



IEC 60404-10

Edition 2.0 2016-10
REDLINE VERSION

INTERNATIONAL STANDARD



Magnetic materials –

Part 10: Methods of measurement of magnetic properties of magnetic electrical steel strip and sheet at medium frequencies

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.030

ISBN 978-2-8322-3725-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Field and scope of application
2 Accuracy and reproducibility
1 Scope.....	7
4 Field of application
2 Normative references	7
3 Terms and definitions	8
4 General principle of a.c. measurements.....	8
4.1 General.....	8
4.2 Principle of the 25 cm Epstein frame method	8
4.3 Test specimen	8
4.4 The 25 cm Epstein frame	9
4.5 Air flux compensation.....	11
4.6 Power supply	12
10 Scope
11 Field of application
12 Principle of measurement
13 Apparatus.....
4.7 Voltage measurement.....	13
4.7.1 General	13
4.7.2 Average type voltmeter	13
4.7.3 RMS voltmeter.....	13
4.8 Current measurement	13
4.9 Frequency measurement.....	13
4.10 Power measurement	13
5 Measuring Procedure for the determination of the specific total loss.....	14
5.1 General.....	14
5.2 Preparation for measurement.....	14
5.3 Source setting Adjustment of power supply	15
5.4 Measurements of power	16
5.5 Determination of the specific total losses	16
5.6 Reproducibility of the specific total loss measurement	17
6 Procedure for the determination of the peak value of magnetic polarization, r.m.s. value of magnetic field strength, peak value of magnetic field strength and specific apparent power	17
6.1 Scope General.....	17
6.2 Test specimen	17
6.3 Principle of measurement.....	18
6.3.1 Peak value of magnetic polarization \hat{J}	18
6.3.2 RMS value of the excitation magnetizing current (of the magnetic field strength).....	18
6.3.3 Peak value of magnetic field strength	18
6.4 Apparatus	20
6.4.1 Average rectified voltage measurement	20

6.4.2	Current measurement	20
6.4.3	Peak current measurement	20
6.4.4	Resistor R_{η}	20
6.4.5	Mutual inductor M_D	20
6.5	Measuring procedure	20
21 Determination of characteristics		
6.6	Determination of the peak value of magnetic polarization \hat{J}	21
6.7	Determination of the r.m.s. value of magnetic field strength \tilde{H}	22
6.8	Determination of the peak value of magnetic field strength \hat{H}	22
6.9	Determination of the specific apparent power S_S	23
6.10	Reproducibility	24
7	Test report	24
Annex A (informative) Epstein frame for use at medium frequencies		25
Annex B (informative) Digital sampling method for the determination of the magnetic properties		26
B.1	General	26
B.2	Technical details and requirements	26
B.3	Calibration aspects	28
B.4	Numerical air flux compensation	29
Bibliography		30
Figure 1 – Double-lapped joints		8
Figure 2 – The 25 cm Epstein frame		10
Figure 3 – Circuit for the wattmeter method		15
Figure 4 – Circuit for measuring r.m.s. value of the excitation magnetizing current		18
Figure 5 – Circuit for measuring the peak value of magnetic field strength using a peak voltmeter		19
Figure 6 – Circuit for measuring the peak value of magnetic field strength using a mutual inductor M		19

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –

**Part 10: Methods of measurement of magnetic properties
of magnetic electrical steel strip and sheet at medium frequencies**

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.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60404-10 has been prepared by IEC technical committee 68: Magnetic alloys and steels.

This second edition cancels and replaces the first edition published in 1988. This edition constitutes a technical revision.

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

- a) adaption to modern measurement and evaluation methods, in particular the introduction of the widely spread digital sampling method for the acquisition and evaluation of the measured data;
- b) introduction of formal changes which adapt this standard to other standards of the 60404 series;
- c) revision of the problem of the air flux compensation taking account of the condition of the higher frequencies;
- d) revision of the capacitive coupling of mutual inductor windings together with the consideration of the alternative method of numerical air flux compensation.

The text of this standard is based on the following documents:

CDV	Report of voting
68/523/CDV	68/556/RVC

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

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

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

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

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

The contents of the corrigendum of March 2018 have been included in this copy.

IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

INTRODUCTION

~~1—Field and scope of application~~

~~This standard is applicable to magnetic steel sheet and strip for the construction of magnetic circuits for use in the frequency range 400 Hz to 10 000 Hz.~~

~~Its object is to define the terminology and to specify the methods for the measurement of magnetic properties of magnetic steel sheet and strip.~~

~~2—Accuracy and reproducibility~~

~~The final accuracy of the test apparatus is a complex function dependent on the measuring instruments and other features of the measuring environment and equipment components; therefore it is not always possible to state the absolute accuracy which can be attained.~~

~~Moreover, experience in the use of a given method indicates the reproducibility which can be expected. Whenever the drafting Technical Committee has agreed upon reproducibility values, these have been given in this standard.~~

Besides the fact that the first edition of this part of IEC 60404 is more than 25 years old, the main purpose of this revision is to adapt it to modern measurement and evaluation methods, in particular to introduce the widely spread digital sampling method for the acquisition and evaluation of the measured data.

In addition, the problem of the air flux compensation had to be re-considered under the condition of the elevated frequencies. Capacitive coupling of mutual inductor windings require observance of significant phase shift influence and suggest consideration of the alternative method of numerical air flux compensation. An increase of the frequency range to 20 kHz was discussed by TC 68 since some manufacturers of electrical steel include this range in their catalogues. However, TC 68 decided to keep the frequency range to that defined in IEC 60404-10:1988: 400 Hz to 10 kHz.

MAGNETIC MATERIALS –

Part 10: Methods of measurement of magnetic properties of ~~magnetic~~ electrical steel strip and sheet at medium frequencies

~~CHAPTER I: GENERAL CONDITIONS FOR A.C. MEASUREMENTS MADE WITH THE 25 CM EPSTEIN FRAME~~

1 Scope

~~This chapter specifies the general conditions for the determination of a.c. magnetic properties of magnetic steel sheet and strip by means of the 25 cm Epstein frame.~~

This part of IEC 60404 is applicable to grain-oriented and non-oriented electrical steel strip and sheet for measurements of a.c. magnetic properties in the frequency range 400 Hz to 10 000 Hz.

The object of this document is to define the general principles and the technical details of the measurement of magnetic properties of electrical steel strip and sheet by means of an Epstein frame.

~~4 Field of application~~

The ~~use of the 25 cm~~ Epstein frame is applicable to ~~flat strip~~ test specimens obtained from magnetic electrical steel strips and sheets of any ~~quality~~ grade. The AC magnetic ~~properties~~ characteristics are determined for ~~a~~ sinusoidal induced voltages, for specified peak values of magnetic polarization and for a specified frequency.

The measurements are to be made at an ambient temperature of $(23 \pm 5)^\circ\text{C}$ on test specimens which have first been demagnetized.

NOTE Throughout this document the term "magnetic polarization" is used as defined in IEC 60050-221. In some standards of the IEC 60404 series, the term "magnetic flux density" was used.

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 60404-8 (all parts), *Magnetic materials – Part 8: Specifications for individual materials*

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

INTERNATIONAL STANDARD

**Magnetic materials –
Part 10: Methods of measurement of magnetic properties of electrical steel strip
and sheet at medium frequencies**



CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references	7
3 Terms and definitions	7
4 General principle of a.c. measurements.....	8
4.1 General.....	8
4.2 Principle of the 25 cm Epstein frame method	8
4.3 Test specimen	8
4.4 The 25 cm Epstein frame	9
4.5 Air flux compensation.....	10
4.6 Power supply	11
4.7 Voltage measurement	11
4.7.1 General	11
4.7.2 Average type voltmeter	11
4.7.3 RMS voltmeter.....	11
4.8 Current measurement	12
4.9 Frequency measurement.....	12
4.10 Power measurement	12
5 Procedure for the determination of the specific total loss	12
5.1 General.....	12
5.2 Preparation for measurement.....	12
5.3 Adjustment of power supply	13
5.4 Measurements of power	14
5.5 Determination of the specific total loss	14
5.6 Reproducibility of the specific total loss measurement	15
6 Procedure for the determination of the peak value of magnetic polarization, r.m.s. value of magnetic field strength, peak value of magnetic field strength and specific apparent power	15
6.1 General.....	15
6.2 Test specimen	15
6.3 Principle of measurement.....	15
6.3.1 Peak value of magnetic polarization \hat{J}	15
6.3.2 RMS value of the magnetizing current (of the magnetic field strength).....	16
6.3.3 Peak value of magnetic field strength	16
6.4 Apparatus	17
6.4.1 Average rectified voltage measurement	17
6.4.2 Current measurement	17
6.4.3 Peak current measurement.....	17
6.4.4 Resistor R_n	18
6.4.5 Mutual inductor M_D	18
6.5 Measuring procedure	18
6.6 Determination of the peak value of magnetic polarization \hat{J}	18
6.7 Determination of the r.m.s. value of magnetic field strength \tilde{H}	19
6.8 Determination of the peak value of magnetic field strength \hat{H}	19

6.9	Determination of the specific apparent power S_S	20
6.10	Reproducibility	21
7	Test report.....	21
Annex A (informative) Epstein frame for use at medium frequencies		22
Annex B (informative) Digital sampling method for the determination of the magnetic properties		23
B.1	General.....	23
B.2	Technical details and requirements	23
B.3	Calibration aspects	25
B.4	Numerical air flux compensation	26
Bibliography.....		27
Figure 1 – Double-lapped joints		8
Figure 2 – The 25 cm Epstein frame		9
Figure 3 – Circuit for the wattmeter method		13
Figure 4 – Circuit for measuring r.m.s. value of the magnetizing current		16
Figure 5 – Circuit for measuring the peak value of magnetic field strength using a peak voltmeter		16
Figure 6 – Circuit for measuring the peak value of magnetic field strength using a mutual inductor M		17

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –**Part 10: Methods of measurement of magnetic properties
of electrical steel strip and sheet at medium frequencies**

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 60404-10 has been prepared by IEC technical committee 68: Magnetic alloys and steels.

This second edition cancels and replaces the first edition published in 1988. This edition constitutes a technical revision.

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

- a) adaption to modern measurement and evaluation methods, in particular the introduction of the widely spread digital sampling method for the acquisition and evaluation of the measured data;
- b) introduction of formal changes which adapt this standard to other standards of the 60404 series;
- c) revision of the problem of the air flux compensation taking account of the condition of the higher frequencies;

- d) revision of the capacitive coupling of mutual inductor windings together with the consideration of the alternative method of numerical air flux compensation.

The text of this standard is based on the following documents:

CDV	Report of voting
68/523/CDV	68/556/RVC

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

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

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

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

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

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of March 2018 have been included in this copy.

INTRODUCTION

Besides the fact that the first edition of this part of IEC 60404 is more than 25 years old, the main purpose of this revision is to adapt it to modern measurement and evaluation methods, in particular to introduce the widely spread digital sampling method for the acquisition and evaluation of the measured data.

In addition, the problem of the air flux compensation had to be re-considered under the condition of the elevated frequencies. Capacitive coupling of mutual inductor windings require observance of significant phase shift influence and suggest consideration of the alternative method of numerical air flux compensation. An increase of the frequency range to 20 kHz was discussed by TC 68 since some manufacturers of electrical steel include this range in their catalogues. However, TC 68 decided to keep the frequency range to that defined in IEC 60404-10:1988: 400 Hz to 10 kHz.

MAGNETIC MATERIALS –

Part 10: Methods of measurement of magnetic properties of electrical steel strip and sheet at medium frequencies

1 Scope

This part of IEC 60404 is applicable to grain-oriented and non-oriented electrical steel strip and sheet for measurements of a.c. magnetic properties in the frequency range 400 Hz to 10 000 Hz.

The object of this document is to define the general principles and the technical details of the measurement of magnetic properties of electrical steel strip and sheet by means of an Epstein frame.

The Epstein frame is applicable to test specimens obtained from electrical steel strips and sheets of any grade. The AC magnetic characteristics are determined for sinusoidal induced voltages, for specified peak values of magnetic polarization and for a specified frequency.

The measurements are to be made at an ambient temperature of $(23 \pm 5)^\circ\text{C}$ on test specimens which have first been demagnetized.

NOTE Throughout this document the term "magnetic polarization" is used as defined in IEC 60050-221. In some standards of the IEC 60404 series, the term "magnetic flux density" was used.

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 60404-8 (all parts), *Magnetic materials – Part 8: Specifications for individual materials*

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