IEC 60404-8-3

Edition 4.0 2023-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Magnetic materials –
Part 8-3: Specifications for individual materials – Cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state

Matériaux magnétiques –
Partie 8-3: Spécifications pour matériaux particuliers – Bandes et tôles magnétiques en acier à grains non orientés, laminées à froid et livrées à l'état semi fini

IEC 60404-8-3:2023-11(en-fr)

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MAGNETIC MATERIALS –

Part 8-3: Specifications for individual materials – Cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state

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IEC 60404-8-3 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 2005. 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;

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c) Change of the length of the test specimen for determination of geometrical characteristics from 2 m to 1 m;

d) Deletion of Annex A with the European numerical system of designation of steels.

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

Draft	Report on voting
68/736/CDV	68/747/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 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

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INTRODUCTION

TC 68 followed the recommendation of the maintenance inquiry, 68/649/INF, to revise this standard in order to maintain consistency with other standard adaptions of the IEC 60404 series. Moreover, the revision is made mainly regarding testing and definitions of geometrical characteristics in accordance with IEC 60404-9. The length of the 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". This revision also includes corrections in order to improve consistency with other IEC 60404-8 series. For example, the supply in the form of coils is considered before the supply in sheets, which reflects the current priority.

As the final annealing of cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state is the responsibility of the user, attention is drawn to the importance of this treatment for the properties of the product.

For this reason the magnetic properties in Table 1 and Table 2 are given for a reference condition (see 7.1.1) obtained by a suitable heat treatment. To ensure that the properties in use are equivalent to those specified, it is important that the heat treatment carried out by the user is equivalent to that used to define the reference condition.

It is recognised that these products can be used in the semi-processed state, in which case the magnetic properties are not subject to the specifications of this document.

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MAGNETIC MATERIALS –

Part 8-3: Specifications for individual materials – Cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state

1 Scope

This part of IEC 60404 defines the grades of cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state in nominal thicknesses of 0,47 mm, 0,50 mm, 0,64 mm, 0,65 mm and 0,79 mm. It gives general requirements, magnetic properties, geometric characteristics, tolerances and technical characteristics as well as inspection procedures. The nominal thicknesses of 0,47 mm, 0,64 mm and 0,79 mm apply to the grades for use at 60 Hz only.

This document applies to cold-rolled non-oriented electrical steel strip and sheet delivered in the semi-processed state, i.e. without final heat treatment, in coils or sheets, and intended for the construction of magnetic circuits. This document does not apply to materials supplied in the fully-processed state.

These materials correspond respectively to classes B2 and 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 (IEV) – Part 121: Electromagnetism*

IEC 60050-221, *International Electrotechnical Vocabulary (IEV) – 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 60404-9, *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 10474:1991, *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.

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

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://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 sheet and the line joining the two extremities of the measured length of this edge

[SOURCE IEC 60404-9:2018, 3.3]

4 Classification

The grades covered by this document are classified according to the specified value of the maximum specific total loss in watts per kilogram after a reference heat treatment (see 7.1.1) and according to the nominal thickness of the product[1]. Products of the nominal thickness 0,50 mm and 0,65 mm are classified according to the specified value of maximum specific total loss, tested at a magnetic polarization of 1,5 T and 50 Hz, in watts per kilogram. The products of the nominal thickness of 0,47 mm, 0,64 mm and 0,79 mm are classified according to the specified value of the maximum specific total loss, 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 0,50 mm and 0,65 mm, or at a magnetic polarization of 1,5 T and 60 Hz, in watts per kilogram, for the products of the nominal thicknesses 0,47 mm, 0,64 mm and 0,79 mm;

c) one hundred times the nominal thickness of the product, in millimetres;

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

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d) the characteristic letter "K" for the grades of cold-rolled non-oriented electrical steel strip or sheet delivered in the semi-processed state;

e) one tenth of the frequency at which the maximum specific total loss is specified, i.e. 5 or 6.

EXAMPLE: M660-50K5 for cold-rolled electrical steel strip or sheet with a specified maximum specific total loss of 6,60 W/kg at a magnetic polarization of 1,5 T at 50 Hz and a nominal thickness of 0,50 mm, supplied in the semi-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 bundles in the case of sheets.

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

The recommended value for 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 can 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 can 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 stack are substantially flat and approximately perpendicular to the top face.

6.3 Delivery condition

The products supplied with slit or trimmed edges shall not have any burrs which will adversely affect its further application or use.

As the result of the method of manufacture and delivery in the form of coils, the products in the as-delivered condition can exhibit residual curvature in the direction of rolling as well as certain internal stresses. Precautions shall be taken by the user to reduce or eliminate the effect of these factors on the application or use of the products.

The products can be supplied either without insulating coating or with thin insulating coating on one or both sides which can act as an "anti-stick" coating during anneal.

NOTE For the classification of surface insulation coatings, see IEC 60404-1-1.

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6.4 Surface condition

The surfaces shall be smooth and clean. 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.

The surface condition and in particular the roughness of the products can be the subject of agreement between the manufacturer and the purchaser at the time of enquiry and order.

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 can 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 Reference condition

The properties defined in 7.1.2 to 7.1.4 shall only apply to test specimens in the reference condition which is obtained by the following heat treatment.

Test strips shall be subjected to a heat treatment in a decarburizing atmosphere at the temperature specified in Table 1 or Table 2 and shall be maintained for 2 h at this temperature. The heating rate shall not exceed 200 °C/h. The cooling rate from the temperatures specified in Table 1 or Table 2 to 550 °C shall not exceed 120 °C/h. The gas for decarburization atmosphere shall have a volume fraction of 20 % H_2, 80 % N_2 with water vapour, the dew-point being +13 °C ± 2 °C to +20 °C ± 2 °C at atmospheric pressure.

NOTE In special cases, the manufacturer can recommend a non-standard reference treatment, for example in a non-decarburizing atmosphere for material with a very low carbon content.

The establishment of the decarburizing atmosphere requires the removal of air from the annealing furnace before raising the temperature. This removal is effected by continuously purging the furnace with an inert protective gas. The flow and pressure of the decarburizing gas shall be regulated to ensure good decarburization at any point on the test specimen and a complete renewal of the atmosphere in the furnace several times during the heat treatment.

The test strips should not have any contact with each other.

7.1.2 Magnetic polarization

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

NOTE Annex A gives, for guidance only, typical values of relative amplitude permeability for steels of nominal thicknesses 0,47 mm, 0,64 mm and 0,79 mm.

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Table 1 – Technological and magnetic properties for use at 50 Hz (magnetic properties are measured using the Epstein method according to IEC 60404-2)

Steel name	Nominal thickness	Reference heat treatment temperature	Maximum specific total loss at 1,5 T [a]		Minimum magnetic polarization at an AC magnetic field strength [a, b]			Conventional density [c]
	mm	°C	W/kg		T			kg/dm³
		(±10 °C)	50 Hz	60 Hz [d]	2 500 A/m	5 000 A/m	10 000 A/m	
M340-50K5	0,50	840	3,40	4,32	1,54	1,62	1,72	7,65
M390-50K5		840	3,90	4,97	1,56	1,64	1,74	7,70
M450-50K5		790	4,50	5,67	1,57	1,65	1,75	7,75
M560-50K5		790	5,60	7,03	1,58	1,66	1,76	7,80
M660-50K5		790	6,60	8,38	1,62	1,70	1,79	7,85
M890-50K5		790	8,90	11,30	1,60	1,68	1,78	7,85
M1050-50K5		790	10,50	13,34	1,57	1,65	1,77	7,85
M390-65K5	0,65	840	3,90	5,07	1,54	1,62	1,72	7,65
M450-65K5		840	4,50	5,86	1,56	1,64	1,74	7,70
M520-65K5		790	5,20	6,72	1,57	1,65	1,75	7,75
M630-65K5		790	6,30	8,09	1,58	1,66	1,76	7,80
M800-65K5		790	8,00	10,16	1,62	1,70	1,79	7,85
M1000-65K5		790	10,00	12,70	1,60	1,68	1,78	7,85
M1200-65K5		790	12,00	15,24	1,57	1,65	1,77	7,85

[a] These values are valid only for test specimens in the reference condition (see 7.1.1).

[b] 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: $4\pi \times 10^{-7}$ Hm^{-1};

H is the magnetic field strength.

NOTE The difference between B and J at 10 000 A/m is equal to 0,013 T.

[c] Other values can be agreed between the steel manufacturer and the purchaser at the time of enquiry and order, see Annex C.

[d] Only for information.

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Table 2 – Technological and magnetic properties for use at 60 Hz (magnetic properties are measured using the Epstein method according to IEC 60404-2)

Steel name	Nominal thickness	Reference heat treatment temperature	Maximum specific total loss at 1,5 T [a]		Minimum magnetic polarization at an AC magnetic field strength [a, b]			Conventional density [c]
	mm	°C	W/kg		T			kg/dm³
		(±10 °C)	60 Hz	50 Hz [d]	2 500 A/m	5 000 A/m	10 000 A/m	
M342-47K6	0,47	840	3,42	2,70	1,52	1,60	1,70	7,65
M364-47K6		840	3,64	2,88	1,53	1,60	1,70	7,65
M386-47K6		840	3,86	3,05	1,53	1,61	1,71	7,65
M419-47K6		840	4,19	3,31	1,54	1,62	1,72	7,70
M441-47K6		790	4,41	3,48	1,54	1,62	1,72	7,70
M507-47K6		790	5,07	4,01	1,57	1,65	1,75	7,75
M595-47K6		790	5,95	4,70	1,58	1,66	1,76	7,80
M728-47K6		790	7,28	5,75	1,59	1,67	1,77	7,80
M838-47K6		790	8,38	6,62	1,60	1,68	1,78	7,85
M441-64K6	0,64	840	4,41	3,48	1,52	1,60	1,70	7,65
M463-64K6		840	4,63	3,66	1,52	1,60	1,70	7,65
M485-64K6		840	4,85	3,83	1,53	1,61	1,71	7,65
M507-64K6		840	5,07	4,01	1,54	1,62	1,72	7,70
M573-64K6		790	5,73	4,53	1,56	1,64	1,74	7,70
M640-64K6		790	6,40	5,06	1,57	1,65	1,75	7,75
M794-64K6		790	7,94	6,27	1,58	1,66	1,76	7,80
M948-64K6		790	9,48	7,49	1,60	1,68	1,78	7,80
M1080-64K6		790	10,80	8,53	1,60	1,68	1,78	7,85
M992-79K6	0,79	790	9,92	7,84	1,57	1,65	1,75	7,75
M1190-79K6		790	11,90	9,42	1,58	1,66	1,76	7,80
M1350-79K6		790	13,50	10,67	1,59	1,67	1,77	7,85

[a] These values are valid only for test specimens in the reference condition (see 7.1.1).

[b] 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: $4\pi \times 10^{-7}$ Hm^{-1};

H is the magnetic field strength.

NOTE The difference between B and J at 10 000 A/m is equal to 0,013 T.

[c] Other values can be agreed between the steel manufacturer and the purchaser at the time of enquiry and order, see Annex C.

[d] Only for information.

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 0,50 mm and 0,65 mm.

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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 thicknesses of 0,47 mm, 0,64 mm and 0,79 mm.

The test shall be made in an alternating magnetic field at 50 Hz for the materials given in Table 1 or at 60 Hz for the materials given in Table 2.

NOTE Annex B gives, for guidance only, the maximum specific total loss for a magnetic polarization of 1,0 T at 50 Hz and for nominal thicknesses 0,50 mm and 0,65 mm.

7.1.4 Anisotropy of loss

A special requirement concerning the anisotropy of loss can 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 0,47 mm, 0,50 mm, 0,64 mm, 0,65 mm and 0,79 mm.

The nominal thicknesses 0,50 mm and 0,65 mm apply to the grades for use at 50 Hz.

The nominal thicknesses 0,47 mm, 0,64 mm and 0,79 mm apply to the grades for use at 60 Hz.

For thickness tolerance, a distinction is made between

– the deviation from the nominal thickness within the same 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 the same acceptance unit shall not exceed the tolerance of Table 3.

Table 3 – Tolerances on nominal thickness

Nominal thickness mm	Tolerance mm
0,47	±0,038
0,50	±0,040
0,64	±0,051
0,65	±0,052
0,79	±0,063

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 0,038 mm, 0,040 mm, 0,051 mm, 0,052 mm and 0,063 mm for products of the nominal thickness 0,47 mm, 0,50 mm, 0,64 mm, 0,65 mm and 0,79 mm respectively.

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