

# INTERNATIONAL STANDARD

Magnetic materials – **STANDARD PREVIEW**  
Part 10: Methods of measurement of magnetic properties of electrical steel strip  
and sheet at medium frequencies  
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[IEC 60404-10:2016](#)

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# INTERNATIONAL STANDARD

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INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

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ICS 29.030

ISBN 978-2-8322-3672-7

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

## FOREWORD

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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.

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## 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.

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## 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*

#### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-221 and IEC 60050-121 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>

## 4 General principle of a.c. measurements

### 4.1 General

Clause 4 specifies the general conditions for the determination of a.c.magnetic properties of electrical steel strip and sheet by means of the 25 cm Epstein frame.

### 4.2 Principle of the 25 cm Epstein frame method

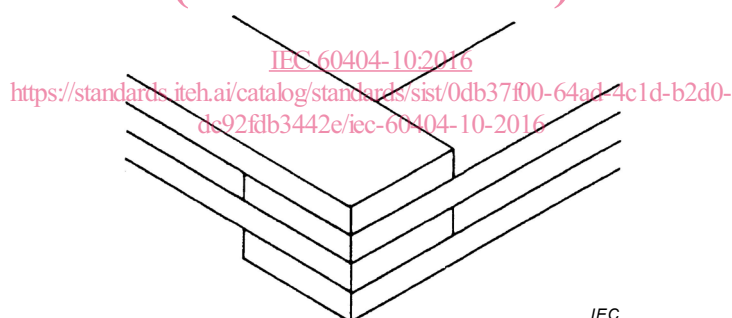
The 25 cm Epstein frame, which comprises a primary winding, a secondary winding and the specimen to be tested as a core, forms an unloaded transformer whose characteristics are measured by the method described in the following subclauses 4.3 to 4.10.

At the higher end of the frequency range, a specially constructed Epstein frame (see Annex A) may be required in which the interwinding capacitances are low, so that the capacitive part of the impedance has a negligible impact on the loss results. The material of the winding formers supporting the windings has a low dielectric loss.

A separate measuring system (for example a commercially available digital bridge capable of measuring resistance, capacitance and inductance) is required to determine the inter-winding capacitance of the Epstein frame.

### 4.3 Test specimen

The strips to be tested are assembled in a square, having double-overlapped corner joints (see Figure 1) thus forming four limbs of equal length and equal cross-sectional area.



**Figure 1 – Double-lapped joints**

The strips shall be sampled in accordance with the appropriate product standard in the IEC 60404-8 series.

They shall be cut by a method which will produce substantially burr-free edges and, if so specified, heat treated in accordance with the corresponding product standard. They shall have the following dimensions:

- width  $b = 30 \text{ mm} \pm 0,2 \text{ mm}$ ;
- length  $280 \text{ mm} \leq l \leq 320 \text{ mm}$ .

The length of the strips shall be equal within a tolerance of  $\pm 0,5 \text{ mm}$ .

When the strips are cut parallel or normal to the direction of rolling, the edge of the parent sheet shall be taken as the reference direction.

The following tolerances shall apply for the angle between the specified and actual direction of cutting:

- $\pm 1^\circ$  for grain-oriented steel sheet;
- $\pm 5^\circ$  for non-oriented steel sheet.

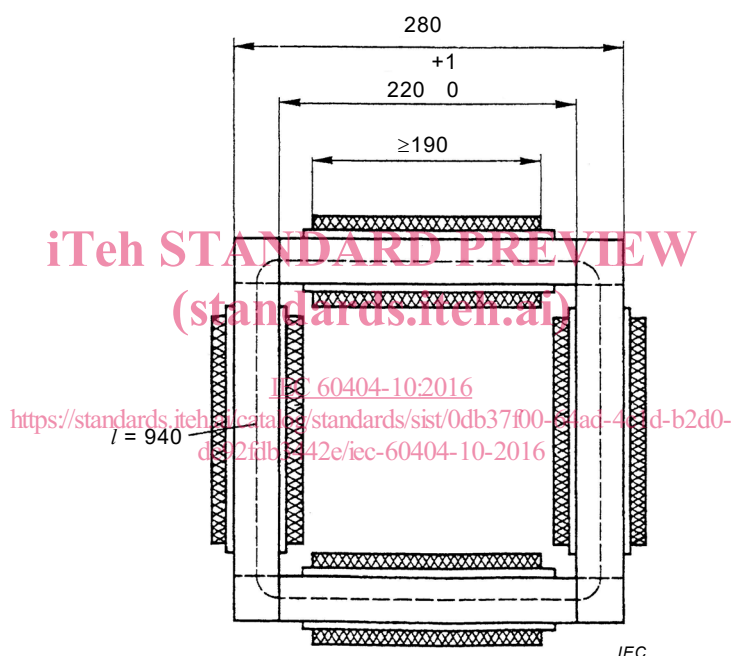
Only flat strips shall be used. Measurements shall be made without additional insulation.

The number of strips comprising the test specimen shall be not less than twelve and shall be a multiple of four. A force of  $(1 \pm 0,1)$  N shall be applied to each corner, normal to the plane of the overlapping strips.

#### 4.4 The 25 cm Epstein frame

The 25 cm Epstein frame (hereinafter referred to as the Epstein frame) shall consist of four solenoids into which the test specimen strips are inserted in such a manner that a closed magnetic circuit is formed (see Figure 2).

Dimensions in millimetres



**Figure 2 – The 25 cm Epstein frame**

If measurements are to be made under the conditions specified in 4.5, a mutual inductor for air flux compensation may be provided.

The winding formers supporting the windings shall be made of hard insulating material of low dielectric loss, such as polystyrene. They have a rectangular cross-section with 32 mm inner width. A height of approximately 5 mm is recommended.

The solenoids shall be fixed to an insulating and non-magnetic base in such a way to form a square (see Figure 2). The length of the sides of the square formed by the internal edges of the strips of the test specimen shall be  $220 +^1_0$  mm (see Figure 2).

In order to avoid undue wear of the winding formers and especially of their inner surfaces, winding formers of larger cross-section can be used into which replaceable liners of appropriate dimensions may be inserted.

Each of the four solenoids shall have two windings:

- a primary winding, on the outside (magnetizing winding);
- a secondary winding, on the inside (voltage winding).

The windings shall be distributed uniformly over a minimum length of 190 mm, each solenoid having one quarter of the total number of turns.

The individual primary windings of the four solenoids shall be connected in series, and the individual secondary windings shall be connected in a similar fashion.

At the higher end of the frequency range, the loss contribution due to the capacitance between the primary and secondary windings and also the self-capacitance of the secondary winding could be significant. The windings shall be spaced to minimize this loss.

The capacitance between the windings and the self-capacitance of the secondary winding shall be measured. If necessary, a correction shall be applied for the loss introduced.

The number of turns of primary and secondary windings shall be chosen to suit the particular conditions of the power supply, measuring equipment and frequency.

A total number of 200 turns for each of the primary and secondary windings is recommended and is commonly used for tests in the frequency range 400 Hz to 10 000 Hz.

The impedance of the magnetizing windings shall be sufficiently small to avoid waveform distortion and minimize internal voltage drops.

The effective magnetic path length,  $l_m$ , of the magnetic circuit shall be conventionally assumed to be equal to 0,94 m.

The active mass,  $m_a$ , i.e. the magnetically active mass of the test specimen, is given by:

$$m_a = \frac{l_m}{4l} m \quad (1)$$

where:

$m_a$  is the magnetically active mass of test specimen, in kilograms;

$m$  is the mass of test specimen, in kilograms;

$l_m$  is the conventional effective magnetic path length, in metres ( $l_m = 0,94$  m);

$l$  is the length of a test specimen strip, in metres.

#### 4.5 Air flux compensation

A compensation for air flux shall be made for magnetic field strengths greater than or equal to 1 000 A/m. At the lower end of the frequency range (less than or equal to 1 000 Hz) a mutual inductor may be used to compensate for the air flux.

The primary winding of the mutual inductor shall be connected in series with the primary winding of the Epstein frame, and the secondary winding of the mutual inductor shall be connected to the secondary winding of the Epstein frame in series opposition (see Figure 3).

An adjustment of the value of the mutual inductance shall be made so that, when passing an alternating current through the combined primary windings in the absence of the specimen in the apparatus, the voltage measured between the non-common terminals of the combined secondary windings shall be no more than 0,1 % of the voltage appearing across the secondary winding of the test apparatus alone.