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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Cores made of soft magnetic materials – Measuring methods – Part 3: Magnetic properties at high excitation level

Noyaux en matériaux magnétiques doux – Méthodes de mesure – Partie 3: Propriétés magnétiques à niveau élevé d'excitation

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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CORES MADE OF SOFT MAGNETIC MATERIALS – MEASURING METHODS –

Part 3: Magnetic properties at high excitation level

FOREWORD

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IEC 62044-3 has been prepared by IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials. It is an International Standard.

This second edition cancels and replaces the first edition published in 2000. This edition constitutes a technical revision.

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

a) addition of Annex F and Annex G.

The text of this International Standard is based on the following documents:

Draft	Report on voting
51/1426/CDV	51/1439/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62044 series, published under the general title *Cores made of soft magnetic materials – Measuring methods*, can be found on the IEC website.

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

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- withdrawn,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

INTRODUCTION

IEC 62044, under the general title *Cores made of soft magnetic materials – Measuring methods,* includes the following parts:

IEC 62044-1: Generic specification

IEC 62044-2: Magnetic properties at low excitation level

IEC 62044-3: Magnetic properties at high excitation level

CORES MADE OF SOFT MAGNETIC MATERIALS – MEASURING METHODS –

Part 3: Magnetic properties at high excitation level

1 Scope

This part of IEC 62044 specifies 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 document can cover the measurement of magnetic properties for frequencies ranging practically from direct current 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 document 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 magnetic flux density and field strength waveforms with only slightly degraded accuracy.

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62044-1:2002, *Cores made of soft magnetic materials – Measuring methods – Part 1: Generic specification*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
effective amplitude permeability
μ_{ea}
magnetic permeability obtained from the peak value of the effective magnetic flux density, $\hat{B}_e$, and the peak value of the effective magnetic field strength, $\hat{H}_e$, at the stated value of either, when the magnetic flux density and magnetic field vary periodically with time and with an average of zero, and the material is initially in a specified demagnetized state

3.1.2
maximum effective amplitude permeability
$\mu_{ea\ max}$
maximum value of the effective amplitude permeability when the amplitude of excitation ($\hat{B}_e$ or $\hat{H}_e$) is varied

3.1.3
excitation
either magnetic flux density or field strength for which the waveform and amplitude both remain within the specified tolerance

Note 1 to entry: When the magnetic flux density (field strength) mode of excitation is chosen, the resultant waveform of field strength (magnetic flux density) can 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) or at which the power loss results in a noticeable temperature rise (particularly at high frequencies), or both

3.1.5
exciting winding
winding of measuring coil to which the exciting voltage is applied or through which the exciting current is flowing

3.1.6
voltage sensing winding
unloaded winding of a measuring coil across which the electromotive force induced by the excitation can be determined

3.1.7
measuring winding
winding, usually secondary, loaded or unloaded, which can be used for measurement apart from the exciting or voltage sensing winding, or both

3.1.8
power loss
power absorbed by the core

3.1.9
pulse excitation without biasing field
excitation in which a core is energized by a voltage pulse, from a remanent flux density to a higher value of flux density in the same direction, and in which the core recovers to the same remanent flux density

Note 1 to entry: The excursion in the B-H plane associated with such a pulse is shown in Figure 1.

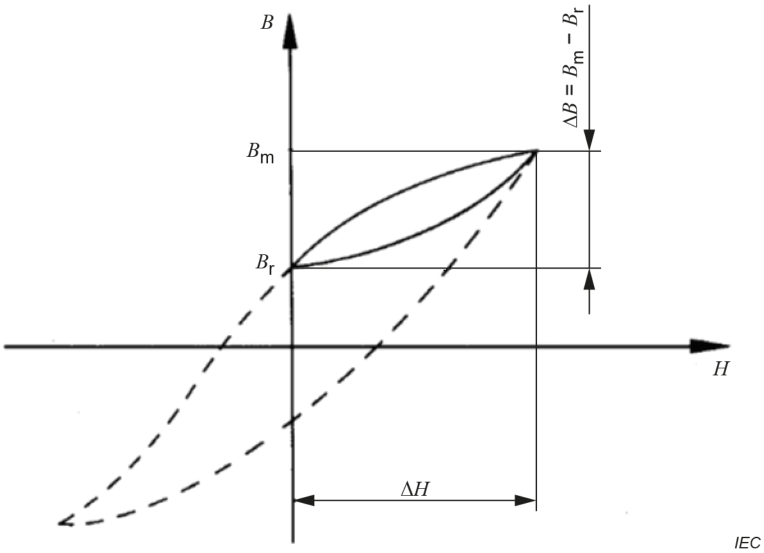

Figure 1 – Pulse excitation without biasing field

Note 2 to entry: If the back-e.m.f. during recovery is limited only by the time constant of the test circuit, then the magnetizing current decays exponentially.

Alternatively the back-e.m.f. can be limited to a constant value, for example by returning the energy via a secondary winding to a voltage source; then the magnetizing current decay is approximately linear. The latter method can prevent excessively high back-e.m.f. and high rates of change of flux. The distinction is mainly relevant to loss measurements.

3.1.10
pulse excitation with biasing field
excitation in which a core is energized by a voltage pulse, from a value of the flux density determined by a biasing field to a flux density in the opposite direction, and in which the core recovers to the same value determined by the biasing field

Note 1 to entry: The excursion in the B-H plane associated with such a pulse is shown in Figure 2.

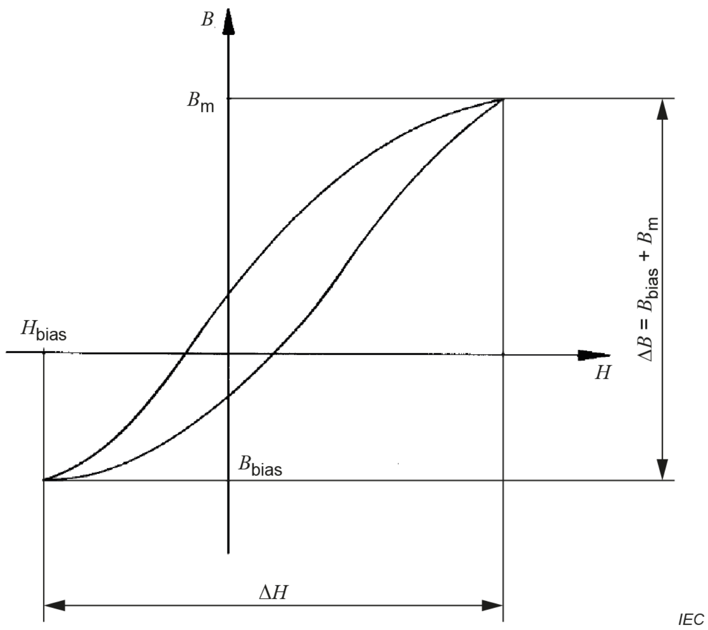

Figure 2 – Pulse excitation with biasing field

Note 2 to entry: See Note to entry 2 of 3.1.9.

3.1.11
pulse permeability
μ_p
relative permeability obtained from the change of flux density and the corresponding change of the field strength when either quantity is varying in an arbitrary form between stated limits:

$$\mu_p = \frac{1}{\mu_0} \cdot \frac{\Delta B}{\Delta H}$$

SEE: Figure 1 and Figure 2.

Note 1 to entry: The value of the pulse permeability depends strongly on the limits of the flux density or field strength excursions; it is not necessary for these limits to be symmetrical with respect to zero.

Note 2 to entry: Often pulse permeability refers to the special case of square voltage pulses being applied to an exciting winding; the flux density waveform is then approximately triangular.

3.1.12
pulse amplitude
U_m
maximum instantaneous value which an ideal voltage pulse would have with respect to the steady value of the voltage between pulses

Note 1 to entry: An ideal pulse is derived from an actual voltage pulse by ignoring unwanted or non-pertinent phenomena such as overshoot (see Figure 1).

3.1.13
pulse duration
t_d
time interval during which the instantaneous value of the pulse exceeds 50 % of the pulse amplitude

$$L_p = \frac{U_m}{\Delta i_m / t_d}$$

where

L_p is the pulse inductance

Δi_m is the total change in i_m during the pulse

SEE: Figure F.1.

Note 1 to entry: For unidirectional drive pulses $\Delta i_m = \hat{i}_m$.

3.1.14
pulse inductance factor
A_{LP}
pulse inductance divided by the square of the number of turns of the test coil

$$A_{LP} = \frac{L_p}{N^2}$$

3.1.15
voltage-time product limit
$(U \cdot t)_{\mathrm{lim}}$
specified limit of the product of the amplitude of a voltage pulse and the time elapsed from the start of the pulse

Note 1 to entry: Within this limit the non-linearity of the magnetizing current through the measuring coil placed on the core should not exceed a specified value.

3.1.16
non-linearity (with time)
ratio of the actual instantaneous value of a characteristic at a time t to the value reached by the extrapolated linear portion of its graph versus time, at the same instant

SEE: Figure F.3.

3.1.17
pulse repetition rate
frequency of recurrence of the pulses in a periodic sequence of pulses

3.2 Symbols

All the formulae in this document 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
$\hat{B}_{\mathrm{e}}$	peak value of the effective magnetic flux density in the core
f	frequency
$\hat{H}_{\mathrm{e}}$	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	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
δ	relative error, deviation, etc.
Δ	absolute error, deviation, etc.
μ_{ea}	effective amplitude permeability
μ_0	permeability of vacuum: approximately $4\pi \times 10^{-7}$ H/m
φ	phase shift
ω	angular frequency = $2\pi f$

NOTE 1 The 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 text of this document, the term flux density stands for the shortened term of magnetic flux density.

4 General requirements 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 magnetic flux density $\hat{B}_e$ 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 the outer to the 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; Δt is the time period during which the core is kept stable under the excitation being set.

4.2 Measuring coil

4.2.1 General

Normally, a measuring coil will be used, but in principle any coaxial line, cavity or other suitable device providing the necessary interaction between the magnetic material and the electromagnetic signal, may also be used.

For measurement on toroid using coils, the turns of the measuring coil shall be distributed in such a way as to keep both the stray capacitance and the stray field as low as necessary for sufficiently accurate measurement.

For measurements made on cores assembled around a coil, the shape of the measuring coil shall correspond to that of the coils used for normal application of the core and its influence on the variation of the inductance to be measured shall be negligible.