

Magnetic materials —

Part 6: Methods of measurement of the magnetic properties of magnetically soft metallic and powder materials at frequencies in the range 20 Hz to 200 kHz by the use of ring specimens

The European Standard EN 60404-6:2003 has the status of a British Standard

ICS 17.220.20; 29.030

National foreword

This British Standard is the official English language version of EN 60404-6:2003. It is identical with IEC 60404-6:2003. It supersedes BS 6404-6:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/NFE/5, Magnetic alloys and steels, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 23 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 26 September 2003

© BSI 26 September 2003

ISBN 0 580 42676 9

Magnetic materials
Part 6: Methods of measurement of the magnetic properties
of magnetically soft metallic and powder materials
at frequencies in the range 20 Hz to 200 kHz
by the use of ring specimens
(IEC 60404-6:2003)

Matériaux magnétiques
Partie 6: Méthodes de mesure
des propriétés magnétiques
des matériaux métalliques
et des matériaux en poudre,
magnétiquement doux, aux fréquences
comprises entre 20 Hz et 200 kHz,
sur des éprouvettes en forme de tore
(CEI 60404-6:2003)

Magnetische Werkstoffe
Teil 6: Verfahren zur Messung der
magnetischen Eigenschaften
weichmagnetischer und pulverförmiger
Werkstoffe bei Frequenzen im Bereich
20 Hz bis 200 kHz mit Hilfe von
Ringproben
(IEC 60404-6:2003)

This European Standard was approved by CENELEC on 2003-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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

Foreword

The text of document 68/271/FDIS, future edition 2 of IEC 60404-6, prepared by IEC TC 68, Magnetic alloys and steels, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60404-6 on 2003-09-01.

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) 2004-06-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2006-09-01

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 and B are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60404-6:2003 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 62044 NOTE Harmonized in the series EN 62044 (not modified).

CONTENTS

INTRODUCTION.....	4
1 Scope.....	5
2 Normative references.....	5
3 General principles of measurement.....	6
3.1 Test specimen.....	6
3.2 Windings.....	7
4 Temperature measurements.....	7
5 Measurement of magnetic permeability and magnetization curve using the voltmeter-ammeter method.....	8
5.1 Introduction.....	8
5.2 Apparatus and connections.....	8
5.3 Determination of magnetic field strength.....	9
5.4 Determination of the magnetic flux density.....	10
5.5 Determination of the r.m.s. amplitude permeability and the relative amplitude permeability.....	10
5.6 Determination of magnetization curve.....	11
6 Measurement of specific total loss by the wattmeter method.....	11
6.1 Principle of measurement.....	11
7 Measurement of magnetic properties using a digital impedance bridge.....	12
7.1 Principle of measurement.....	12
7.2 Apparatus.....	13
7.3 Procedure.....	13
7.4 Determination of the relative a.c. inductance permeability.....	14
7.5 Determination of the specific total loss.....	14
8 Measurement of magnetic properties using digital methods.....	14
8.1 Introduction.....	14
8.2 Apparatus and connections.....	15
8.3 Magnetizing current waveform.....	15
8.4 Magnetizing winding.....	15
8.5 Determination of the magnetic field strength.....	15
8.6 Determination of the magnetic flux density.....	16
8.7 Determination of the relative a.c. permeability.....	16
8.8 Determination of a.c. magnetization curve.....	16
8.9 Determination of the specific total loss.....	16
9 Uncertainties.....	17
10 Test report.....	17
Annex A (informative) Guidance on requirements for windings and instrumentation in order to minimise additional losses.....	20
Annex B (informative) Sinusoidal waveform control by digital means.....	21
Annex ZA (normative) Normative references to international publications with their corresponding European publications.....	22
Bibliography.....	23

INTRODUCTION

This edition of IEC 60404-6 has been prepared by WG2 in the TC68 maintenance programme of publications. The d.c. measurements in the first edition of this standard are now covered in IEC 60404-4 and Amendment 1 to that standard. This edition of IEC 60404-6 includes measurements on magnetically soft powder materials. Since measurements on these materials at high frequencies employ some of the techniques used to measure magnetic components, there has been active collaboration with IEC TC51. IEC TC51 recently started to publish the new IEC 62044 series which will be composed of four parts. IEC 62044-3 presents methods of measurement of magnetic properties at high excitation levels appropriate to various ferrite core applications, whereas this edition of IEC 60404-6 covers the requirements of material measurements excluding ferrites, so that the two standards do not overlap.

MAGNETIC MATERIALS –

Part 6: Methods of measurement of the magnetic properties of magnetically soft metallic and powder materials at frequencies in the range 20 Hz to 200 kHz by the use of ring specimens

1 Scope

This part of IEC 60404 specifies methods for the measurement of a.c. magnetic properties of materials in the frequency range 20 Hz to 200 kHz other than electrical steels and soft ferrites. The materials covered by this part of IEC 60404 include those speciality alloys listed in IEC 60404-8-6, amorphous and nanocrystalline materials, pressed and sintered and metal injection moulded parts such as are listed in IEC 60404-8-9, cast parts and magnetically soft composite materials.

The object of this part is to define the general principles and the technical details of the measurement of the magnetic properties of magnetically soft materials by means of ring methods. For materials supplied in powder form, a ring test specimen is formed by the appropriate pressing method for that material.

DC magnetic measurements on magnetically soft materials shall be made in accordance with the ring method of IEC 60404-4. The determinations of the magnetic characteristics of magnetically soft components shall be made in accordance with IEC 62044-3.

Normally, the measurements shall be made at an ambient temperature of $(23 \pm 5)^\circ\text{C}$ on ring test specimens which have first been magnetized, then demagnetized. Measurements can be made over other temperature ranges by agreement between supplier and purchaser.

2 Normative references

The following referenced documents are indispensable for the application 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 62044-3:2000, *Cores made of soft magnetic materials – Measuring methods – Part 3: Magnetic properties at high excitation levels*

IEC 60404-2:1996, *Magnetic materials – Part 2: Methods of measurement of the magnetic properties of electrical steel sheet and strip by means of an Epstein frame*

IEC 60404-4:1995, *Magnetic materials – Part 4: Methods of measurement of d.c. magnetic properties of iron and steel*
Amendment 1:2000

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

IEC 60404-8-9:1994, *Magnetic materials – Part 8: Specifications for individual materials – Section 9: Standard specification for sintered soft magnetic materials*

ISO/IEC Guide to the expression of uncertainty in measurement, 1993

3 General principles of measurement

The measurements are made on a closed magnetic circuit in the form of a ring test specimen wound with one or two windings.

3.1 Test specimen

The test specimen shall be in the form of a ring of rectangular cross-section which may be formed by

- a) winding thin strip or wire to produce a clock-spring wound toroidal core; or
- b) punching, laser cutting or photochemically etching ring laminations; or
- c) pressing and sintering of powders, metal injection moulding or casting.

In the case of powder materials, the production of a ring test specimen by metal injection moulding or by pressing (with heating if applicable) shall be carried out in accordance with the material manufacturer's recommendations to achieve the optimum magnetic performance of the powder material.

For all types of test specimen, burrs and sharp edges should be removed prior to heat treatment. In the case of high permeability material, it is preferable to enclose the ring test specimen in a two-part annular case. The case dimensions shall be such that it closely fits without introducing stress into the material of the test specimen.

The ring shall have dimensions such that the ratio of the outer to inner diameter shall be no greater than 1,4 and preferably less than 1,25.

For solid and pressed powder materials, the dimensions of the test specimen, that is the outer and inner diameters and the height of the ring, shall be measured with suitable calibrated measuring instruments. The respective dimensions shall be measured at several locations on a test specimen and averaged. The cross-sectional area of the test specimen shall be calculated from

$$A = \frac{(D - d)}{2} h \quad (1)$$

where

A is the cross-sectional area of the test specimen, in square metres;

D is the outer diameter of the test specimen, in metres;

d is the inner diameter of the test specimen, in metres;

h is the height of the test specimen, in metres.

For a stack of laminations or a toroidal wound core, the cross-sectional area of the test specimen shall be calculated from the mass, density and the values of the inner and outer diameter of the ring. The mass and diameters shall be measured with suitable calibrated instruments. The density shall be the conventional density for the material supplied by the manufacturer. The cross-sectional area shall be calculated from

$$A = \frac{2 m}{\rho \pi (D + d)} \quad (2)$$