IEC 60404-8-7

Edition 5.0 2020-09
REDLINE VERSION

INTERNATIONAL STANDARD

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

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IEC 60404-8-7:2020-09 RLV(en)

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MAGNETIC MATERIALS –

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

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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 60404-8-7 has been prepared by IEC technical committee 68: Magnetic alloys and steels.

This fifth edition cancels and replaces the fourth edition published in 2017. This edition constitutes a technical revision.

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

– insertion of a third class of grain-oriented electrical steels for magnetic domain refined high permeability grades;
– introduction of the single sheet tester (SST) method as reference measurement method for this third class of material together with a conversion factor for transposition of the SST measurement results to equivalent Epstein values;
– update of the electrical steel range to take account of the current offers and demands of grades.

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

CDV	Report on voting
68/641/CDV	68/657/RVC

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

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

A list of all the 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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INTRODUCTION

This revision of International Standard IEC 60404-8-7 has been prepared by the experts of the Working Group 1 of the IEC technical committee 68: Magnetic alloys and steels.

The insertion of a third class of electrical steels for magnetic domain refined high permeability grades is the main reason of this revision. Most of the technologies of magnetic domain refinement result in material that does not withstand the stress relief annealing after cutting without changing the magnetic properties (i.e. the specific total loss). In the case of this material, the Epstein method according to IEC 60404-2, requiring the annealing of the Epstein test specimens, is not suitable. Therefore, the single sheet tester (SST) method specified in IEC 60404-3 is employed for such non-heatproof magnetic material.

The introduction of the SST as the reference measurement method for these magnetic domain refined high permeability grades was preceded by intense discussions within IEC/TC 68.

The specific total loss measured by use of the SST specified in IEC 60404-3 tends to be larger than the value measured by the use of the Epstein frame in accordance with IEC 60404-2. The magnetic polarization at H = 800 A/m measured by use of the SST tends to be a little lower than the value measured by the use of the Epstein frame.

The significant difference between Epstein and SST loss results made it necessary to introduce a conversion factor, F_c, applied to the SST results. This conversion factor is to create continuity in the quality characteristics ratio of conventional grain-oriented electrical steel grades and of high permeability grades (Epstein related loss values) to the magnetic domain refined high permeability grades (SST related loss values), particularly over the transition zone between these grades. Otherwise, it could be confusing to the users of this document that the higher quality materials assessed by the SST method would be listed with seemingly higher values of the specific total loss, compared with the lower values obtained by the Epstein method on the lower quality materials.

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Considerations of the widely spread grades of domain refined high permeability grain-oriented electrical steel led to the consented value of F_c = 0,925 to be applied to the specific total loss values at 1,7 T measured by the SST method.

The magnetic polarization of magnetic domain refined high permeability grades at H = 800 A/m is the value taken from the SST measurement without conversion to an equivalent Epstein value.

Consequently, the magnetic domain refined high permeability grades will be listed in a new Table 3 as a new class of grain-oriented electrical steel strip and sheet.

MAGNETIC MATERIALS –

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

1 Scope

This part of IEC 60404 defines the grades of cold-rolled grain-oriented electrical steel strip and sheet in nominal thicknesses of 0,20 mm, 0,23 mm, 0,27 mm, 0,30 mm and 0,35 mm. In particular, it gives general requirements, magnetic properties, geometric characteristics, tolerances and technological characteristics, as well as inspection procedures.

This document applies to Goss textured grain-oriented electrical steel strip and sheet supplied in the final annealed condition in coils or sheets, and intended for the construction of magnetic circuits.

The grades are grouped into ~~two~~ three classes:

– conventional grades;

– high permeability grades~~, including grades which may be delivered in the domain refined condition~~.

– magnetic domain refined high permeability grades.

They correspond to Class C22 of IEC 60404-1.

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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* ~~(available at http://www.electropedia.org/)~~

IEC 60050-221, *International Electrotechnical Vocabulary – Chapter 221: Magnetic materials and components* ~~(available at http://www.electropedia.org/)~~

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

IEC 60404-1-1, *Magnetic materials – Part 1-1: Classification – Surface insulations of electrical steel sheet, strip and laminations*

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

IEC 60404-3~~:1992~~, *Magnetic materials – Part 3: Methods of measurement of the magnetic properties of ~~magnetic~~ electrical steel strip and sheet ~~and strip~~ by means of a single sheet tester* ~~IEC 60404-3:1992/AMD1:2002~~

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

IEC 60404-11, *Magnetic materials – Part 11: Method of test for the determination of surface insulation resistance of magnetic sheet and strip*

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

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 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~~

~~Note 1 to entry: See IEC 60404-9.~~

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 rolling direction 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 rolling direction of the product, which characterizes the internal stress of the materials

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

3.5
number of bends
~~number of alternate bends possible before the appearance of the first crack in the base metal visible to the naked eye~~

~~Note 1 to entry: The number of bends constitutes an indication of the ductility of the product.~~

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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 prior to when sudden failure occurs by fracture

[SOURCE: IEC TR 63114:2018, 3.2]

~~**3.4**~~
~~**internal stresses**~~
~~stresses which are characterized by a deviation in relation to the line of cutting~~

4 Classification

The grades covered by this document are classified according to the specified value of maximum specific total loss at a magnetic polarization of 1,7 T and 50 Hz, in watts per kilogram, and according to the nominal thickness of the product[1] (0,20 mm, 0,23 mm, 0,27 mm, 0,30 mm and 0,35 mm).

5 Designation

The steel name comprises the following in the order given:

1) a letter “M” for electrical steel;
2) one hundred times the specified value of maximum specific total loss at 1,7 T and 50 Hz, in watts per kilogram;
3) one hundred times the nominal thickness of the product, in millimeters;
4) the characteristic letter
   - “S” for conventional grades;
   - “P” for high permeability grades;
   - “R” for magnetic domain refined high permeability grades;
5) one tenth of the frequency 50 Hz, i.e. 5.

EXAMPLE ~~M140~~ M120-30S5 for cold-rolled grain-oriented electrical steel strip or sheet of conventional grade with a maximum specific total loss of ~~1,40~~ 1,20 W/kg at 1,7 T and 50 Hz, and a nominal thickness of 0,30 mm, supplied in the fully-processed state.

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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~~ or in bundles in the case of sheets.

The mass of the 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.

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

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

marking of welds or interleaves may be agreed between the manufacturer and the purchaser at the time of enquiry and order.

For coils containing repair 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 are substantially flat and approximately perpendicular to the top face.

6.3 Delivery condition

Cold-rolled grain-oriented electrical steel products are usually supplied with an insulating coating on both sides. This coating generally consists of an EC-5-G coating on an EC-2 coating in accordance with IEC 60404-1-1[2]. Other types of coating exist which are used only when particularly specified.

6.4 Surface condition

The surfaces shall be smooth and clean, free from grease and rust[3]. Dispersed defects such as scratches, blisters, cracks, etc. are only permitted if they are within the limits of the tolerances on thickness and if they are not detrimental to the correct use of the supplied product.

The insulation coating present on the surface of the product shall be sufficiently adherent so that it does not become detached during ~~cutting~~ core manufacturing operations or heat treatment under conditions specified by the ~~supplier~~ manufacturer.

If the product is to be immersed in a fluid, an agreement between the manufacturer and the purchaser, initiated by the purchaser, should be reached to ensure compatibility between the fluid and the coating.

6.5 Suitability for cutting

The product shall be suitable for cutting accurately into the usual shapes at any point when appropriate cutting tools are used.

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7 Technical requirements

7.1 Magnetic properties

7.1.1 General

The properties defined in 7.1.2 and 7.1.3 shall apply to products in the delivery condition defined in 6.3 and to the aged condition defined in 8.3.1.1 and 8.3.1.2.

The Epstein strips shall receive a stress relief heat treatment after cutting under conditions specified by the manufacturer.

~~The single sheet test specimens shall not be heat treated.~~

The test specimen for the single sheet tester (SST) method shall not be heat treated.

7.1.2 Magnetic polarization

The specified minimum values of peak magnetic polarization at the peak magnetic field strength of 800 A/m at 50 Hz or 60 Hz shall be as given in ~~Table 1 and Table 2~~ Tables 1 Table to 3.

~~2 Other types of coating exist which are used only when particularly specified.~~

3 Not to be confused with some coloration of the insulating coating inherent to the manufacturing process.

7.1.3 Specific total loss

The specified values of maximum specific total loss at 50 Hz or 60 Hz shall be as given in ~~Table 1 and Table 2~~ Table 1 Table to 3.

7.1.4 Magnetic properties of magnetic domain refined high permeability grades

The magnetic properties[4] are measured in accordance with the single sheet tester method specified in IEC 60404-3.

In Table 3, the specific total loss at 1,7 T and 50 Hz or 60 Hz is treated on the basis of an equivalent Epstein value obtained by multiplying the SST measurement result at 1,7 T and 50 Hz or at 60 Hz by a conversion factor, F_c, equal to 0,925.

The conversion factor, F_c, for non-specific values, e.g. at 1,5 T, may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

In Table 3, the magnetic polarization at H = 800 A/m is measured in accordance with the SST method without conversion to an equivalent Epstein value.

There are technologies of heatproof magnetic domain refinement which result in samples that withstand the annealing without changing the magnetic properties (i.e. the specific total loss). In that case the Epstein method according to IEC 60404-2 shall be used with annealing the Epstein test specimen. The manufacturer shall inform the purchaser on the application of the Epstein method at the time of enquiry and order.

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4 The specific total loss measured by an SST specified in IEC 60404-3 tends to be higher than the value measured by an Epstein frame specified in IEC 60404-2. The magnetic polarization at H = 800 A/m measured by an SST tends to be a little lower than the value measured by an Epstein frame.

Table 1 – Technological and magnetic properties of the conventional grades of grain-oriented electrical steel strip and sheet (magnetic properties are measured using the Epstein method according to IEC 60404-2)

Steel name	Nominal thickness	Maximum specific total loss at 1,5 T W/kg		Maximum specific total loss at 1,7 T W/kg		Minimum magnetic polarization ~~for~~ at H = 800 A/m [a]	Minimum stacking factor
	mm	at 50 Hz	at 60 Hz	at 50 Hz	at 60 Hz	T	
M110-23S5	0,23	0,73	0,96	1,10	1,45	1,78	0,945
M120-23S5		0,77	1,01	1,20	~~1,57~~ 1,58	1,78	
M110-27S5	0,27	0,77	1,02	1,10	1,48	1,80	0,950
M120-27S5		0,80	1,07	1,20	1,58	1,78	
M130-27S5		0,85	1,12	1,30	~~1,68~~ 1,71	1,78	
M120-30S5	0,30	0,83	1,13	1,20	1,58	1,80	0,955
M130-30S5		0,85	1,15	1,30	1,71	1,78	
M140-30S5		0,92	1,21	1,40	~~1,83~~ 1,84	1,78	
M135-35S5	0,35	0,97	1,29	1,35	1,78	1,80	0,960
M145-35S5		1,03	1,36	1,45	1,91	1,78	
M155-35S5		1,07	1,41	1,55	2,04	1,78	

[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

$J = B - \mu_0 H$

where

J is the magnetic polarization;

B is the magnetic flux density;

μ_0 is the magnetic constant: $4\ \pi \times 10^{-7}$ H·m^{-1};

H is the magnetic field strength.

The difference between B and J at H = 800 A/m is equal to 0,001 T.

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