



BSI Standards Publication

## Magnetic materials

---

Part 13: Methods of measurement of resistivity, density and stacking factor of electrical steel strip and sheet (IEC 60404-13:2018)

## National foreword

This British Standard is the UK implementation of EN IEC 60404-13:2018. It is identical to IEC 60404-13:2018. It supersedes BS EN 60404-13:2007, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/108, Magnetic Alloys and Steels.

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.

© The British Standards Institution 2018  
Published by BSI Standards Limited 2018

ISBN 978 0 580 85980 9

ICS 17.220.20; 19.020; 29.020; 29.030

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2018.

### Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

---

EUROPEAN STANDARD

**EN IEC 60404-13**

NORME EUROPÉENNE

EUROPÄISCHE NORM

October 2018

ICS 17.220.20; 29.030

Supersedes EN 60404-13:2007

English Version

**Magnetic materials - Part 13: Methods of measurement of resistivity, density and stacking factor of electrical steel strip and sheet**  
**(IEC 60404-13:2018)**

Matériaux magnétiques - Partie 13: Méthodes de mesure de la résistivité, de la masse volumique et du facteur de foisonnement des bandes et tôles en acier électrique  
(IEC 60404-13:2018)

Magnetische Werkstoffe - Teil 13: Verfahren der Messung des spezifischen elektrischen Widerstandes, der Dichte und des Stapelfaktors von Elektrobänd und -blech  
(IEC 60404-13:2018)

This European Standard was approved by CENELEC on 2018-08-14. 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 CEN-CENELEC Management Centre 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 CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



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

**CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels**

## **European foreword**

The text of document 68/574/CDV, future edition 2 of IEC 60404-13, prepared by IEC/TC 68 "Magnetic alloys and steels" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60404-13:2018.

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) 2019-05-14
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2021-08-14

This document supersedes EN 60404-13:2007.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

## **Endorsement notice**

The text of the International Standard IEC 60404-13:2018 was approved by CENELEC as a European Standard without any modification.

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

ISO 1183-1:2012	NOTE	Harmonized as EN ISO 1183-1:2012 (not modified)
ISO 2738:1999	NOTE	Harmonized as EN ISO 2738:1999 (not modified)

**Annex ZA**  
(normative)

**Normative references to international publications  
with their corresponding European publications**

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.

NOTE 1 Where 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](http://www.cenelec.eu).

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-121	-	International Electrotechnical Vocabulary - Part 121: Electromagnetism	-	-
IEC 60050-221	-	International Electrotechnical Vocabulary. Chapter 221: Magnetic materials and components	-	-
IEC 60404-2	-	Magnetic materials - Part 2: Methods of measurement of the magnetic properties of electrical steel sheet and strip by means of an Epstein frame	EN 60404-2	-
IEC 60404-3	-	Magnetic materials - Part 3: Methods of measurement of the magnetic properties of magnetic sheet and strip by means of a single sheet tester	-	-
ISO 1183-3	-	Plastics - Methods for determining the density of non-cellular plastics - Part 3: Gas pycnometer method	EN ISO 1183-3	-



## CONTENTS

FOREWORD.....	4
1 Scope.....	6
2 Normative references .....	6
3 Terms and definitions .....	6
4 Determination of the resistivity.....	7
4.1 General.....	7
4.2 Principles of measurement.....	7
4.2.1 Method of determining $\rho$ for an Epstein strip specimen (Method R1) .....	7
4.2.2 Method of determining $\rho$ for a rectangular sheet specimen (Method R2) with supplementary remarks for strip specimen.....	8
4.2.3 Determination of thickness $d$ .....	9
4.3 Test specimen .....	10
4.3.1 Epstein strip specimen.....	10
4.3.2 Rectangular sheet specimen.....	10
4.4 Apparatus .....	10
4.4.1 Common requirements for Method R1 and Method R2 .....	10
4.4.2 Requirements for Method R1 .....	10
4.4.3 Requirements for Method R2 .....	11
4.5 Measuring procedure .....	11
4.5.1 Determination of the thickness $d$ of the test specimen.....	11
4.5.2 Procedure with strip specimen (Method R1).....	11
4.5.3 Procedure with rectangular sheet specimen (Method R2) .....	11
4.6 Reproducibility .....	11
4.7 Test report .....	12
5 Determination of the density .....	12
5.1 General.....	12
5.2 Method based on the measurement of resistance (Method D1) .....	13
5.2.1 Principles of measurement .....	13
5.2.2 Test specimen .....	14
5.2.3 Measuring procedure .....	14
5.2.4 Reproducibility.....	15
5.3 Gas pycnometer method (Method D2).....	15
5.3.1 Principles of measurement .....	15
5.3.2 Test specimen .....	15
5.3.3 Test apparatus .....	15
5.3.4 Measuring procedure .....	15
5.3.5 Reproducibility.....	15
5.4 Test report .....	15
6 Determination of the stacking factor.....	16
6.1 General.....	16
6.2 Test specimen .....	16
6.3 Measuring procedure .....	16
6.4 Reproducibility .....	17
6.5 Test report .....	17
Annex A (informative) An example of the apparatus for the measurement of the resistivity using a rectangular sheet specimen (Method R2) .....	19

Annex B (informative) An example of the determination of density using the gas pyknometer method (Method D2) .....	20
B.1 Overview.....	20
B.2 Test specimen .....	20
B.3 Apparatus .....	21
B.4 Calibration .....	21
B.5 Measuring procedure .....	21
B.6 Repeatability.....	22
Annex C (informative) Calculation of density based on silicon and aluminium content (Method D4).....	23
Bibliography.....	24
Figure 1 – Circuit for the measurement of resistance of an Epstein strip specimen (Method R1).....	7
Figure 2 – Circuit for the measurement of resistance of a rectangular sheet specimen (Method R2).....	8
Figure 3 – Experimental data and the regression line of the density $\rho_m$ against the product $\rho_m \cdot \rho$ for non-oriented electrical steel sheet [6] .....	13
Figure 4 – Schematic diagram of stacking specimen and rams.....	17
Figure A.1 – Schematic cross-sectional view of the arrangement of the contact holder .....	19
Figure B.1 – Diagram illustrating the two-chamber pressure gas pyknometer .....	21
Table B.1 – Number of test discs of diameter 36 mm .....	20



## INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

**MAGNETIC MATERIALS –****Part 13: Methods of measurement of resistivity, density  
and stacking factor of electrical steel strip and sheet**

## 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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60404-13 has been prepared by IEC Technical Committee 68: Magnetic alloys and steels.

This second edition cancels and replaces the first edition published in 1995 and constitutes a technical revision.

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

- a) the sequence of the density and resistivity sections is changed and the title of the document revised to reflect this;
- b) the van-der-Pauw method (Method R2) is also applicable to Epstein strip specimens;
- c) the gas pycnometer method is introduced, and the liquid immersion method and the calculation method based on the chemical composition are quoted;

- d) the requirements of the stacking factor section, such as the tolerance of the dimensions of the test specimen and the repeatability of measurement, are changed;
- e) an example of the apparatus for determination of the resistivity using a rectangular sheet, which was previously part of the main body of the text, is moved to constitute informative Annex A;
- f) an example of the determination of the density by using the gas pyknometer method is added as an informative Annex B;
- g) an example of the determination of density based on the calculation of silicon and aluminium contents is added as an informative Annex C.

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

CDV	Report on voting
68/574/CDV	68/586A/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 60404 series, under the general title *Magnetic materials*, can be found on the IEC web site.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://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.

## MAGNETIC MATERIALS –

### Part 13: Methods of measurement of resistivity, density and stacking factor of electrical steel strip and sheet

#### 1 Scope

This part of IEC 60404 specifies the methods used for determining the resistivity, density and stacking factor of grain-oriented and non-oriented electrical steel strip and sheet. These quantities are necessary to establish the physical characteristics of the material. Moreover, the density is necessary to allow specified values of the magnetic polarization, resistivity and stacking factor to be determined.

Since these properties are functions of temperature, the measurements will be made at an ambient temperature of  $(23 \pm 5)$  °C except when specified in this document.

#### 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 60050-121, *International Electrotechnical Vocabulary – Part 121: Electromagnetism*

IEC 60050-221, *International Electrotechnical Vocabulary – Chapter 221: Magnetic materials and components*

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

IEC 60404-3, *Magnetic materials – Part 3: Methods of measurement of the magnetic properties of magnetic sheet and strip by means of a single sheet tester*

ISO 1183-3, *Plastics – Methods for determining the density of non-cellular plastics – Part 3: Gas pycnometer method*

#### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-121, IEC 60050-221 and ISO 1183-3 apply.

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

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