IEC 62044-3

Edition 2.0 2023-07

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



IEC 62044-3:2023-07(en-fr)



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, …). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

IEC 62044-3

Edition 2.0 2023-07

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.030, 29.100.10

ISBN 978-2-8322-7172-8

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

CONTENTS

FOREWORD 5
INTRODUCTION 7
1 Scope 8
2 Normative references 8
3 Terms, definitions and symbols 8
3.1 Terms and definitions 8
3.2 Symbols 12
4 General requirements for measurements at high excitation level 13
4.1 General statements 13
4.1.1 Relation to practice 13
4.1.2 Core effective parameters and material properties 13
4.1.3 Reproducibility of the magnetic state 13
4.2 Measuring coil 13
4.2.1 General 13
4.2.2 Number of turns 14
4.2.3 Single winding and double winding 14
4.3 Mounting of cores consisting of more than one part 15
4.4 Measuring equipment 15
5 Specimens 18
6 Measuring procedures 18
6.1 General procedure 18
6.2 Measuring method for the effective amplitude permeability 19
6.2.1 Purpose 19
6.2.2 Principle of the measurement 19
6.2.3 Circuit and equipment 19
6.2.4 Measuring procedure 19
6.2.5 Calculation 20
6.3 Measuring methods for the power loss 20
6.3.1 Purpose 20
6.3.2 Methods and principles of the measurements 20
7 Information to be stated 23
8 Test report 24
Annex A (informative) Basic circuits and related equipment for the measurement of amplitude permeability 25
Annex B (informative) Root-mean-square method for the measurement of power loss – Example of a circuit and related procedure 27
B.1 Method of measurement 27
B.2 Measuring coil 27
B.3 Measuring equipment 28
B.4 Measuring procedure 28
B.5 Pulse measurement and accuracy 29
Annex C (informative) Multiplying methods for the measurement of power loss – Basic circuits and related measurement procedures 30
C.1 Basic circuits 30
C.2 Requirements 31
C.3 Measuring coil 31

C.4 Accuracy 31
C.5 V-A-W (volt-ampere-watt) meter method 32
C.6 Impedance analyzer method 32
C.7 Digitizing method 32
C.8 Vector spectrum method 33
C.9 Cross-power method 33
Annex D (informative) Reflection method for the measurement of power loss – Basic circuit and related measurement procedures 34
D.1 Basic circuit 34
D.2 Requirements 34
D.3 Measuring coil 34
D.4 Measuring procedure and accuracy 35
Annex E (informative) Calorimetric measurement methods for the measurement of power loss 36
E.1 Basic circuit 36
E.2 Requirements 37
E.3 Measuring coil 37
E.4 Accuracy 37
E.5 Measurements at thermal equilibrium 37
E.5.1 General 37
E.5.2 Measurement across calibrated thermal resistance 37
E.5.3 Measurement by matching the temperature rise in the core and resistor 38
E.6 Measurements at non-thermal equilibrium 38
Annex F (normative) Magnetic properties under pulse condition 39
F.1 Object 39
F.2 Measurement methods 39
F.3 Principle of the methods 39
F.4 Specimens 39
F.5 Measuring coil 39
F.6 Measuring equipment 40
F.7 Measuring procedure 41
F.7.1 General 41
F.7.2 Measurement of pulse inductance factor and magnetizing current 42
F.7.3 Measurement of the non-linearity of the magnetizing current 43
F.8 Calculation 44
Annex G (informative) Examples of circuits for pulse measurements 46
Bibliography 47

Figure 1 – Pulse excitation without biasing field 10
Figure 2 – Pulse excitation with biasing field 10
Figure A.1 – Basic circuits for the measurement of amplitude permeability 26
Figure B.1 – Example of a measuring circuit for the RMS method 27
Figure C.1 – Basic circuits for multiplying methods 31
Figure D.1 – Basic circuit 34
Figure E.1 – Basic circuit and related measurement procedures – Measurement set-up 36
Figure F.1 – Voltage pulse parameters 42
Figure F.2 – Typical measuring waveforms 43

Figure F.3 – Non-linearity of magnetizing current 44
Figure G.1 – Measurement without bias and with single pulses 46
Figure G.2 – Measurement with bias and with repeated pulses 46

Table 1 – Some multiplying methods and related domains of excitation waveforms, acquisition, processing 21

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

CORES MADE OF SOFT MAGNETIC MATERIALS – MEASURING METHODS –

Part 3: Magnetic properties at high excitation level

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

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.

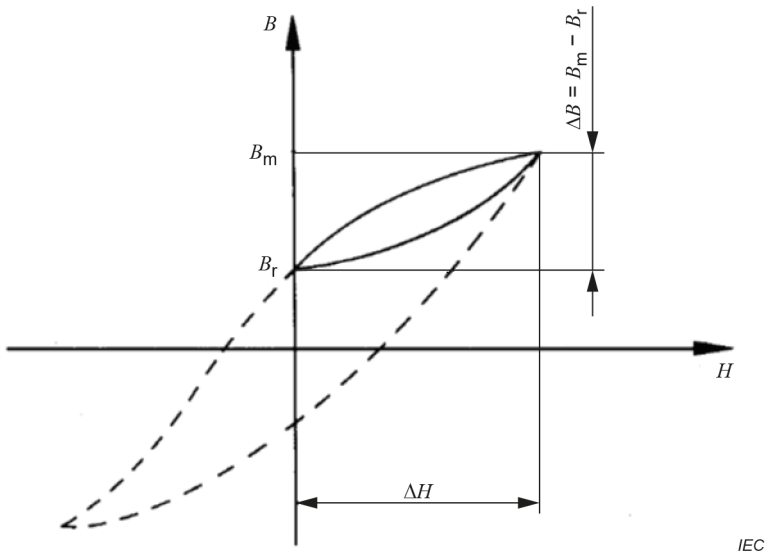


Figure 1 – Pulse excitation without biasing field

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.

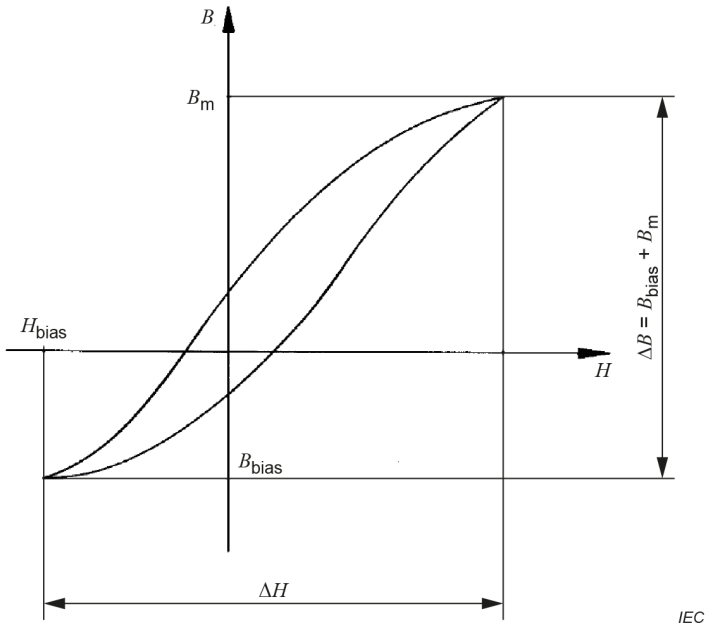


Figure 2 – Pulse excitation with biasing field

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 $\Delta i_m = \hat{\imath}_m$.

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
$(U \cdot t)_{\text{lim}}$
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

$\hat{B}_{\text{e}}$ peak value of the effective magnetic flux density in the core

f frequency

$\hat{H}_{\text{e}}$ 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.