



**BSI Standards Publication**

## **Cores made of soft magnetic materials — Measuring methods**

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Part 3: Magnetic properties at high excitation level

## National foreword

This British Standard is the UK implementation of EN 62044-3:2000, incorporating corrigendum November 2021. It is derived from IEC 62044-3:2000. It supersedes BS EN 62044-3:2001.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum October 2021 is indicated in the text by **AC1** **AC1**.

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

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Published by BSI Standards Limited 2022

ISBN 978 0 539 20242 7

ICS 29.030; 29.100.10

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 15 August 2001.

### Amendments/corrigenda issued since publication

| Date          | Text affected                                                            |
|---------------|--------------------------------------------------------------------------|
| 31 March 2022 | Implementation of IEC corrigendum with CENELEC endorsement November 2021 |

EUROPEAN STANDARD

**EN 62044-3:2001**

NORME EUROPÉENNE

EUROPÄISCHE NORM

May 2001

ICS 29.030; 29.100.10

English version

**Cores made of soft magnetic materials - Measuring methods**  
**Part 3: Magnetic properties at high excitation level**  
(IEC 62044-3:2000)

Noyaux en matériaux magnétiques doux -  
Méthodes de mesure  
Partie 3: Propriétés magnétiques à niveau  
élevé d'excitation  
(CEI 62044-3:2000)

Kerne aus weichmagnetischen  
Materialien - Messverfahren  
Teil 3: Messungen der magnetischen  
Eigenschaften im  
Leistungsbereich  
(IEC 62044-3:2000)

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Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

**Central Secretariat: rue de Stassart 35, B - 1050 Brussels**

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## Foreword

The text of document 51/573/FDIS, future edition 1 of IEC 62044-3, prepared by IEC TC 51, Magnetic components and ferrite materials, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62044-3 on 2001-03-01.

The following dates were fixed:

- latest date by which the EN has to be implemented  
at national level by publication of an identical  
national standard or by endorsement (dop) 2001-12-01
- latest date by which the national standards conflicting  
with the EN have to be withdrawn (dow) 2004-03-01

Annexes designated "normative" are part of the body of the standard.  
Annexes designated "informative" are given for information only.  
In this standard, annex ZA is normative and annexes A to E are informative.  
Annex ZA has been added by CENELEC.

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## Endorsement notice

The text of the International Standard IEC 62044-3:2000 was approved by CENELEC as a European Standard without any modification.

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## Endorsement notice to corrigendum November 2021

The text of the corrigendum IEC 62044-3:2000/COR1:2021 was approved by CENELEC as EN 62044-3:2001/AC:2021-11 without any modification.

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## CORES MADE OF SOFT MAGNETIC MATERIALS – MEASURING METHODS –

### Part 3: Magnetic properties at high excitation level

#### 1 Scope

This standard provides measuring methods for power loss and amplitude permeability of magnetic cores forming the closed magnetic circuits intended for use at high excitation levels in inductors, chokes, transformers and similar devices for power electronics applications.

The methods given in this standard can cover the measurement of magnetic properties for frequencies ranging practically from d.c. to 10 MHz, and even possibly higher, for the calorimetric and reflection methods. The applicability of the individual methods to specific frequency ranges is dependent on the level of accuracy that is to be obtained.

The methods in this standard are basically the most suitable for sine-wave excitations. Other periodic waveforms can also be used; however, adequate accuracy can only be obtained if the measuring circuitry and instruments used are able to handle and process the amplitudes and phases of the signals involved within the frequency spectrum corresponding to the given induction and field strength waveforms with only slightly degraded accuracy.

NOTE It may be necessary for some magnetically soft metallic materials to follow specific general principles, customary for these materials, related to the preparation of specimens and prescribed calculations. These principles are formulated in IEC 60404-8-6.

#### 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 62044. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 62044 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(221):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 221: Magnetic materials and components*

Amendment 1 (1993)

Amendment 2 (1999)

IEC 60205:1966, *Calculation of the effective parameters of magnetic piece parts*

IEC 60367-1:1982, *Cores for inductors and transformers for telecommunications – Part 1: Measuring methods*

IEC 60401:1993, *Ferrite materials – Guide on the format of data appearing in manufacturers' catalogues of transformer and inductor cores*

IEC 60404-8-6:1999, *Magnetic materials – Part 8-6: Specifications for individual materials – Soft magnetic metallic materials*

IEC 61332:1995, *Soft ferrite material classification*

### 3 Terms, definitions and symbols

#### 3.1 Definitions

For the purposes of this International Standard, the following definitions apply in addition to those of IEC 60050(221).

##### 3.1.1

**(effective) amplitude permeability (symbols: amplitude permeability:  $\mu_a$ , effective amplitude permeability:  $\mu_{ea}$ )**

magnetic permeability obtained from the peak value of the effective magnetic induction,  $\hat{B}_e$ , and the peak value of the magnetic field strength,  $\hat{H}_e$ , at the stated value of either, when the magnetic induction and magnetic field vary periodically with time and with an average of zero, and the material is initially in a specified neutralized state

NOTE 1 This definition differs from that of IEC 60050 [221-03-07].

NOTE 2 Two amplitude permeabilities are in common use, namely:

- that in which the peak values apply to the actual waveforms of the induction and field strength,
- that in which the peak values apply to the fundamental components of waveforms of the induction and the field strength.

NOTE 3 The induction and the field strength and, consequently, the amplitude permeability may even be quasi-static quantities, provided the core is cyclically magnetized and no excursion of the B-H curve appears.

##### 3.1.2

**maximum (effective) amplitude permeability (symbol  $\mu_{ea \max}$ )**

maximum value of the (effective) amplitude permeability when the amplitude of excitation ( $\hat{B}_e$  or  $\hat{H}_e$ ) is varied

NOTE This definition differs from that of IEC 60050 [221-03-10].

##### 3.1.3

**excitation**

either induction or field strength for which the waveform and amplitude both remain within the specified tolerance

NOTE When the induction (field strength) mode of excitation is chosen, the resultant waveform of field strength (induction) may be distorted with respect to the excitation waveform due to the non-linear behaviour of the magnetic material.

##### 3.1.4

**high excitation level**

excitation at which the permeability depends on excitation amplitude (particularly at low frequencies) and/or at which the power loss results in a noticeable temperature rise (particularly at high frequencies)

##### 3.1.5

**sinusoidal excitation**

excitation of harmonic content of less than 1 %

##### 3.1.6

**exciting winding**

winding of measuring coil to which the exciting voltage is applied or through which the exciting current is flowing

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### 3.1.7

#### **voltage sensing winding**

unloaded winding of a measuring coil across which the electromotive force induced by the excitation may be determined

### 3.1.8

#### **measuring winding**

winding, usually secondary, loaded or unloaded, which can be used for measurement apart from the exciting and/or voltage sensing winding

### 3.1.9

#### **power loss**

power absorbed by the core

## 3.2 Symbols

All the formulae in this standard use basic SI units. When multiples or sub-multiples are used, the appropriate power of 10 shall be introduced.

|             |                                                                 |
|-------------|-----------------------------------------------------------------|
| $A_e$       | effective cross-sectional area of the core                      |
| $\hat{B}_e$ | peak value of the effective induction in the core               |
| $f$         | frequency                                                       |
| $\hat{H}_e$ | peak value of the effective magnetic field strength in the core |
| $l_e$       | effective magnetic path length of the core                      |
| $L$         | inductance                                                      |
| $i$         | instantaneous value of the current                              |
| $I$         | current                                                         |
| $N$         | number of turns of winding of the measuring coil                |
| $P$         | power loss in the core                                          |
| $Q_c$       | quality factor of the core for a given frequency                |
| $R$         | resistance                                                      |
| $t$         | time                                                            |
| $T$         | temperature                                                     |
| $u$         | instantaneous value of the voltage                              |
| $U$         | voltage                                                         |
| $V_e$       | effective volume of the core                                    |
| $\delta$    | relative error, deviation, etc.                                 |
| $\Delta$    | absolute error, deviation, etc.                                 |
| $\mu_{ea}$  | (effective) amplitude permeability                              |
| $\mu_0$     | magnetic constant = $4\pi \times 10^{-7}$ H/m                   |
| $\pi$       | the number 3,14159...                                           |
| $\varphi$   | phase shift                                                     |
| $\omega$    | angular frequency = $2\pi f$                                    |

NOTE 1 Additional subscript, upper script, etc. gives a more specific meaning to the given symbol.

NOTE 2 Symbols which are used sporadically are defined in the place where they appear in the text.

NOTE 3 Effective parameters, such as effective magnetic path length,  $l_e$ , effective cross-sectional area,  $A_e$ , and effective volume of the core,  $V_e$ , are calculated in accordance with IEC 60205.

NOTE 4 In the further text of this standard, the terms induction and field strength stand for the shortened terms magnetic induction and magnetic field strength.

## 4 General precautions for measurements at high excitation level

### 4.1 General statements

#### 4.1.1 Relation to practice

The measuring conditions, methods and procedures shall be chosen in such a way that the measured results are suitable for predicting the performance of the core under practical circumstances. This does not imply that all these stipulations, especially those related to the excitation waveforms, have to correspond to terms encountered in practice.

#### 4.1.2 Core effective parameters and material properties

Since the core is in general of non-uniform cross-section and generally has non-uniformly distributed windings along the core path, the measurement does not yield the amplitude permeability and the power loss of the material, but the effective values of these parameters appropriate to the effective induction  $\hat{B}_e$  and the effective field strength  $\hat{H}_e$  in the core.

For the measurement of the amplitude permeability and the power loss of the material, the core shall have a ring or toroidal shape in which the ratio of outer to inner diameter should not be greater than 1,4 and should have windings distributed uniformly, close to the core, of inductive coupling coefficient practically equal to unity.

#### 4.1.3 Reproducibility of the magnetic state

To obliterate various remanence and time effects in the core material, the measurement shall be made at a well-defined and reproducible magnetic state.

Any measurement under specified excitation, unless otherwise stated, is to be made at the time  $t_m = t_c + \Delta t$  after the magnetic conditioning start;  $t_c$  is the time period within which the magnetic conditioning is completed and, whereupon, the specified excitation is set;  $\Delta t$  is the time period during which the core is kept stable under the excitation being set.

### 4.2 Measuring coil

**4.2.1** The number of turns shall be specified for each winding in relation to the measuring conditions, the equipment used and the accuracy to be obtained. The windings shall be wound as close to the core as possible, to make the coupling (magnetic flux linkage) coefficients between the measuring coil windings and the core and between the windings of measuring coil, as close to 100 % as possible.

The resistance, self-capacitance and inter-winding capacitance of windings should be as low as possible to make the related errors negligible.

In the case of ring or toroidal cores, the turns shall be distributed evenly around the core circumference.

The connectors, primarily of exciting winding, should consist of insulated strands, if this is necessary for measurements at high frequencies.

NOTE When winding a sharp-edge core, care should be taken to ensure that the wire insulation is not ruptured and, in the case of stranded wire, strands are not broken.

**4.2.2** The use of a single winding both for excitation and voltage sensing is recommended if

- the coupling between the exciting winding and the voltage sensing winding is so reduced that it results in a non-negligible error in the determination of the measuring induction  $B$  in the core;
- the inter-winding capacitance is too high;
- there is no measuring circuitry contra-indication against the direct connection of the exciting winding to input(s) of measuring instruments.

NOTE When single winding is used, it is recommended that its resistance be made as low as possible to make the winding ohmic power loss negligible compared to the power loss in the core.

The use of separate exciting and voltage sensing windings (double winding) is recommended if, for whatever reason, the exciting winding should be galvanically separated from the voltage and the current measuring instruments, for example, to avoid a floating or d.c. connection to their inputs.

NOTE 1 When the exciting and voltage sensing windings are used, it is critical to make their magnetic coupling coefficient as close to 100 % as possible.

NOTE 2 When the voltage needed for calculation of the induction in the core is measured across the voltage sensing winding then only the power loss in the core is determined with the exclusion of the ohmic power loss in the current-carrying (exciting) winding.

NOTE 3 The use of two windings is recommended at more than 200 kHz.

### 4.3 Mounting of cores consisting of more than one part

The core, which consists of more than one part and which is to be assembled around the measuring coil, shall be held together with glue, tape or a clamping device throughout the measurement.

Whichever method is used to join the core parts together, it shall have the following characteristics:

- distribution of the joining force uniformly over the mating surfaces, without the introduction of bending stresses in the core;
- holding of all the core parts rigidly and without changing the position to each other;
- when a specified clamping method is used, an initial over-force of about 10 % shall be applied when the core is closed, in order to break down fine irregularities between the cleaned mating surfaces. Next, the specified clamping force  $\pm 5$  % shall be applied;
- keeping the joining force constant within  $\pm 1$  % during all measuring operations within all measuring conditions, including the full specified temperature range.

The mounting of such cores shall be carried out in accordance with the following instructions.

The mating surface shall be inspected for damage and cleanness. Damaged cores shall not be used. The mating surface shall be cleaned by non-abrasive means, for example, by rubbing gently on a dry washing-leather. Next, the mating surfaces shall be degreased if they have to be glued. Dust particles shall be blown off with clean dry compressed air. The mating surfaces shall never be touched with bare fingers. The core parts shall then be assembled around the measuring coil, the latter being locked in position with respect to the core by suitable means, for example, a foam-washer. The core parts are centered and glued or placed in clamping device. The glue, if used, shall be spread evenly on the mating surface to form a film as thin as possible and then properly hardened.

In the case where the clamping device is used, the clamping force specified in the relevant specification shall be applied. The glued, taped or clamped cores shall relax under the specified conditions (see clause 3 of IEC 60367-1) for a time sufficient to allow any variation of stress effects, due to clamping, gluing or taping, to become negligible.

#### 4.4 Measuring equipment

Any suitable measuring equipment may be used. Examples of appropriate circuits are given in annexes A to E.

In addition to any requirement specified for the particular method and/or measuring circuit used, the following general requirements shall be met.

**4.4.1** To ensure the induction (field strength) mode of excitation, the output impedance of the exciting source shall be low (high) compared with the series impedance of the exciting winding of the measuring coil assembled with the core under test and the current sensing resistor.

**4.4.2** When the sinusoidal waveform of excitation is specified, the total harmonic content of the excitation source shall be less than 1 %. When square pulses are specified, the relevant requirements of clause 16 of IEC 60367-1 shall be met.

**4.4.3** During the period of measurement, the excitation amplitude variations shall not exceed  $\pm 0,05$  % and the frequency stability shall be adequate for the measuring method and the equipment used.

**4.4.4** The frequency range of voltmeters and other voltage sensing instruments shall include all harmonics of the measured voltage having amplitudes of 1 % or more of their fundamentals. This frequency range shall be specified in the relevant instrument specification.

**4.4.5** The voltmeters and other voltage sensing instruments used shall be high-impedance instruments, the connection of which will have only a negligible effect on the measuring circuit, especially at high frequencies. The probes of a high-input resistance and a low-input capacitance can reduce the load effects.

**4.4.6** The accuracy of the voltmeters and/or voltage sensing instruments, determined for the calibrating sinusoidal waveform, shall be within  $\pm 0,5$  % for r.m.s. and average values and  $\pm 1$  % for peak values, provided that the peak factor of waveforms to be measured is within limits imposed by the instrument.

If inaccuracies exceed the above limits, only a sine-wave excitation of total harmonic content less than 1 % is recommended and

- to determine the r.m.s., average and peak values of sinusoidal waveforms, a true r.m.s. sensing voltmeter of accuracy within  $\pm 1$  % is recommended. The average and peak values are obtained by multiplying the indicated r.m.s. values by the following factors: average value =  $0,9 \times \text{r.m.s. value}$ , peak value =  $1,414 \times \text{r.m.s. value}$ ;
- to determine the r.m.s., average and peak values of non-sinusoidal waveforms, a digital storage and processing oscilloscope or appropriate acquisition and processing instrument shall be used. It shall be capable of capturing and processing the waveform with the sampling rate not less than 150 samples per waveform period and the resolution not less than 8 bits.

NOTE The peak factor is the ratio of the peak value to the r.m.s. value of measured waveform.