

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Magnetic materials –
Part 8-6: Specifications for individual materials – Soft magnetic metallic
materials**

**Matériaux magnétiques –
Partie 8-6: Spécifications pour matériaux particuliers – Matériaux métalliques
magnétiquement doux**



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Tél.: +41 22 919 02 11

Fax: +41 22 919 03 00

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –

**Part 8-6: Specifications for individual materials –
Soft magnetic metallic materials**

FOREWORD

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International Standard IEC 60404-8-6 has been prepared by IEC technical committee 68: Magnetic alloys and steels.

This consolidated version of IEC 60404-8-6 consists of the second edition (1999) [documents 68/197/FDIS and 68/200/RVD] and its amendment 1 (2007) [documents 68/325A/CDV and 68/328/RVC].

The technical content is therefore identical to the base edition and its amendment(s) and has been prepared for user convenience.

It bears the edition number 2.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

MAGNETIC MATERIALS –

Part 8-6: Specifications for individual materials – Soft magnetic metallic materials

1 Scope

This part of IEC 60404 specifies the general requirements, magnetic properties, geometric characteristics and tolerances as well as inspection procedures for pure iron, silicon-iron, nickel-iron and cobalt-iron. The materials are in the form of bar, billet, sheet, strip or wire. The alloys covered correspond to those defined by classes A, C1, C2, E1 to E4 and F1 to F3 in IEC 60404-1.

Magnetic materials used primarily for relays, pure iron and steel products, classified only by coercivity, are covered in IEC 60404-8-10. IEC 60404-8-10 is less restrictive in terms of magnetic properties than the pure iron material (class A) and the silicon-iron alloys (classes C21 and C22) specified in this standard, but it gives more comprehensive dimensional tolerances.

Non-oriented and oriented silicon steels (C21 and C22) for industrial power frequency applications, classified by specific total loss, are covered in IEC 60404-8-2, IEC 60404-8-4 and IEC 60404-8-7.

Non-oriented and oriented thin magnetic materials for use at medium frequencies, classified by specific total loss, are covered in IEC 60404-8-8.

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 60050(121):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 121: Electromagnetism*

IEC 60050(131):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 131: Electric and magnetic circuits*

IEC 60050(221):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 221: Magnetic materials and components*

IEC 60404-1:1979, *Magnetic materials – Part 1: Classification*

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*

IEC 60404-6:1986, *Magnetic materials – Part 6: Methods of measurement of the magnetic properties of isotropic nickel-iron soft magnetic alloys, types E1, E3 and E4*

IEC 60404-7:1982, *Magnetic materials – Part 7: Method of measurement of the coercivity of magnetic materials in an open magnetic circuit*

IEC 60404-8-2:1998, *Magnetic materials – Part 8-2: Specifications for individual materials – Cold-rolled electrical alloyed steel sheet and strip delivered in the semi-processed state*

IEC 60404-8-4:1998, *Magnetic materials – Part 8-4: Specifications for individual materials – Cold-rolled non-oriented electrical steel sheet and strip delivered in the fully-processed state*

IEC 60404-8-7:1998, *Magnetic materials – Part 8-7: Specifications for individual materials – Cold-rolled grain-oriented electrical steel sheet and strip delivered in the fully-processed state*

IEC 60404-8-8:1991, *Magnetic materials – Part 8: Specifications for individual materials – Section 8: Specification for thin magnetic steel strip for use at medium frequencies*

IEC 60404-8-10:1994, *Magnetic materials – Part 8: Specifications for individual materials – Section 10: Specification for magnetic materials (iron and steel) for use in relays*

IEC 60404-9:1987, *Magnetic materials – Part 9: Methods of determination of the geometrical characteristics of magnetic steel sheet and strip*

IEC 60635:1978, *Toroidal strip-wound cores made of magnetically soft material*

ISO 404:1992, *Steel and steel products – General technical delivery requirements*

ISO 10474:1991, *Steel and steel products – Inspection documents*

3 Definitions

For the purpose of this part of IEC 60404, the definitions of the principal terms relative to magnetic properties and to electric and magnetic circuits given in IEC 60050(121), IEC 60050(131) and IEC 60050(221) apply, as well as the following definitions.

3.1 ageing

change of coercivity, expressed as a percentage, resulting from heat treatment

3.2 bar

solid product of uniform cross-section supplied in straight lengths. The cross-section may be round, square, rectangular or regular polygonal.

flat: A bar of rectangular cross-section, rolled on the four faces, whose thickness is generally 5 mm or greater and whose width is not greater than 150 mm

round: A bar of circular cross-section whose diameter is generally 8 mm or greater

3.3 billet

solid product of uniform cross-section, which may be square, round or rectangular, with a width less than twice the thickness

3.4 edge camber

the edge camber is characterized by the greatest distance between an edge of the sheet and the line joining the two extremities of the measured length of this edge (see IEC 60404-9)

3.5**flatness (wave factor)**

the flatness of a sheet is characterized by the wave factor, which is the relation of the height of the wave to its length (see IEC 60404-9)

3.6**heat**

product of a furnace melt or of a number of melts that are mixed prior to casting

3.7**lot**

material from the same heat, of the same form, produced at the same time and, if annealed, heat-treated together or sequentially in a continuous furnace

3.8**rod**

cold-drawn product of uniform rectangular or round cross-section, supplied in straight lengths

3.9**sheet and plate**

flat-rolled product of uniform cross-section, supplied in coils or cut lengths. The width is over 600 mm; sheets have a thickness under 5 mm and plates have a thickness over 5 mm

3.10**straightness of long products**

straightness is characterized by the greatest distance between the bar and the line joining the two ends of the bar

3.11**strip**

flat-rolled product of uniform cross-section, supplied in coils or cut lengths. The width is under 600 mm and the thickness under 5 mm

3.12**wire**

rolled or drawn product of uniform round or rectangular cross-section, supplied in coils

3.13 Abbreviations for test specimens

Type E.S.: Elongated specimen for test samples, of circular, rectangular or polygonal cross-section, with a length to diameter ratio of at least 5/1, according to IEC 60404-7.

Type L.R.: Laminated cores of stamped or etched rings (for magnetic head ring, a core with 10 mm outside diameter and 6 mm inside diameter can be used).

Type S.R.: Solid rings or square frames, formed or machined from solid material. The outside diameter of the ring shall be between 30 mm and 50 mm, with an outside/inside diameter ratio from 1,2 to 1,4.

NOTE Types L.R. and S.R. are only applicable to essentially isotropic materials.

Type S.W.: Strip-wound cores as defined by IEC 60635. For dimensional restrictions, see table 5. The outside diameters of test cores are between 30 mm and 80 mm.

4 Classification

The materials covered by this standard are classified according to the main alloying element and the content of this element. The subclassification takes into account the different uses of the alloys.

4.1 Alloy class A (pure iron)

This material is classified according to the maximum value of coercivity.

4.2 Alloy class C (silicon-iron)

Alloy C1, with 0 % to 5 % weight of silicon, is classified according to the maximum value of coercivity.

Alloys C2, with 0,4 % to 5 % weight of silicon, are classified according to the shape of the hysteresis loop and the minimum permeability in an a.c. measurement with a L.R. specimen made of material with a thickness of 0,35 mm; the measuring point is $\hat{H} = 1,6$ A/m.

4.3 Alloy class E (nickel-iron)

These alloys are classified according to the shape of the hysteresis loop and the minimum amplitude permeability in an a.c. measurement (50 Hz or 60 Hz), under sine flux conditions, with a S.W. specimen made of material with a thickness of 0,10 mm.

4.4 Alloy class F (cobalt-iron)

These alloys are classified according to the shape of the hysteresis loop and to the maximum value of coercivity.

5 Designation

The conventional designation of the materials comprises the following in the order given:

- a) the letter for the alloy class: A, C, E or F (see table 1);
- b) the number according to the content of the main alloying element (see table 1);
- c) for alloy classes C, E and F, the number 1 or 2 according to the shape of the hysteresis loop:
 - 1 = round (non-oriented)
 - 2 = rectangular (oriented by texture or by thermomagnetic treatment);
- d) a dash;
- e) depending on the alloy class, either the maximum value for the coercivity in amperes per metre or the peak value of the minimum permeability divided by 1 000 for a given magnetic field strength ($\hat{H} = 0,4$ A/m or $1,6$ A/m) and a given thickness measured with a certain test specimen (see above under classification).

Example:

E31-10: nickel-iron with 45 % to 50 % weight of nickel, a round hysteresis loop, and a minimum permeability of 10 000 for a strip-wound core made of a sheet with a thickness of 0,10 mm.

6 General requirements

6.1 Chemical composition and production process

The typical composition of each of the material classes covered by this standard is given in table 1.

The actual composition and production process are left to the discretion of the manufacturer, unless otherwise agreed between the manufacturer and purchaser, and specified in the order.

6.2 Delivery condition

The materials covered by this standard may be delivered in the hot-finished, cold-worked or annealed condition. The condition required shall be specified in the order.

6.2.1 Form of supply

Coils shall be of constant width and wound in such a manner that the edges are superimposed in a regular manner and the side faces of the coil are substantially flat. Coils shall be sufficiently tightly wound that they do not collapse under their own weight.

Coils can occasionally present welds or interleaves resulting from the removal of defective zones, subject to prior agreement between the parties. The value of the additional thickness due to the weld is subject to special agreement. If necessary, the marking of welds or interleaves may form the subject of a special agreement. For coils containing repair welds or interleaves, each part of the strip shall be of the same quality material.

The edges of parts welded together shall not be so much out of alignment as to affect the further processing of the material.

The mass of coils shall be agreed upon at the time of ordering.

6.2.2 Surface condition

The surface condition of sheets or strips shall be uniform, clean, and free from grease and rust.

Isolated imperfections such as scratches, blisters, etc. may be tolerated if the thickness remains within the tolerance limits and the manufacture or performance of the final product is not affected.

The nature of the surface condition will depend on the final treatment. For material in the hot-rolled condition, the material exhibits a hot mill scale.

7 Technical requirements

7.1 Magnetic properties

Unless otherwise required by the order, the magnetic properties shall be determined for each lot of material on a representative sample taken from the lot and heat-treated in accordance with the recommendations of the manufacturer or as specified by the purchaser. Acceptance testing of sheets and strips shall be carried out by a.c. testing of laminated rings (type L.R.) or strip-wound cores (type S.W.), or by d.c. testing of either solid rings (type S.R.), laminated rings (type L.R.) or elongated specimens (type E.S.).

The properties shall meet the magnetic requirements specified in Tables 2 to 4 for the alloy, the magnetic grade and the thickness specified in the order. For intermediate thicknesses not given in the table, the values for the next thicker group shall apply. When a.c. magnetic testing is used to demonstrate conformance of the alloy to this standard, either amplitude permeability measurements (Table 2a) or serial inductance permeability measurements (Table 2b) can be used. It is not a requirement of this standard that both methods must be used. The method used shall be subject to agreement between the manufacturer and the purchaser.

7.2 Geometric characteristics and tolerances

7.2.1 Flat products: sheet, plate and strip

7.2.1.1 Thickness

The thickness of sheet and strip shall not vary by more than the tolerances indicated in table 6.

7.2.1.2 Width

The width of strip shall not vary by more than the tolerances indicated in table 7.

7.2.1.3 Flatness

The wave factor, expressed as a percentage, shall not exceed 2 % and flatness shall be as agreed between manufacturer and purchaser.

7.2.1.4 Edge camber

The edge camber shall be as agreed between the manufacturer and the purchaser.

7.2.2 Cold-drawn bar, rod and wire

The diameter, width and thickness tolerances shall be as specified in table 8.

7.2.3 Hot-finished bar

Tolerances shall be as agreed between the manufacturer and the purchaser.

8 Inspection and testing

8.1 General

The materials defined by this standard are generally ordered with inspection in accordance with ISO 404. The purchaser shall specify, when ordering, the properties for which the verification shall be made, the type of inspection and the related document (see ISO 10474).

In the case of an order without inspection, as a dispensation from ISO 404, the manufacturer and the purchaser shall agree which property shall be certified, for example the maximum coercivity of the delivered material.

Each acceptance unit shall comprise not more than 23 t of the same grade and the same nominal dimensions. Different acceptance units can be adopted by special agreement.

For products supplied in coil form, each coil shall constitute an acceptance unit.

When the products are delivered in the form of slit coils, the test results applying to the parent unit of acceptance shall apply.

Except by special agreement, the same rules apply to the characteristics which are specifically specified.

8.2 Selection of samples

As far as possible only one sample for acceptance inspection shall be taken from each acceptance unit. The same sample shall serve to check the various properties by choosing a suitable order for the execution of the tests.

8.2.1 Flat products

In the case of coils, the first internal turn and the last external turn shall be regarded as wrapping and not as representative of the quality of the rest of the coil. The selection shall be made from the first internal or external turns, excluding the wrapping turn. The selection shall be made away from weld zones or interleaves. In the case of sheets or plates, the sample shall be taken from the upper part of the bundle.

8.2.2 Long products

The sample shall be taken from the bundle.

8.2.3 Wire

The sampling shall be carried out at the end of the coil.

8.3 Magnetic properties

8.3.1 Magnetic testing, d.c. methods

Measurement of d.c. flux density, permeability and coercivity shall be in accordance with IEC 60404-4 and IEC 60404-6.

8.3.2 Magnetic testing, a.c. methods

Measurement of a.c. flux density and permeability shall be in accordance with IEC 60404-2 and IEC 60404-6. Unless otherwise specified, a test frequency of 50 Hz or 60 Hz shall be used. When amplitude permeability measurements are made, the test conditions shall conform to sine flux (sine B). When inductance permeability measurements are made, the serial inductance permeability shall be measured.

8.3.3 Test specimens

The type of test specimens to be used for testing is indicated in tables 2 to 4 by the abbreviations for test specimens given in 3.13.