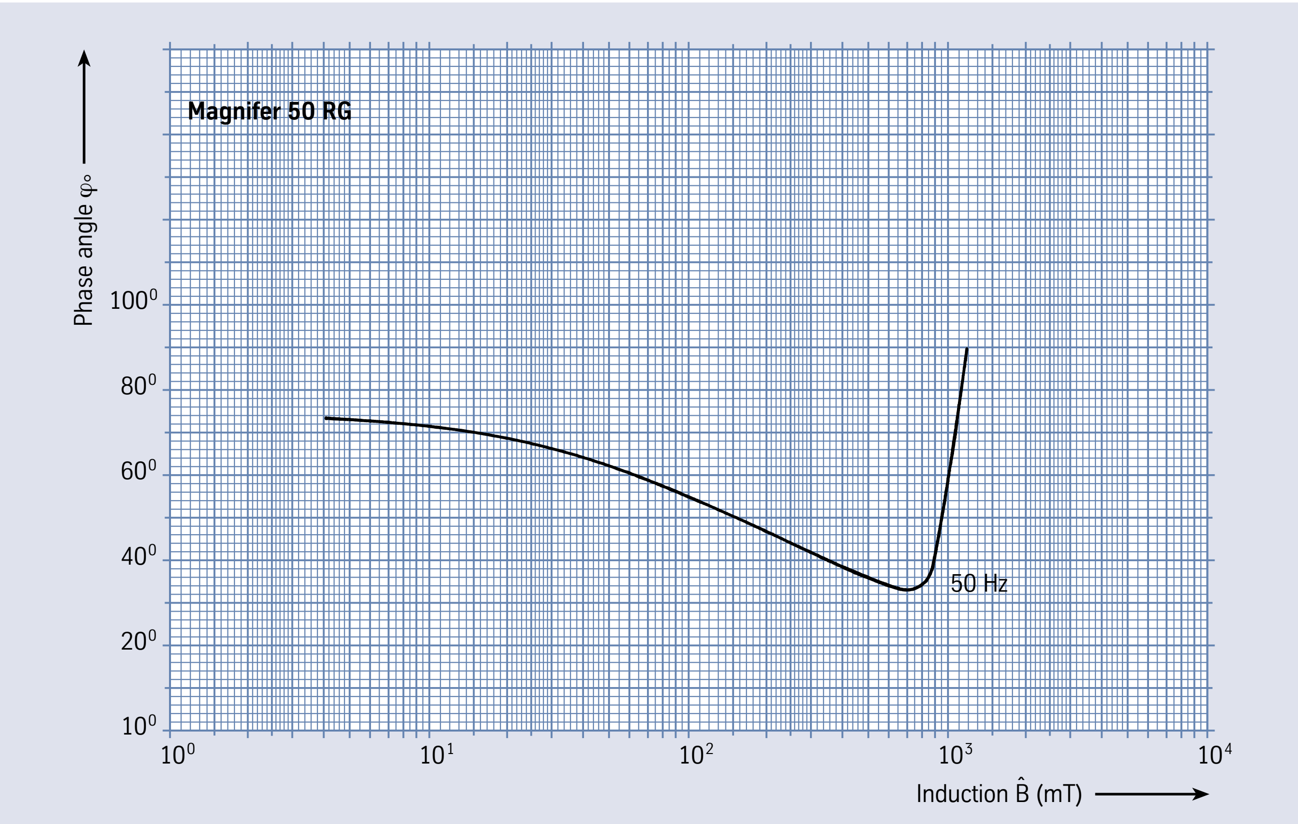


Fig. 5 – Phase angle $\varphi_\circ$ of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.2 mm strip thickness.

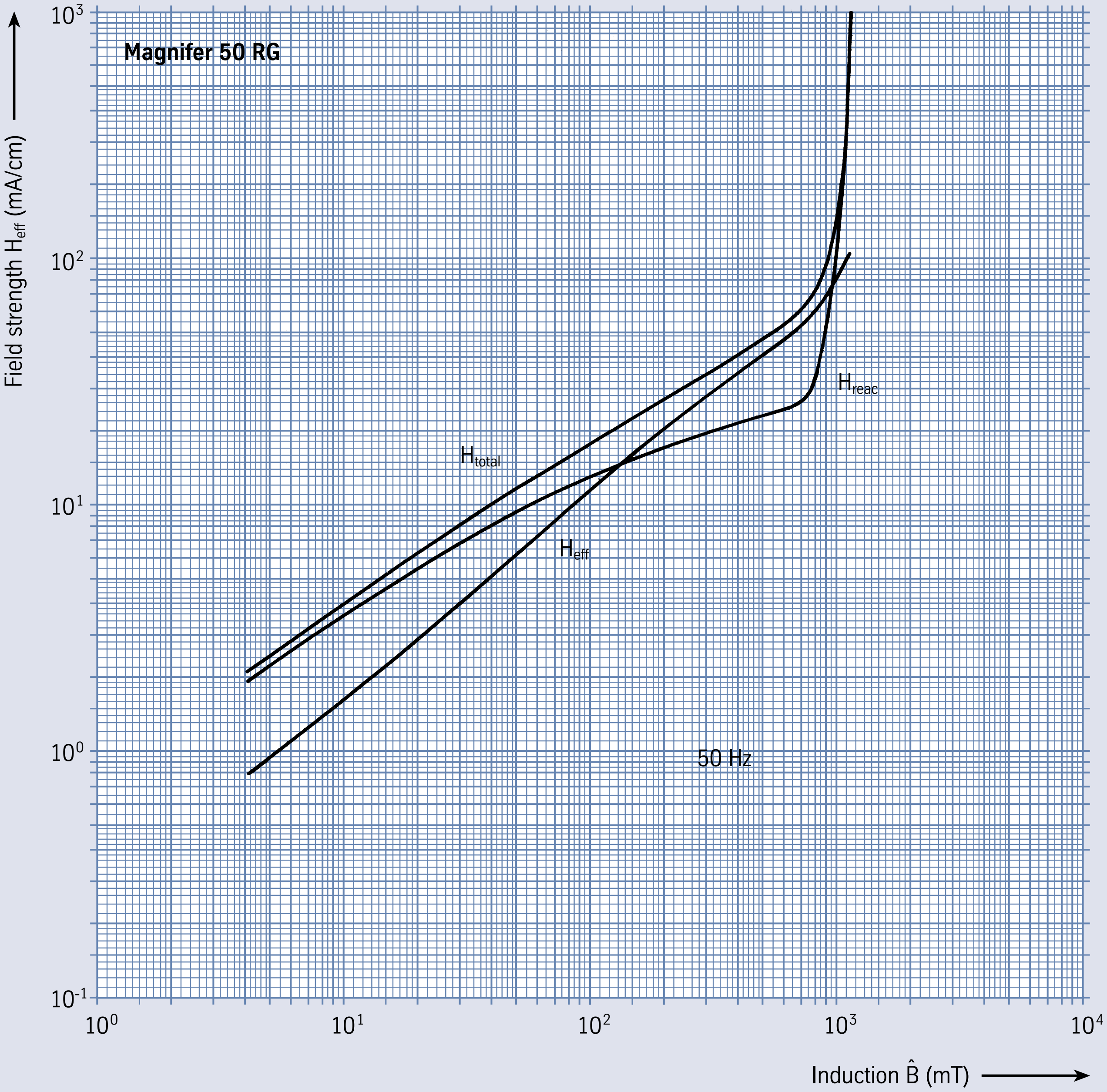


Fig. 6 – Components of the magnetization curve of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.2 mm strip thickness.

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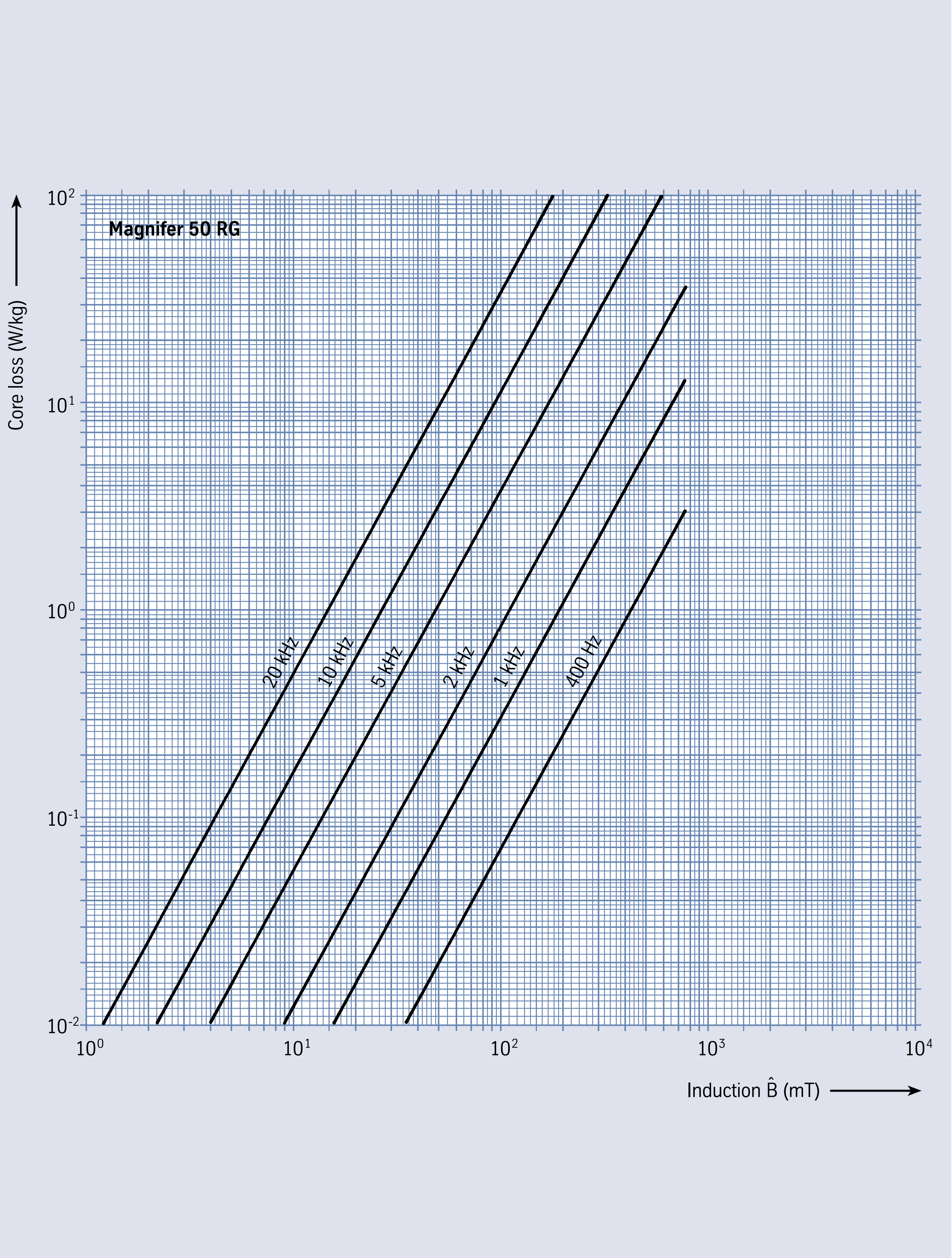

Fig. 7 – Core loss of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.2 mm strip thickness at various frequencies.

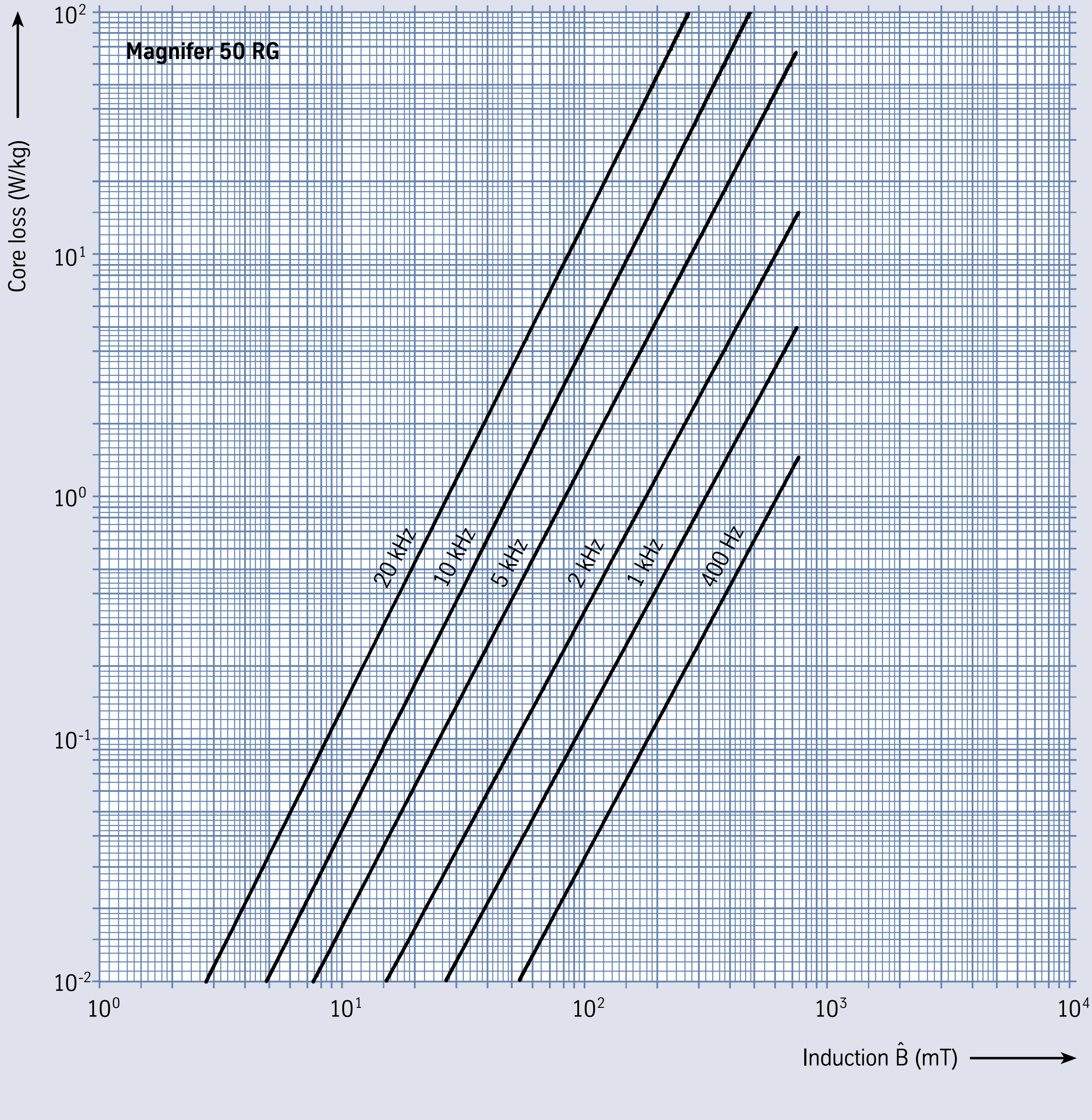

Fig. 8 – Core loss of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.05 mm strip thickness at various frequencies.

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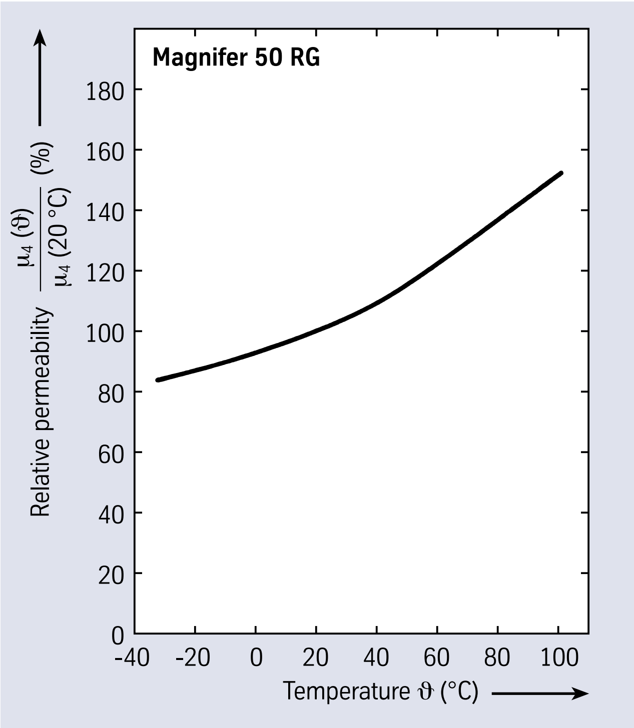

Fig. 9 – Initial permeability of Magnifer 50 RG in relation to temperature.

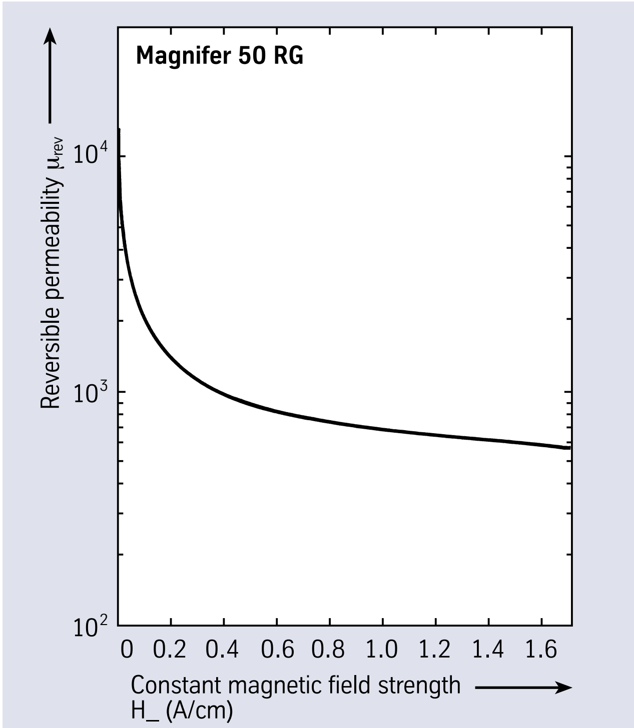

Fig. 10 – Reversible permeability of Magnifer 50 RG, measured using 50 x 40 mm toroidal tape-wound cores of 0.2 mm strip thickness at 100 Hz.

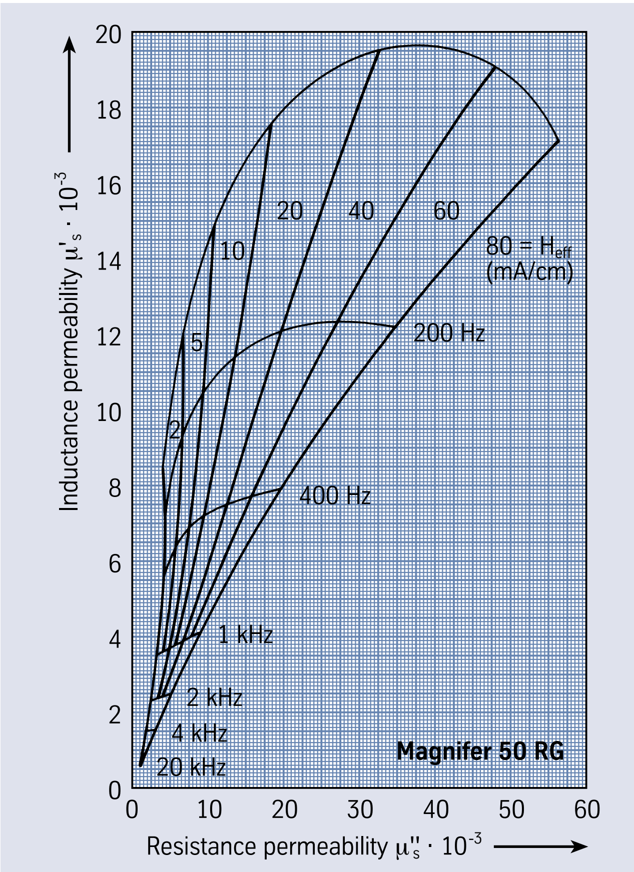

Fig. 11 – Locus curves of complex permeability of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.2 mm strip thickness.

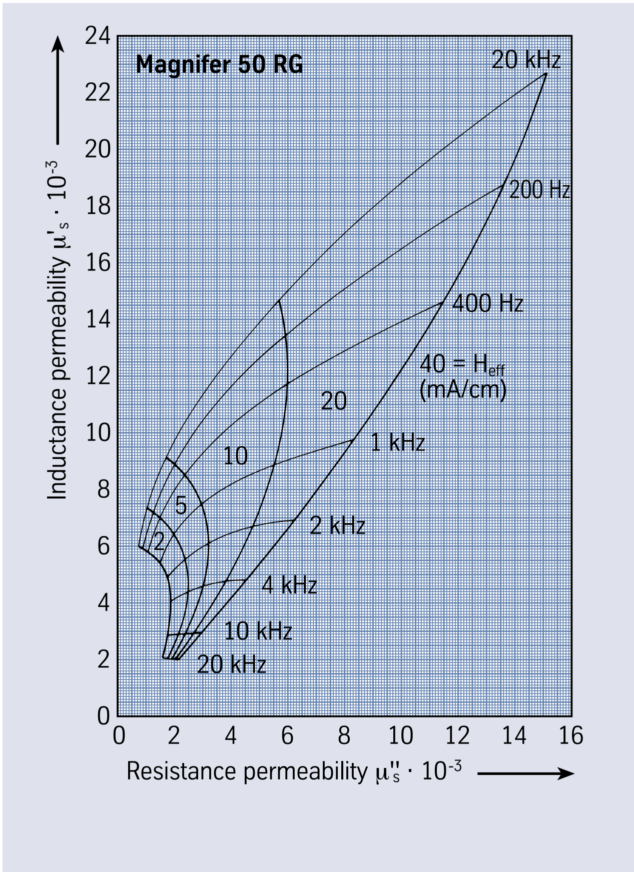

Fig. 12 – Locus curves of complex permeability of Magnifer 50 RG, measured using toroidal tape-wound cores of 0.05 mm strip thickness.

Technical publication

The alloy Magnifer 50 is the subject of the following ThyssenKrupp VDM technical publication:

H. Hattendorf:
A 48% Ni-Fe alloy of low coercivity and improved corrosion resistance in a cyclic damp heat test, Journal of Magnetism and Magnetic Materials 231 (2001) L29 – L32.

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