BS EN 60401-3:2016

BSI Standards Publication

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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National foreword

This British Standard is the UK implementation of EN 60401-3:2016. It is identical to IEC 60401-3:2015. It supersedes BS EN 60401-3:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/51, Transformers, inductors, magnetic components and ferrite materials.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

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 (IEC 60401-3:2015)

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 (IEC 60401-3:2015)

Begriffe und Bezeichnungssystem für Kerne aus weichmagnetischen Ferriten - Teil 3: Leitfaden für das Datenformat für Übertrager- und Spulenkerne in Herstellerkatalogen (IEC 60401-3:2015)

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 51/1106/FDIS, future edition 2 of IEC 60401-3, prepared by IEC/TC 51 "Magnetic components and ferrite materials" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60401-3:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-10-08
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-01-08

This document supersedes EN 60401-3:2003.

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60424 Series	NOTE	Harmonized as EN 60424 Series.
IEC 60424-1	NOTE	Harmonized as EN 60424-1.
IEC 60424-2	NOTE	Harmonized as EN 60424-2.
IEC 60424-3	NOTE	Harmonized as EN 60424-3.
IEC 60424-4	NOTE	Harmonized as EN 60424-4.
IEC 60424-5	NOTE	Harmonized as EN 60424-5.
IEC 61631	NOTE	Harmonized as EN 61631.
IEC 62044-1	NOTE	Harmonized as EN 62044-1.
IEC 62211	NOTE	Harmonized as EN 62211.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 61332	2005	Soft ferrite material classification	EN 61332	2005
IEC 62044-2	-	Cores made of soft magnetic materials - Measuring methods - Part 2: Magnetic properties at low excitation level	EN 62044-2	-
IEC 62044-3	-	Cores made of soft magnetic materials - Measuring methods - Part 3: Magnetic properties at high excitation level	EN 62044-3	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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.

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.

IEC 61332:2005, *Soft ferrite material classification*

IEC 62044-2, *Cores made of soft magnetic materials – Measuring methods – Part 2: Magnetic properties at low excitation level*

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^2 to 100 mm^2. 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 [a]	THD_F, Z_N, P_V	μ_i, B_s, $(\tan\delta)/\mu_i$, η_B, T_c, α_F, D_F
Property graph	All properties	
Table of (shaped) core properties		A_L, THD_F, Z_N, P_V
[a] Any other values in a table of material properties not specified here are to be given as "typical value".		

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				
			Frequency kHz	Field strength kA/m	Peak flux density mT	Temperature (see Clause 4) °C	Footnotes
Initial permeability	μ_i		≤ 10		< 0,50	25	
Saturation magnetic flux density	B_s	mT	≤ 10	1,2 (μ_i > 1 000) 3 (1 000 ≥ μ_i>500) 10 (500 ≥ μ_i >100) 20 (100 ≥ μ_i)		25; 100 [k]	
Remanent flux density	B_r	mT	≤ 10			25; 100	a
Coercivity	H_c	A/m	≤ 10			25; 100	a
Losses at low flux density	$\tan\delta/\mu_i$				< 0,25	25	b
Hysteresis material constant	η_B	T^{-1}	10 (μ_i ≥ 500)		B_1 B_2 1,5 3,0	25	c
			100 (μ_i < 500)		0,3 1,2		
Curie temperature	T_c	°C	≤ 10		< 0,25		d
Relative temperature factor	α_F	10^{-6}/°C	≤ 10		< 0,25	between 25 and −40 / −25 / +5 / +55 / +85	e
(Mass) density	d_b	kg/m³					
Disaccommodation factor	D_F	10^{-6}	≤ 10		< 0,25	25; 40	d
Resistivity[l]	ρ	Ωm	DC			25	f
Total harmonic distortion factor	THD_F	dB	5		50	25	g
Normalized impedance	Z_N	Ω/m			< 0,25	25	d
The following properties are only valid for materials used for power applications							
Power loss (volume) density	P_v	kW/m³	25		200	100; 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; 100	i

Table 2 *(2 of 2)*

Property - valid for test ring cores only sizes R10 to R36 (see Clause 3)	Symbol	Unit	Measuring conditions				
			Frequency	Field strength	Peak flux density	Temperature (see Clause 4)	Footnotes
			kHz	kA/m	mT	°C	
Amplitude permeability	μ_a		≤ 25		400	25	j
					320	100	

a Information should be given about the measuring method, especially the frequency.

b Measurement shall be made at a frequency chosen from Table 1 and Table 2 of IEC 61332:2005 corresponding to μ_i.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.

c η_B shall be based on measurement at two flux densities B_1 and B_2, such that $B_1 \leq B_2/2$.

d The measuring method shall be in accordance with IEC 62044-2.

e $\alpha_F = \frac{\mu_T - \mu_{ref}}{\mu_{ref}^2} \times \frac{1}{T - T_{ref}}$. The measuring method shall be in accordance with IEC 62044-2.

f The firing skin shall be removed from the test piece. The electric field strength shall not exceed 0,1 kV/m.

g $THD_F = 20\lg\left(\frac{V_m / V_1}{\mu_{ea} / CCF}\right)$ where $CCF = \frac{1}{\sqrt{1 + \left(3\omega L_p / R_s\right)^2}}$

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.

h The effective volume V_e according to IEC 62044-3 shall be used to determine the volume-related power loss P_v. For determination of the volume related power loss P_v , 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.

i This condition shall be applied for the core to be used for a back-light.

j For determination of the amplitude permeability, the measuring method shall be in accordance with IEC 62044-3.

k Both temperatures are to be used for material for power applications: for other applications the higher temperature is optional.

l Formerly referred to as "specific resistance”.

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.

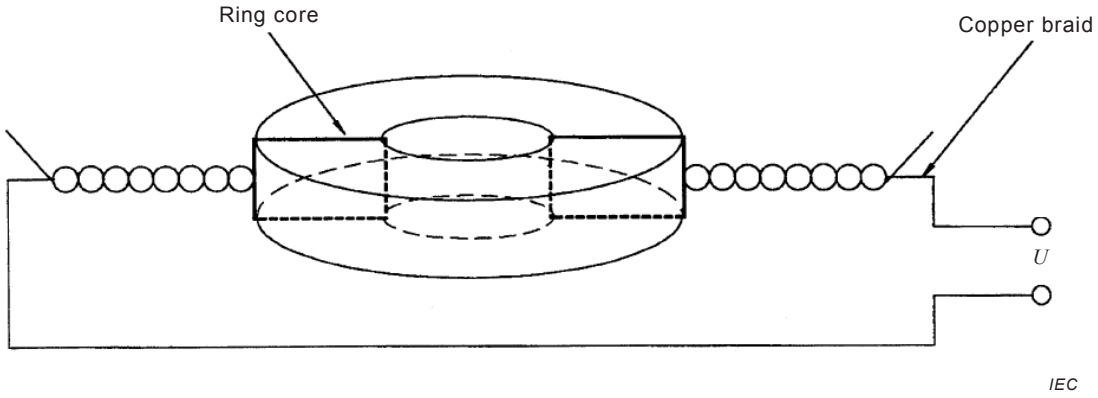
Annex A
(informative)

Breakdown voltage test for insulated ring cores – Measurement techniques

A.1 Method A

This procedure may be used for testing ring cores having inner diameters larger than 6 mm. Figure A.1 shows the principle of a typical measurement. The ring core to be tested is wound by at least two single turns whose leads are short-circuited and are positioned 180° apart. Both windings should be wound tight around the core cross section in order to ensure a maximum mechanical contact. The wires consist of bare copper, for example 100 wires of 0,06 mm. The two ends of the windings are connected to the output of a generator providing the necessary test voltage (DC or AC).

This test method only ensures that the specified voltage is reached at the winding positions. It is recommended for the cases where the uniformity of insulation coating has been verified, or is assumed.



Key

U Test voltage (U_{DC}: in case of DC and U_{eff}: in case of AC).

Figure A.1 – Method A: measurement principle

NOTE Figures A.1, A.2, A.3 and A.4 are schematic only, and the dimensions drawn are not to scale.

A.2 Method B

A.2.1 General

Three variations of method B are defined.

A.2.2 Method B 1

The measuring device consists of two outer ring-shaped shells (1) and two cylinders (2), located in the centre of the specimen (3). It touches the ring core to be tested along the most critical edges.

By this arrangement, the breakdown voltage test can be carried out either in the axial or in the radial direction. Therefore, the voltage polarity of the generator has to be switched as indicated on the drawing of Figure A.2.

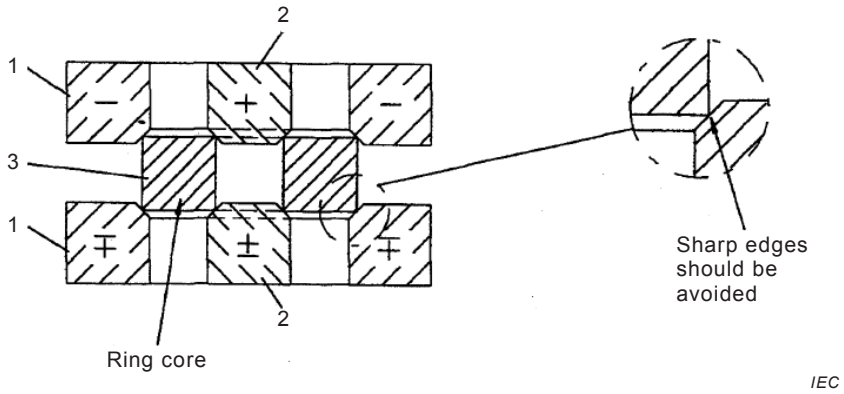


Figure A.2 – Method B 1: Measurement principle

A.2.3 Method B 2

This version of method B is a simplified one. The device consists of two shells which contact the specimen as indicated on the drawing of Figure A.3. This method is only usable in the axial direction.

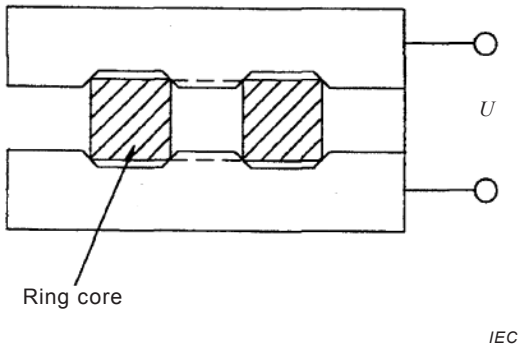


Figure A.3 – Method B 2: Measurement principle

A.2.4 Method B 3

The test device consists of two metal disks covered with conductive rubber plates or copper wire-mesh with rubber backing as indicated in Figure A.4. The specimen is placed between the conductive rubber plates and a specified pressure is applied to the plates to ensure contact with the edges of the specimen.

This method is applicable to test the breakdown voltage of medium and large ring cores in the axial direction only.

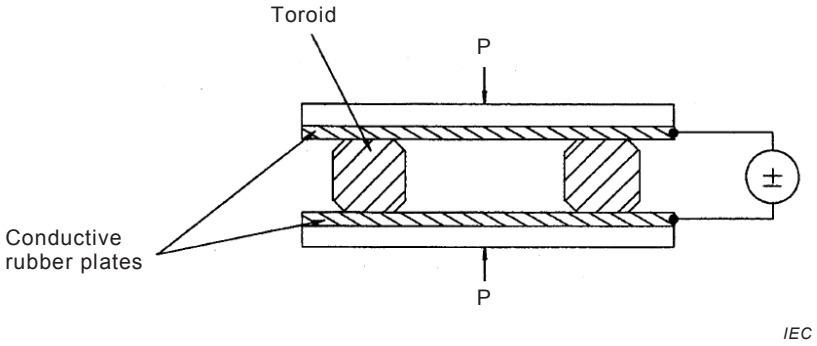


Figure A.4 – Method B 3: Measurement principle

A.3 Notes on voltage breakdown testing

The methods shown above are effective for making repeatable measurements of the voltage breakdown performance of ring core toroid coatings. The conductor arrangements are not the same as application conductors, and therefore there is necessarily a correlation offset between the voltage breakdown measured in the core test and the voltage breakdown measured in finished wound inductive components.

Most prominently, ring cores are generally wound with insulated magnet wire, and the insulation of the magnet wire significantly increases the potential isolation. The voltage breakdown measured for a wound inductive device is not only a function of the ring core coating, but of the magnet wire, windings, tapes and epoxies used.

Voltage breakdown can be a destructive test, in which case the sample size should be small, but the resulting voltage values are specific, and comparable from batch to batch. Alternatively, voltage breakdown can be a non-destructive test by stopping at a pre-defined level, in which case the sample size can be larger, but the resulting information only indicates pass or fail.

Practical coating processes generally result in quite variable thicknesses and variable voltage breakdown measurements. Manufacturers generally test production batches using small samples and destructive testing. As a result there is generally a large head room between typically measured voltage breakdown and the specified minimum.

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[1] IEC 60424 (all parts), *Ferrite cores – Guide on the limits of surface irregularities*

[2] IEC 60424-1, *Ferrite cores – Guidelines on the limits of surface irregularities – Part 1: General specification*

[3] IEC 60424-2, *Ferrite cores – Guidelines on the limits of surface irregularities of ferrite cores – Part 2: RM-cores*

[4] IEC 60424-3, *Ferrite cores – Guidelines on the limits of surface irregularities – Part 3: ETD-cores, EER-cores, EC-cores and E-cores*

[5] IEC 60424-4, *Ferrite cores – Guidelines on the limits of surface irregularities – Part 4: Ring-cores*

[6] IEC 60424-5, *Ferrite cores – Guidelines on the limits of surface irregularities – Part 5: Planar-cores*

[7] IEC TR 61604, *Dimensions of uncoated ring cores of magnetic oxides*

[8] IEC 61631, *Test method for the mechanical strength of cores made of magnetic oxides*

[9] IEC 62044-1, *Cores made of soft magnetic materials – Measuring methods – Part 1: Generic specification*

[10] IEC 62211, *Inductive components – Reliability management*

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