

INTERNATIONAL STANDARD

CONSOLIDATED VERSION

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 60404-8-4 edition 4.1 contains the fourth edition (2022-09) [documents 68/700/CDV and 68/713/RVC] and its amendment 1 (2026-06) [documents 68/793/CDV and 68/806/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

IEC 60404-8-4 has been prepared by IEC technical committee 68: Magnetic alloys and steels. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2013. This edition constitutes a technical revision.

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

- a) modification of terms and technical requirements concerning geometrical characteristics to be consistent with IEC 60404-9:2018;
- b) insertion of Table 3 – Tolerances on nominal thickness;
- c) change of the length of test specimen for determination of geometrical characteristics from 2 m to 1 m.

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

Draft	Report on voting
68/700/CDV	68/713/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This revision of International Standard IEC 60404-8-4 has been prepared by the experts of the Working Group 1 of the IEC Technical Committee 68: Magnetic alloys and steels.

The third edition of IEC 60404-8-4 was issued in 2013. After that, other IEC 60404 standards were revised and IEC TC 68 decided in 2019 at their meeting in Düsseldorf to revise this document to maintain consistency for user's convenience. The revision is made mainly on technical amendments regarding testing and definitions of geometrical characteristics in accordance with IEC 60404-9. The length of test specimen for determination of geometrical characteristics is changed from 2 m to 1 m. The term of "flatness" is divided into "edge wave (wave factor)" and "residual curvature" and the horizontal method is introduced for verification of residual curvature. This revision also includes corrections in order to improve consistency with other standards of the IEC 60404-8 series.

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1 Scope

This part of IEC 60404 defines the grades of cold-rolled non-oriented electrical steel strip and sheet in nominal thicknesses of 0,35 mm, 0,47 mm, 0,50 mm, 0,65 mm and 1,00 mm. In particular, it gives general requirements, magnetic properties, geometric characteristics, tolerances and technological characteristics, as well as inspection procedure. The nominal thickness 0,47 mm applies to the grades for use at 60 Hz only.

This document applies to cold-rolled non-oriented electrical steel strip and sheet supplied in the fully-processed state, i.e. the final annealed condition, in coils or sheets, and intended for the construction of magnetic circuits. This document does not apply to materials supplied in the semi-processed state.

NOTE The cold-rolled non-oriented electrical steel strip and sheet supplied in the semi-processed state is specified in IEC 60404-8-3.

The grades defined in this document correspond to Class C21 of IEC 60404-1.

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

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

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

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

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

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

ISO 7799, *Metallic materials – Sheet and strip 3 mm thick or less – Reverse bend test*

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

3 Terms and definitions

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

3.1

edge wave

wave factor

variations of flatness of a length of strip or a sheet taking a form of waves at the slit edge of the product

Note 1 to entry: The edge wave is characterized by the wave factor which is the relation of the height of the wave to its length, expressed as a percentage.

[SOURCE: IEC 60404-9:2018, 3.1]

3.2

residual curvature

variations of flatness of a length of strip or a sheet taking a permanent curvature in the direction of rolling of the product

[SOURCE: IEC 60404-9:2018, 3.2]

3.3

edge camber

greatest distance between a longitudinal edge of a length of strip or a sheet and the line joining the two extremities of the measured length of this edge

[SOURCE: IEC 60404-9:2018, 3.3]

3.4

deviation from the shearing line

internal stress

greatest distance between corresponding points on the two sheared edges of a length of strip or a sheet sheared in the middle of the width, in parallel to the direction of rolling of the product, which characterizes the internal stress of the materials

[SOURCE: IEC 60404-9:2018, 3.4]

3.5

number of bends

counts of alternate bending in the reverse bend test prior to the appearance of the first crack in the base metal of the specimen visible to the naked eye or sudden failure occurs by fracture

[SOURCE: IEC TR 63114:2018, 3.2]

4 Classification

The grades covered by this document are classified according to the specified value of maximum specific total loss and according to the nominal thickness of the product¹. The products of the nominal thicknesses 0,35 mm, 0,50 mm, 0,65 mm and 1,00 mm are classified according to the specified values tested at a magnetic polarization of 1,5 T and 50 Hz, in watts

1 In the rest of the document, the word "product" is used to mean "strip and sheet".

per kilogram. The product of the nominal thickness 0,47 mm is classified according to the specified value tested at a magnetic polarization of 1,5 T and 60 Hz, in watts per kilogram.

5 Designation

The steel name comprises the following in the order given:

- a) a letter "M" for electrical steel;
- b) one hundred times the specified value of maximum specific total loss at a magnetic polarization of 1,5 T and 50 Hz, in watts per kilogram, for the products of the nominal thicknesses 0,35 mm, 0,50 mm, 0,65 mm and 1,00 mm, or at a magnetic polarization of 1,5 T and 60 Hz, in watts per kilogram, for the products of the nominal thickness 0,47 mm;
- c) one hundred times the nominal thickness of the product, in millimeters;
- d) the characteristic letter "A" for the grades of cold-rolled non-oriented electrical steel strip or sheet supplied in the fully-processed state;
- e) one tenth of the frequency at which the maximum specific total loss is specified, i.e. 5 or 6.

EXAMPLE M250-35A5 for cold-rolled non-oriented electrical steel strip or sheet with a maximum specific total loss of 2,50 W/kg at a magnetic polarization of 1,5 T and 50 Hz, and a nominal thickness of 0,35 mm, supplied in the fully-processed state.

6 General requirements

6.1 Production process

The production process of the steel and its chemical composition are left to the discretion of the manufacturer.

6.2 Form of supply

The product is supplied in coils in the case of strip and in bundles in the case of sheets.

The mass of coils or bundles of sheets shall be agreed between the manufacturer and the purchaser at the time of enquiry and order.

The recommended value for the internal diameter of coils is approximately 508 mm or approximately 610 mm.

Strip 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 in order that they do not collapse under their own weight.

Strip may exhibit welds or interleaves resulting from the removal of defective zones if agreed between the manufacturer and the purchaser at the time of enquiry and order. If necessary, the marking of welds or interleaves may be agreed between the manufacturer and the purchaser at the time of enquiry and order.

For coils containing welds or interleaves, each part of the strip shall be of the same grade.

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

Sheets which make up each bundle shall be stacked so that the side faces of the bundle are substantially flat and approximately perpendicular to the top face.

6.3 Delivery condition

The products are usually supplied either without insulation coating or with insulation coating on one or both sides. If the product is supplied with insulation coating, the nature of the coating, its properties, the stacking factor and their verification are subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

NOTE Further information on the classification of surface insulation coatings can be found in IEC 60404-1-1.

6.4 Surface condition

The surfaces shall be smooth and clean, free from grease and rust². Dispersed defects such as scratches, blisters, cracks, etc. are only permitted if they are within the tolerances on thickness and if they are not detrimental to the correct use of the supplied product.

For products supplied with insulation coating, the coating shall be sufficiently adherent so that it does not become detached during manufacturing operations. During the reverse bend test (see 8.4.4.2), the coating shall not become detached after a bend of 90°. If the coating becomes detached during the test, the sample of the product from which the test specimen was taken shall be subjected to a shearing test. By shearing the sample with well sharpened tools, a detachment of large pieces of the coating shall not be admissible. However, some slight chipping of the coating at the sheared edges shall be tolerated.

6.5 Suitability for cutting

The product shall be able to be cut or punched without causing premature wear of tools. The product shall be suitable for cutting or punching accurately into the usual shapes at any point when appropriate cutting or punching tools and technologies are used.

A special requirement concerning suitability for cutting or punching of the product may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

7 Technical requirements

7.1 Magnetic properties

7.1.1 General

The properties defined in 7.1.2 to 7.1.4 shall apply to products in the delivery conditions defined in 6.3.

For products supplied with insulation coating, the mass of the coating shall be taken into account to determine the magnetic properties.

7.1.2 Magnetic polarization

The specified values of minimum magnetic polarization, expressed as a peak value, at AC magnetic field strengths H of 2 500 A/m, 5 000 A/m and 10 000 A/m, expressed as a peak value, shall be as given in Table 1 at 50 Hz or Table 2 at 60 Hz.

² This should not be confused with some coloration of the insulation coating inherent to the manufacturing process.

Table 1 – Technological properties and magnetic properties (magnetic properties are measured using the Epstein method according to IEC 60404-2)

Steel name	Nominal thickness mm	Maximum specific total loss at 1,5 T W/kg		Minimum magnetic polarization ^a at an AC magnetic field strength T			Maximum anisotropy of loss %	Minimum stacking factor	Minimum number of bends	Conventional density ^c kg/dm ³
		at 50 Hz	at 60 Hz ^b	2 500 A/m	5 000 A/m	10 000 A/m				
M210-35A5		2,10	2,65	1,49	1,60	1,70	±17		2	7,60
M230-35A5		2,30	2,90	1,49	1,60	1,70	±17		2	7,60
M235-35A5		2,35	2,97	1,49	1,60	1,70	±17		2	7,60
M250-35A5		2,50	3,14	1,49	1,60	1,70	±17		2	7,60
M270-35A5	0,35	2,70	3,36	1,49	1,60	1,70	±17	0,95	2	7,65
M300-35A5		3,00	3,74	1,49	1,60	1,70	±17		3	7,65
M330-35A5		3,30	4,12	1,49	1,60	1,70	±17		3	7,65
M360-35A5		3,60	4,55	1,49	1,60	1,70	±17		3	7,65
M230-50A5		2,30	2,95	1,49	1,60	1,70	±17		2	7,60
M250-50A5		2,50	3,21	1,49	1,60	1,70	±17		2	7,60
M270-50A5		2,70	3,47	1,49	1,60	1,70	±17		2	7,60
M290-50A5		2,90	3,71	1,49	1,60	1,70	±17		2	7,60
M310-50A5		3,10	3,95	1,49	1,60	1,70	±14		3	7,65
M330-50A5		3,30	4,20	1,49	1,60	1,70	±14		3	7,65
M350-50A5		3,50	4,45	1,50	1,60	1,70	±12		5	7,65
M400-50A5		4,00	5,10	1,53	1,63	1,73	±12	0,96	5	7,70
M470-50A5	0,50	4,70	5,90	1,54	1,64	1,74	±10		10	7,70
M530-50A5		5,30	6,66	1,56	1,65	1,75	±10		10	7,70
M600-50A5		6,00	7,53	1,57	1,66	1,76	±10		10	7,75
M700-50A5		7,00	8,79	1,60	1,69	1,77	±10		10	7,80
M800-50A5		8,00	10,06	1,60	1,70	1,78	±10		10	7,80
M940-50A5		9,40	11,84	1,62	1,72	1,81	±8		10	7,85
M1000-50A5		10,00	12,60	1,62	1,72	1,81	±8		10	7,85

Steel name	Nominal thickness mm	Maximum specific total loss at 1,5 T W/kg		Minimum magnetic polarization ^a at an AC magnetic field strength T			Maximum anisotropy of loss %	Minimum stacking factor	Minimum number of bends	Conventional density ^c kg/dm ³
		at 50 Hz	at 60 Hz ^b	2 500 A/m	5 000 A/m	10 000 A/m				
M310-65A5		3,10	4,08	1,49	1,60	1,70	±15		2	7,60
M330-65A5		3,30	4,30	1,49	1,60	1,70	±15		2	7,60
M350-65A5		3,50	4,57	1,49	1,60	1,70	±14		2	7,60
M400-65A5		4,00	5,20	1,52	1,62	1,72	±14		2	7,65
M470-65A5		4,70	6,13	1,53	1,63	1,73	±12	0,97	5	7,65
M530-65A5	0,65	5,30	6,84	1,54	1,64	1,74	±12		5	7,70
M600-65A5		6,00	7,71	1,56	1,66	1,76	±10		10	7,75
M700-65A5		7,00	8,98	1,57	1,67	1,76	±10		10	7,75
M800-65A5		8,00	10,26	1,60	1,70	1,78	±10		10	7,80
M1000-65A5		10,00	12,77	1,61	1,71	1,80	±10		10	7,80
M600-100A5		6,00	8,14	1,53	1,63	1,72	±10		2	7,60
M700-100A5		7,00	9,38	1,54	1,64	1,73	±8		3	7,65
M800-100A5	1,00	8,00	10,70	1,56	1,66	1,75	±6	0,98	5	7,70
M1000-100A5		10,00	13,39	1,58	1,68	1,76	±6		10	7,80
M1300-100A5		13,00	17,34	1,60	1,70	1,78	±6		10	7,80

^a It has been common practice for many years to give values of magnetic flux density. In fact, the Epstein frame is used to determine magnetic polarization (intrinsic flux density) which is defined as follows in accordance with IEC 60050-121:

$$J = B - \mu_0 H$$

where

- J is the magnetic polarization;
- B is the magnetic flux density;
- μ_0 is the magnetic constant: $4\pi \times 10^{-7} \text{ H m}^{-1}$;
- H is the magnetic field strength.

^b Only for information.

^c Other values may be agreed between the manufacturer and the purchaser at the time of enquiry and order, see Annex B.

Table 2 – Technological properties and magnetic properties for strip and sheet of nominal thickness 0,47 mm for use at 60 Hz only
(magnetic properties are measured using the Epstein method according to IEC 60404-2)

Steel name	Nominal thickness mm	Maximum specific total loss at 1,5 T W/kg		Minimum magnetic polarization ^a at an AC magnetic field strength T			Maximum anisotropy of loss %	Minimum stacking factor	Minimum number of bends	Conventional density ^c kg/dm ³
		at 50 Hz ^b	at 60 Hz	2 500 A/m	5 000 A/m	10 000 A/m				
M370-47A6		2,92	3,70	1,49	1,60	1,70	±18		2	7,65
M380-47A6		3,00	3,80	1,49	1,60	1,70	±14		3	7,65
M408-47A6		3,22	4,08	1,49	1,60	1,70	±14		3	7,65
M419-47A6		3,31	4,19	1,49	1,60	1,70	±14		3	7,70
M452-47A6	0,47	3,57	4,52	1,50	1,60	1,70	±14	0,96	5	7,70
M507-47A6		4,01	5,07	1,51	1,61	1,71	±14		5	7,70
M638-47A6		5,04	6,38	1,54	1,64	1,74	±12		10	7,75
M836-47A6		6,60	8,36	1,58	1,68	1,77	±12		10	7,80
M990-47A6		7,82	9,90	1,58	1,68	1,77	±12		10	7,80

^a It has been common practice for many years to give values of magnetic flux density. In fact the Epstein frame is used to determine magnetic polarization (intrinsic flux density) which is defined as follows in accordance with IEC 60050-121:

$$J = B - \mu_0 H$$

where
 J is the magnetic polarization;
 B is the magnetic flux density;
 μ_0 is the magnetic constant: $4\pi \times 10^{-7} \text{ H m}^{-1}$;
 H is the magnetic field strength.

^b Only for information.

^c Other values may be agreed between the manufacturer and the purchaser at the time of enquiry and order, see Annex B.

7.1.3 Specific total loss

The specified values of maximum specific total loss at a magnetic polarization of 1,5 T and 50 Hz shall be as given in Table 1 for products of the nominal thicknesses 0,35 mm, 0,50 mm, 0,65 mm and 1,00 mm. They apply to:

- aged or non-aged test strips (see 8.3.1), for products of the nominal thicknesses 0,35 mm, 0,50 mm and 0,65 mm;
- non-aged test strips, for products of the nominal thickness 1,00 mm.

The specified values of maximum specific total loss at a magnetic polarization of 1,5 T and 60 Hz shall be as given in Table 2, for products of the nominal thickness 0,47 mm.

A special requirement concerning the value of maximum specific total loss measured using test strips cut parallel to the direction of rolling only or test strips cut perpendicular to the direction of rolling only may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

NOTE Annex A gives non-specified values of maximum specific total loss at a magnetic polarization of 1,0 T and 50 Hz.

7.1.4 Anisotropy of loss

The permitted values of maximum anisotropy of loss at a magnetic polarization of 1,5 T shall be as given in Table 1 and Table 2.

A special requirement concerning the declaration of the measured value of anisotropy of loss may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

7.2 Geometrical characteristics and tolerances

7.2.1 Thickness

The nominal thicknesses of the product are 0,35 mm, 0,47 mm, 0,50 mm, 0,65 mm and 1,00 mm.

The nominal thickness 0,47 mm applies only to the grades for use at 60 Hz only.

For thickness tolerance, a distinction is made between

- the deviation from the nominal thickness within an acceptance unit;
- the difference in thickness in a direction parallel to the direction of rolling in a length of strip or sheet;
- the difference in thickness in a direction perpendicular to the direction of rolling. This tolerance applies only to products supplied with a width greater than 150 mm.

At any point, the deviation from the nominal thickness within an acceptance unit shall not exceed the tolerance of Table 3.

The additional thickness due to welds with respect to the measured thickness of the product shall not exceed 0,10 mm.

The difference in thickness in a direction parallel to the direction of rolling in a 1 m length of the product shall not exceed

- 0,030 mm, 0,038 mm and 0,040 mm for products of the nominal thicknesses 0,35 mm, 0,47 mm and 0,50 mm respectively;