

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

**Terms and nomenclature for cores made of magnetically soft ferrites –  
Part 3: Guidelines on the format of data appearing in manufacturers catalogues  
of transformer and inductor cores**

**Termes et nomenclature pour noyaux en matériaux ferrites magnétiquement  
doux –**

**Partie 3: Lignes directrices relatives aux formats des données figurant dans les  
catalogues des fabricants de noyaux pour transformateurs et inductances**



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**TERMS AND NOMENCLATURE FOR CORES MADE  
OF MAGNETICALLY SOFT FERRITES –****Part 3: Guidelines on the format of data appearing in manufacturers  
catalogues of transformer and inductor cores**

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International Standard IEC 60401-3 has been prepared IEC technical committee 51: Magnetic components and ferrite materials.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) addition of reliability in Clause 6.

The text of this standard is based on the following documents:

FDIS	Report on voting
51/1106/FDIS	51/1121/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60401 series, published under the general title *Terms and nomenclature for cores made of magnetically soft ferrites*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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## INTRODUCTION

For various reasons, a manufacturer may wish to publish in its catalogue typical data for material parameters as measured on test pieces. It is the object of this part of IEC 60401 to promote the comparability of such information in the area of soft ferrite materials.

Except for several specific property limits that should be given separately for each particular core, the properties described in this standard are material characteristics, intended to facilitate meaningful evaluation of ferrite materials. It should be recognized, however, that there is no direct relation between material characteristics as measured on test pieces and the corresponding parameters measured on other cores, made of the same material, because of differences in geometry and variation in production processes. Also, the extrapolation of material characteristics to other flux densities and other frequencies will not permit valid comparison of cores of different materials under these new conditions of operation.

It is therefore emphasized that it is impossible to design and specify a core on the basis of material properties published by a manufacturer in its catalogue, without due contact with that manufacturer. Also, the publication of material characteristics should not be considered as a guarantee for core properties; for this purpose, only the specification of that core should be used.

It is strongly recommended that, together with the material characteristics, manufacturers publish a note covering the two statements above on the limitations of this kind of information.

This standard further addresses the comparability of various grades of ferrite from different manufacturers by defining the baseline reliability and temperature performance that is inherent for all MnZn ferrite materials, and the limitations that exist when specifying related performance characteristics in ferrite cores.

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## TERMS AND NOMENCLATURE FOR CORES MADE OF MAGNETICALLY SOFT FERRITES –

### Part 3: Guidelines on the format of data appearing in manufacturers catalogues of transformer and inductor cores

#### 1 Scope

This part of IEC 60401 gives guidelines for a uniform method of presentation for the properties of magnetically soft ferrite materials and measuring conditions under which they should be determined. It is intended for use in manufacturers' catalogues of transformer and inductor cores, in order to aid the comparability of such data. Additional guidance is given for users and manufacturers concerning testing and specification of reliability for ferrite cores and for devices using ferrite cores.

#### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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IEC 61332:2005, *Soft ferrite material classification*

IEC 60401-3:2015

IEC 62044-2, *Cores made of soft magnetic materials – Measuring methods – Part 2: Magnetic properties at low excitation level* 9328a422b63f/iec-60401-3-2015

IEC 62044-3, *Cores made of soft magnetic materials – Measuring methods – Part 3: Magnetic properties at high excitation level*

#### 3 Measuring methods

The measuring methods should conform to the general procedures and precautions given in IEC 62044-1, IEC 62044-2 and IEC 62044-3. The test piece for the magnetic measurements should be a ring-core, preferably one of the sizes R10 to R36 in accordance with IEC TR 61604, and having corresponding  $A_e$  values within the range 8 mm<sup>2</sup> to 100 mm<sup>2</sup>. Table 2 indicates recommended test conditions.

#### 4 Table of material properties and measuring conditions

The conditions laid down in Table 2 have been chosen as representative of those that are in common use. This means that in the majority of cases the values now published by manufacturers will differ only slightly from the corresponding values at the measuring conditions given in Table 2. It is therefore expected that only small adjustments to existing catalogues will be required.

The following rules are recommended for the use of Table 2 by manufacturers:

- a) properties not of importance for the application of the material in question should be omitted;
- b) where for one property several measuring conditions are stated with one or more underlined, the conditions underlined shall be used and the rest are optional;



- c) if none of the measuring conditions is underlined, the choice is free and at least one shall be used;
- d) values obtained under measuring conditions deviating from those specified in the table may be added to those required according to items b) and c) above.

## 5 Integrity of value

The following rules shown in Table 1 shall be applied for the property values given in Table 2. It is recommended to describe whether each value in a manufacturer's document is a "typical value" or a "limit value" for better understanding.

**Table 1 – Rules for property values given in Table 2**

Type of document	Typical value	Limit value
Table of material properties <sup>a</sup>	$THD_F, Z_N, P_V$	$\mu_i, B_S, (\tan\delta)\mu_i, \eta_B, T_C, \alpha_F, D_F$
Property graph	All properties	
Table of (shaped) core properties		$A_L, THD_F, Z_N, P_V$
<sup>a</sup> Any other values in a table of material properties not specified here are to be given as "typical value".		

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Table 2 – Property values and measuring conditions (1 of 2)

Property - valid for test ring cores only sizes R10 to R36 (see Clause 3)	Symbol	Unit	Measuring conditions				Footnotes
			Frequency kHz	Field strength kA/m	Peak flux density mT	Temperature (see Clause 4) °C	
Initial permeability	$\mu_i$		$\leq 10$		$< 0,50$	25	
Saturation magnetic flux density	$B_s$	mT	$\leq 10$	1,2 ( $\mu_i > 1\ 000$ ) 3 ( $1\ 000 \geq \mu_i > 500$ )		<u>25</u> ; 100 <sup>k</sup>	
Remanent flux density	$B_r$	mT	$\leq 10$	10 ( $500 \geq \mu_i > 100$ ) 20 ( $100 \geq \mu_i$ )		<u>25</u> ; 100	a
Coercivity	$H_c$	A/m	$\leq 10$			<u>25</u> ; 100	a
Losses at low flux density	$\tan \delta / \mu_i$				$< 0,25$	25	b
Hysteresis material constant	$\eta_B$	T <sup>-1</sup>	10 ( $\mu_i \geq 500$ )		$B_1$ $B_2$ 1,5 3,0	25	c
			100 ( $\mu_i < 500$ )		0,3 1,2		
Curie temperature	$T_c$	°C	$\leq 10$		$< 0,25$		d
Relative temperature factor	$\alpha_F$	10 <sup>-6</sup> /°C	$\leq 10$		$< 0,25$	between $\left\{ \begin{array}{l} -40 \\ -25 \\ 25 \text{ and } \begin{array}{l} +5 \\ +55 \\ +85 \end{array} \end{array} \right.$	e
(Mass) density	$d_b$	kg/m <sup>3</sup>					
Disaccommodation factor	$D_F$	10 <sup>-6</sup>	$\leq 10$		$< 0,25$	25; 40	d
Resistivity <sup>l</sup>	$\rho$	$\Omega\text{m}$	DC			25	f
Total harmonic distortion factor	$THD_F$	dB	5		50	25	g
Normalized impedance	$Z_N$	$\Omega/\text{m}$			$< 0,25$	25	d
The following properties are only valid for materials used for power applications							
Power loss (volume) density	$P_v$	kW/m <sup>3</sup>	25		200	Minimum loss temperature	h
			100		200		
			100		100		
			200		100		
			300		100		
			500		50		
			1 000		50		
			2 000		20		
			5 000		10		
50		150	25; <u>100</u>	i			

Table 2 (2 of 2)

Property - valid for test ring cores only sizes R10 to R36 (see Clause 3)	Symbol	Unit	Measuring conditions				Footnotes
			Frequency kHz	Field strength kA/m	Peak flux density mT	Temperature (see Clause 4) °C	
Amplitude permeability	$\mu_a$		≤ 25		400 <u>320</u>	25 <u>100</u>	j
<p>a Information should be given about the measuring method, especially the frequency.</p> <p>b Measurement shall be made at a frequency chosen from Table 1 and Table 2 of IEC 61332:2005 corresponding to <math>\mu_i</math>. The losses at low flux density may be given in a graph as a function of frequency. Low-level losses comprise both the eddy current and the residual losses but the former can be made insignificant as compared to the latter, see Clause 3.</p> <p>c <math>\eta_B</math> shall be based on measurement at two flux densities <math>B_1</math> and <math>B_2</math>, such that <math>B_1 \leq B_2/2</math>.</p> <p>d The measuring method shall be in accordance with IEC 62044-2.</p> <p>e <math>\alpha_F = \frac{\mu_T - \mu_{ref}}{\mu_{ref}^2} \times \frac{1}{T - T_{ref}}</math>. The measuring method shall be in accordance with IEC 62044-2.</p> <p>f The firing skin shall be removed from the test piece. The electric field strength shall not exceed 0,1 kV/m.</p> <p>g <math>THD_F = 20 \lg \left( \frac{V_m / V_1}{\mu_{ea} / CCF} \right)</math> where <math>CCF = \frac{1}{\sqrt{1 + (3\omega L_p / R_s)^2}}</math></p> <p>The measuring method and core size shall be in accordance with IEC 62044-2. This property is applied only for a specific application such as XDSL. IEC 60401-3:2015</p> <p>h The effective volume <math>V_e</math> according to IEC 62044-3 shall be used to determine the volume-related power loss <math>P_v</math>. For determination of the volume related power loss <math>P_v</math>, the voltage for the required flux density shall be calculated in accordance with IEC 62044-3. The power losses may be shown in a series of graphs as functions of flux density with the frequency as a parameter of individual graphs. Where specific values of power loss are quoted, these shall correspond to the preferred combinations of frequency and flux density shown in Table 2.</p> <p>i This condition shall be applied for the core to be used for a back-light.</p> <p>j For determination of the amplitude permeability, the measuring method shall be in accordance with IEC 62044-3.</p> <p>k Both temperatures are to be used for material for power applications: for other applications the higher temperature is optional.</p> <p>l Formerly referred to as "specific resistance".</p>							

## 6 Reliability

Reliability as it relates to ferrite cores is different from reliability for inductors or transformers, because cores are necessarily incorporated mechanically into the structures of inductors or transformers. It is those structures that see application conditions, and exhibit endurance or lack of endurance in use. IEC 62211 is the IEC guide for magnetics reliability. It addresses wound devices, not cores in isolation.

Guidelines for data to be shown in manufacturers' catalogues for ferrite cores do not include reliability testing or specification limits, and in practice reliability claims are not made in manufacturers' catalogues.

It is important for users of ferrites to be aware of some general facts about inherent ferrite material properties:

- a) Ferrites are dense ceramics, not alloys, and not heterogeneous structures. They are inherently very chemically stable.
- b) Curie temperature and maximum rated temperature for ferrites are not the same. Ferrites can be safely exposed to temperatures far higher than Curie temperature, so long as the temperature change is not too rapid, and the ferrite is not required to perform magnetically while above the Curie temperature.
- c) Temperature effects in ferrites are reversible, which means that a core will return to the same magnetic performance at the same temperature no matter what other temperatures it is exposed to in the meantime. This is generally true up to the limit of a temperature far above Curie, where the material becomes reactive. But it is not true if the change in temperature is rapid enough to cause thermal shock cracks.
- d) Reliability testing, such as is required for many automotive components, or such as for inductive components in IEC 62211, is not relevant for ferrites alone. It is the performance of assembled inductive devices – including ferrite, wire, terminations, potting, coil formers, mounting fixtures, etc. – that is logical to assess for reliability.
- e) Chips and small cracks are not special reliability hazards for ferrites. Chip and crack sizes are controlled for cosmetic and workmanship reasons, and are subject to standard limits in the IEC 60424 series.
- f) Mechanical strength generally is considered to be adequate and repeatable by handling during manufacture. It is also documented in some case by break strength testing. See IEC 61631.
- g) Manufacturers generally qualify ring core coatings for adequate adhesion, temperature stability, and solvent resistance. For each different coating, a maximum continuous operating temperature limit applies. Standard practice is to conduct voltage breakdown testing for each batch of coated parts. See Annex A.
- h) Different winding wires and different winding techniques result in varying degrees of mechanical impact or stress delivered to the coating. Manufacturers are unable to guarantee that coatings will remain undamaged regardless of the impact or stress applied from winding. It is not uncommon for winding impact to cause coating chips on normally coated ring cores.
- i) Mechanical stresses from winding, potting, or encapsulation can degrade electrical performance. Such stress effects are reversible, as long as cracks are not created. It is generally not possible for the manufacturer to significantly alter or control the susceptibility of ferrite cores to shifts due to mechanical stress. It is an inherent property of ferrites. Higher permeability materials tend to be more sensitive. Different grades of material exhibit different characteristic sensitivity.