IEC 60404-8-7

Edition 5.0 2020-09
REDLINE VERSION

INTERNATIONAL STANDARD

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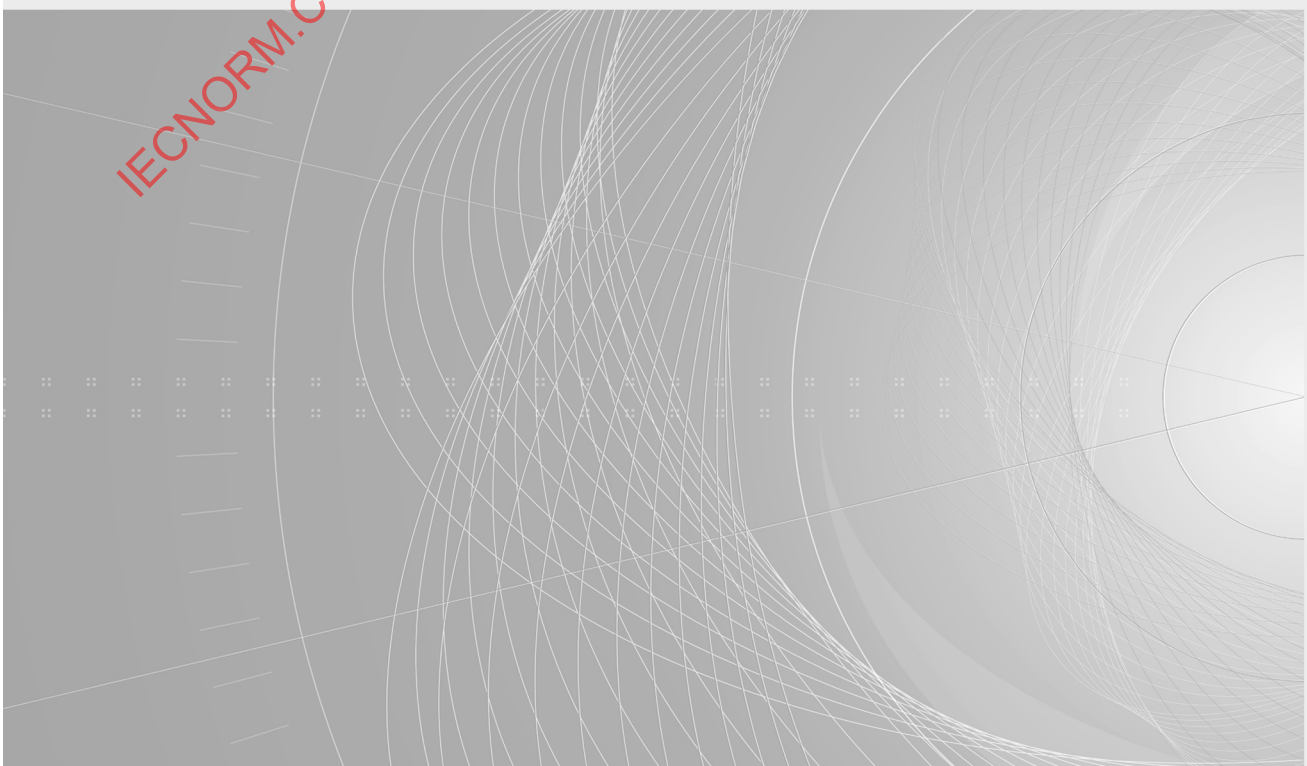
Magnetic materials –
Part 8-7: Specifications for individual materials – Cold-rolled grain-oriented electrical steel strip and sheet delivered in the fully-processed state



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

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.030

ISBN 978-2-8322-8876-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

FOREWORD

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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.

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.

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.~~

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.

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.

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.

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 π x 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.

Table 2 – Technological and magnetic properties of the high permeability 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 1,7 T W/kg		Minimum magnetic polarization for H = 800 A/m [a]	Minimum stacking factor
	mm	50 Hz	60 Hz	T	
M80-23P5 [b]	0,23	0,80	1,05	1,85	0,945
M85-23P5 [b]		0,85	1,12	1,85	
M90-23P5 [b]		0,90	1,19	1,85	
M95-23P5		0,95	1,25	1,85	
M100-23P5		1,00	1,32	1,85	
M90-27P5 [b]	0,27	0,90	1,19	1,85	0,950
M95-27P5 [b]		0,95	1,25	1,85	
M100-27P5		1,00	1,32	1,88	
M110-27P5		1,10	1,45	1,88	
M100-30P5	0,30	1,00	1,30	1,88	0,955
M105-30P5		1,05	1,38	1,88	
M110-30P5		1,10	1,46	1,88	
M115-30P5		1,15	1,52	1,85	
M120-30P5		1,20	1,58	1,85	
M115-35P5	0,35	1,15	1,51	1,88	0,960
M125-35P5		1,25	1,64	1,88	
M135-35P5		1,35	1,77	1,88	

[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: $4\ \pi \times 10^{-7}$ $H \cdot m^{-1}$;

H is the magnetic field strength.

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

[b] This grade may be delivered in the domain refined condition. Domain refined products shall be distinct from non-refined products, see Clause 11 l). The magnetic properties of some domain refined products may deteriorate when the product is subjected to heat treatment.

Steel name	Nominal thickness	Maximum specific total loss at 1,7 T W/kg		Minimum magnetic polarization at H = 800 A/m [a]	Minimum stacking factor
	mm	at 50 Hz	at 60 Hz	T	
M85-23P5	0,23	0,85	1,12	1,88	0,945
M90-23P5		0,90	1,18	1,87	
M95-23P5		0,95	1,25	1,87	
M100-23P5		1,00	1,32	1,85	
M90-27P5	0,27	0,90	1,19	1,88	0,950
M95-27P5		0,95	1,25	1,88	
M100-27P5		1,00	1,32	1,88	
M110-27P5		1,10	1,45	1,88	
M95-30P5	0,30	0,95	1,25	1,88	0,955
M100-30P5		1,00	1,32	1,88	
M105-30P5		1,05	1,38	1,88	
M110-30P5		1,10	1,45	1,88	
M120-30P5		1,20	1,58	1,85	
M115-35P5	0,35	1,15	1,51	1,88	0,960
M125-35P5		1,25	1,64	1,88	
M135-35P5		1,35	1,77	1,88	

[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 π x 10^{-7} $H \cdot m^{-1}$;

H is the magnetic field strength.

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

Table 3 – Technological and magnetic properties of magnetic domain refined high permeability grades of grain-oriented electrical steel strip and sheet (magnetic properties are measured using the Single Sheet Test method* according to IEC 60404-3).

Steel name	Nominal thickness	Maximum specific total loss at 1,7 T* W/kg		Minimum magnetic polarization at H = 800 A/m [a]	Minimum stacking factor
	mm	at 50 Hz	at 60 Hz	T	
M70-20R5	0,20	0,70	0,92	1,85	0,940
M75-20R5		0,75	0,99	1,85	
M75-23R5	0,23	0,75	0,99	1,85	0,945
M80-23R5		0,80	1,05	1,85	
M85-23R5		0,85	1,12	1,85	
M90-23R5		0,90	1,18	1,85	
M85-27R5	0,27	0,85	1,12	1,85	0,950
M90-27R5		0,90	1,18	1,85	
M95-27R5		0,95	1,25	1,85	

[a] It has been common practice for many years to give values of magnetic flux density instead of values of 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.

* The values of the specific total loss are given by the results of the SST measurements multiplied by the conversion factor, Fc, as described in 7.1.4. In the case of heat-proof DR materials, when the Epstein method is to be applied (7.1.4), the listed values are to be considered as the grade limit loss values as measured directly by the Epstein method.

7.2 Geometric characteristics and tolerances

7.2.1 Thickness

The nominal thicknesses of the product are 0,20 mm, 0,23 mm, 0,27 mm, 0,30 mm and 0,35 mm.

For thickness tolerance, a distinction is made between

– the ~~allowable tolerance on~~ deviation from the nominal thickness within the same acceptance unit;

– the difference in thickness in a sheet or in a length of strip in a direction parallel to the direction of rolling;

– the difference in thickness in a direction perpendicular to the direction of rolling. This tolerance applies only to products with a width greater than 150 mm.

At any point, the ~~allowable~~ deviation from the nominal thickness within ~~the same~~ an acceptance unit shall not exceed ~~± 0,030 mm except for the 0,23 mm thickness for which this tolerance shall not exceed ± 0,025 mm~~ the tolerances of Table 4. The additional thickness due to welds with respect to the measured thickness of the ~~steel~~ product shall not exceed 0,050 mm.

The difference in thickness in a sheet or in a length of strip of ~~2~~ 1 m in a direction parallel to the direction of rolling shall not exceed 0,030 mm.

~~In addition,~~ For products with a width greater than 150 mm, the difference in thickness in a direction perpendicular to the direction of rolling shall not exceed 0,020 mm, the measurements being made at least ~~40~~ 20 mm from the edges (see 8.4.3.1). For narrow strips, other agreements may be needed.

Table 4 – Tolerances on nominal thickness

Nominal thickness mm	Tolerance mm
0,20	± 0,020
0,23	± 0,023
0,27	± 0,027
0,30	± 0,030
0,35	± 0,030

7.2.2 Width

The commonly available nominal widths are less than or equal to 1 000 mm.

The product can be supplied either in a width chosen from the specific range of the manufacturer or in the finally used width.

For products supplied in a width chosen from the specific range of the manufacturer, the permitted tolerances shall be $^{+2}_{0}$ mm;

For products supplied in the finally used width, the tolerances of Table 5 shall apply.

Table 5 – Tolerances on nominal width

Nominal width l mm	Tolerance [a] mm
$l \leq 150$	0 - 0,2
$150 < l \leq 400$	0 - 0,3
$400 < l \leq 750$	0 - 0,5
$750 < l \leq 1\,000$ [b]	0 - 0,6
[a] By agreement between the manufacturer and the purchaser at the time of enquiry and order, the tolerances on the nominal width can be all positive tolerances. [b] Nominal widths greater than 1 000 mm may be delivered. In this case, the tolerance should be agreed between the manufacturer and the purchaser at the time of enquiry and order.	

For products supplied with as-rolled edges, tolerances on geometric characteristics shall be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

7.2.3 Length

The tolerance on the length of sheets in relation to the length ordered shall be $^{+0,5}_{0}$ %, but with a maximum of + 6 mm.

7.2.4 Edge wave (wave factor)

~~The verification of the edge wave does not apply to products of width less than or equal to 150 mm. The wave factor (see 8.4.3.4), expressed as a percentage, shall not exceed 1,5 %.~~

The verification of the edge wave applies only to products with a width greater than 150 mm. The wave factor (see 8.4.3.3) shall not exceed 1,5 %.

7.2.5 Residual curvature

~~A requirement concerning residual curvature may be specified by agreement between the manufacturer and the purchaser when ordering products of width greater than 150 mm.~~

~~In this case the distance between the bottom edge of the test piece and the supporting plate shall not exceed 35 mm for sheets and shall be subject to agreement for coils.~~

The verification of residual curvature applies only to products with a width greater than 150 mm.

A requirement concerning residual curvature may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

Two methods for the determination of the residual curvature in the rolling direction of the product are described in IEC 60404-9: a horizontal method and a vertical method. The horizontal method is recommended from the aspect of worker's safety.

- Horizontal method:

  In this method, the maximum distance between the test specimen and a flat surface table, on which the test specimen is placed, shall not exceed 17,5 mm for sheets and shall be subject to agreement for coils.

- Vertical method:

  In this method, the maximum distance between the bottom edge of the test specimen and the supporting plate shall not exceed 35 mm for sheets and shall be subject to agreement for coils.

7.2.6 Edge camber

The verification of edge camber does not apply to products of width less than or equal to 150 mm. The edge camber shall not exceed ~~0,9~~ 0,5 mm for a measuring length of ~~2~~ 1 m.

7.2.7 Burr height

The determination of the burr height applies only to slit coils delivered in the ~~width in which they will~~ finally ~~be~~ used width. The measured burr height shall not exceed 0,025 mm.

7.3 Technological characteristics

7.3.1 Density

The density of cold-rolled grain-oriented electrical steel is not specified.

The conventional value of density used to calculate the magnetic properties and the stacking factor shall be 7,65 kg/dm^3.

7.3.2 Stacking factor

The minimum values shall be as specified in Table 1, Table 2 and Table 3.

7.3.3 Number of bends

The specified minimum number of bends ~~is~~ shall be 1. This value applies to test specimens cut parallel to the direction of rolling.

7.3.4 Deviation from the shearing line (internal stress~~es~~)

The products shall be, as far as possible, free from internal stresses.

The verification of ~~internal stress~~ the deviation from the shearing line is not applicable to a product of width less than 500 mm (slit coil). The measured gap shall not exceed 1 mm (see ~~8.3.3.3~~ 8.4.4.3).

7.3.5 Insulation coating resistance

The insulation coating resistance expressed in Ω·mm² represents the electrical resistance offered to the passage of current through the coating.

The measured insulation coating resistance before or after the possible application of a stress relief heat treatment shall be not less than 500 Ω mm² / side unless otherwise agreed between the manufacturer and the purchaser at the time of enquiry and order.

The stress relief heat treatment, when applied, shall be carried out under conditions specified by the manufacturer.

8 Inspection and testing

8.1 General

The products defined by this document can be ordered with or without specific inspection in accordance with ISO 404. However, as a dispensation from ISO 404, in the case of an order without inspection, the manufacturer shall supply ~~a certificate~~ an inspection document type 3.1 according to ISO 10474 giving the specific total loss of the supplied product.

In the case of an order with specific inspection, the type of inspection document in accordance with ISO 10474 shall be specified when ordering. In this case, the delivery is divided into acceptance units.

Each acceptance unit shall comprise 3,0 t or the remaining fraction thereof of the same grade and the same nominal thickness. Different acceptance units can be adopted by special agreement between the manufacturer and the purchaser at the time of enquiry and order.

For coils of more than 3,0 t, each coil shall constitute an acceptance unit.

Except by special agreement, the same rules apply to the inspection of deviation from the shearing line (internal stress~~es~~), suitability for cutting, ~~surface~~ insulation coating resistance and tolerances ~~of shape and dimensions~~ on geometrical characteristics.

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

8.2 Selection of samples

Test samples shall be taken from each acceptance unit.

The first internal turn and last external turn of the coil shall be considered 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, and outside any welding zones or interleaves.

In the case of sheets, the selection shall be made preferably from the upper part of the bundle.

By choosing a suitable order for the execution of the tests, the same sample shall serve to ~~check~~ verify the various properties.

8.3 Preparation of test specimens

8.3.1 Magnetic properties

8.3.1.1 Epstein frame

For the measurement of magnetic polarization and specific total loss using the 25 cm Epstein frame in accordance with IEC 60404-2, the test specimen shall consist of a minimum of 24 Epstein test strips having the following dimensions:

– length 280 mm to 320 mm, the lengths being equal within ~~a~~ the tolerance of ± 0,5 mm;

– width 30 mm within the tolerance of ± 0,2 mm.

All the test specimens shall be cut parallel to the direction of rolling. The permitted tolerance for the angle between the direction of rolling and the direction of cutting is ± 1°.

As far as possible, the selection of test strips shall be made uniformly across the width of the product. The test strips shall be carefully cut without deformation. Cutting or punching shall be carried out only with well sharpened tools.

Before the measurements, the test ~~strips~~ specimens shall be subjected to a stress relief heat treatment in accordance with the manufacturer's specification.

In the case of measurements of specific total loss on aged test strips, these shall be aged by heating at (225 ± 5) °C for a duration of 24 h and shall be cooled to ambient temperature.

8.3.1.2 Single sheet tester (SST)

~~In the case where~~ For the measurement of magnetic polarization and of specific total loss ~~shall be made~~ using the single sheet tester (SST) method specified in IEC 60404-3 ~~(see 8.4.2 below)~~, the test specimen ~~for the single sheet tester~~ shall consist of one sheet having the following dimensions:

– length from 500 mm to 610 mm;

  The value of 500 mm is recommended;

– width from 300 mm to 500 mm;

  It is recommended to use width values between 450 mm to 500 mm.

All the test specimens shall be cut parallel to the direction of rolling. The permitted tolerance for the angle between the direction of rolling and the direction of cutting is ± 1°.

~~In the case of measurements of specific total loss on aged test pieces, these shall be aged by heating at (225 ± 5) °C for a duration of 24 h and shall be cooled to ambient temperature.~~

As far as possible, the selection of test specimens shall be made uniformly across the width of the product and consist of a number representative of the full width of the strip. The test specimens shall be carefully cut without deformation. Cutting shall be carried out only with well sharpened tools.

The single sheet test specimen shall not be heat treated.

An aging test on single sheet test specimen is not appropriate.

8.3.2 Geometrical characteristics and tolerances

For the measurement of thickness, width, ~~flatness~~ edge wave (wave factor), residual curvature, deviation from the shearing line (internal stress) and edge camber, the test specimen shall consist of a sheet or a ~~2~~ 1 m length of sheet or strip.

For the measurement of the residual curvature of the vertical method, the test specimen shall consist of a sample ($500\ ^{+2,5}_{0}$) mm in length and of width equal to the delivery width of the product.

Tolerance on the length of the test specimen may be agreed between the manufacturer and the purchaser at the time of enquiry and order.

8.3.3 Technological characteristics

8.3.3.1 Stacking factor

The test specimen shall consist of at least 24 strips of the same size; in case of dispute, the test shall be made with 100 strips. ~~They~~ The strips shall have a width of at least 20 mm and a surface area of at least 5 000 mm^2, the tolerance on the width and length of strips being respectively equal to ± 0,2 mm and ± 0,5 mm. The test strips shall be carefully deburred before the test. Epstein strips may be used for this test (see IEC 60404-13).

8.3.3.2 Number of bends

Five test specimens at least 20 mm wide shall be taken from outside the welding zones, parallel to the direction of rolling, with a view to making the bend perpendicular to the direction of rolling. The edge of the product shall not constitute one side of the test specimen.

The test specimens shall be carefully cut without deformation.

~~**8.3.3.3 Internal stresses**~~

~~The test specimen shall consist of a sheet or 1 m length of strip.~~

8.3.3.3 Insulation coating resistance

For products with a width equal to or greater than 600 mm, four strips shall be selected over the whole width of the product. The width of each strip depends on the method to be used, e.g. 50 mm for the test method in accordance with IEC 60404-11.

For products with a width less than 600 mm ~~wide~~, the selection of strips for inspection of insulation coating resistance shall be subject to agreement ~~when ordering~~ between the manufacturer and the purchaser at the time of enquiry and order.

Before the measurements, depending on the agreement (see 7.3.5), the test specimen may need to be ~~heat-treated~~ given a stress relief heat treatment in accordance with the specification of the manufacturer.

8.4 Test methods

8.4.1 General

For each specified property, one test shall be carried out per acceptance unit. Unless otherwise specified, the tests shall be made at a temperature of (23 ± 5) °C.

8.4.2 Magnetic properties

~~The test shall be made using a 25 cm Epstein frame in accordance with IEC 60404-2.~~

~~NOTE As an alternative to the Epstein method, the single sheet tester (SST) described in IEC 60404-3 can be used by agreement between the manufacturer and purchaser at the time of enquiry and order. In this case the specified values to be obtained with the single sheet tester can also be subject to agreement. The relationships between the SST and Epstein test results which are given in Annex C of IEC 60404-3:1992/AMD1:2002 can be used as a guide.~~

~~For the grades of domain-refined products (see Table 2), the test shall be made using the single sheet tester specified in IEC 60404-3, according to the instructions of the manufacturer. The single sheet test specimen is not heat treated.~~

In the cases of conventional grades (see Table 1) and of high permeability grades (see Table 2) the test shall be made using a 25 cm Epstein frame in accordance with IEC 60404-2. As an alternative to the Epstein method, the single sheet tester (SST) method specified in IEC 60404-3 may be used by agreement between the manufacturer and the purchaser at the time of enquiry and order. In this case the specified values to be measured by the SST method may also be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

In the case of magnetic domain refined high permeability grades (see Table 3), the test shall be made using an SST in accordance with IEC 60404-3.

There are technologies of heat proof 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 specified in 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.

8.4.3 Geometrical characteristics and tolerances

8.4.3.1 Thickness

The measurement of thickness shall be made at any point located ~~more than 40~~ at least 20 mm from the edges. For products of a width less than ~~80~~ 40 mm, the measurement of thickness

shall be made along the longitudinal axis (rolling direction) of the ~~sheet or strip~~ product. This measurement shall be made using a micrometer ~~with an accuracy~~ having a resolution of 0,001 mm.

8.4.3.2 Width

The width shall be measured perpendicular to the longitudinal axis (rolling direction) of the product with a calibrated measuring instrument.

8.4.3.3 Edge wave (wave factor)

The wave factor shall be determined in accordance with IEC 60404-9.

8.4.3.4 Residual curvature

~~The residual curvature in the longitudinal direction of the strip shall be determined in accordance with IEC 60404-9.~~

The residual curvature in the longitudinal axis (rolling direction) of the product shall be determined in accordance with IEC 60404-9.

8.4.3.5 Edge camber

The edge camber shall be determined in accordance with IEC 60404-9.

8.4.3.6 Burr height

The burr height shall be determined in accordance with IEC 60404-9.

8.4.4 Technological characteristics

8.4.4.1 Stacking factor

The stacking factor shall be measured in accordance with IEC 60404-13.

8.4.4.2 Number of bends

The test consists of bending the test specimen through 90° alternately to each side of its initial position,according to the method of bending defined by ISO 7799. The radius of bending chosen shall be 5 mm.

A bend of 90° from the initial position with return to the initial position counts as one bend.

The test shall be continued until the number of bends specified in 7.3.3 is reached without an occurrence of cracks. Alternatively, the test shall be stopped on the appearance of the first crack in the base metal visible to the naked eye (any audible crack should also be inspected by the naked eye to confirm base metal failure), or when sudden failure occurs by fracture. The last bend shall not be counted.

NOTE The procedure of the reverse bend test can be found in IEC TR 63114.

8.4.4.3 Deviation from the shearing line (internal stress~~es~~)

~~The internal stresses shall be determined in accordance with IEC 60404-9.~~

The deviation from the shearing line shall be determined in accordance with IEC 60404-9.

8.4.4.4 Insulation coating resistance

~~The test can be carried out by different methods, among which is the method in accordance with IEC 60404-11 on both sides of the product.~~

The insulation coating resistance shall be measured in accordance with IEC 60404-11 on both sides of the product. Other test methods may be used by agreement between the manufacturer and the purchaser at the time of enquiry and order.

8.5 Retests

When a test does not give the specified result, this test shall be repeated on double the number of test specimens from other sheets of the acceptance unit or on other strips from the coils. The

delivery shall be considered to conform to the order if all results of additional tests are in accordance with the requirements of this document.

After re-treatment, the manufacturer has the right to present again for test acceptance units which had not been found to comply with the order.

9 Marking, labelling and packaging

Marking, labelling and packaging of the products may be agreed between the manufacturer and the purchaser at the time of ~~ordering~~ enquiry and order.

10 Complaints

Internal or external defects shall justify a complaint only if they are clearly prejudicial to the method of working or the judicious use of the product.

The purchaser shall give to the manufacturer the opportunity of convincing himself of the fairness of the claim by presenting the product in dispute and evidence for the complaint.

In all cases, the terms and conditions of complaints shall be in accordance with ISO 404.

11 Information to be supplied by the purchaser

For a product to comply adequately with the requirements of this document, the purchaser shall include the following information in his enquiry and order:

a) the quantity;

b) the type of product (strip or sheet);

c) the number of this document (IEC 60404-8-7);

d) the steel name ~~or number~~ (see Clause 5);

e) the dimensions of strips or sheets required (including any limitations on the external diameter of a coil) (see 6.2 and 7.2.2);

f) any limitations on the mass of a coil or a bundle of sheets (see 6.2);

g) any special requirement about residual curvature (see 7.2.~~6~~5);

h) any special requirement about insulation coating resistance (see 7.3.5);

i) any special requirement regarding the thickness measurement and tolerance across the width of narrow strip (see 7.2.1 and 8.4.3.1);

j) the inspection procedure required including the nature of the related documents (see 8.1);

k) any special requirement about the specified values to be measured by the single sheet ~~testing~~ tester (SST) method (see 8.4.2);

l) whether or not the product can be delivered in a magnetic domain refined ~~condition~~ state by any technology (~~see Table 2, footnote b)~~ heatproof or non-heatproof).

Bibliography

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

~~[2] IEC 60404-11, *Magnetic materials – Part 11: Method of test for the determination of surface insulation resistance of magnetic sheet and strip*~~

[1] IEC TR 63114, *Electrical steel – Reverse bend test method of electrical steel strip and sheet*

IEC 60404-8-7

Edition 5.0 2020-09

INTERNATIONAL STANDARD

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

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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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.

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.

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 three classes:

– conventional grades;

– high permeability grades;

– magnetic domain refined high permeability grades.

They correspond to Class C22 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 60404-1-1, *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 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 60404-11, *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*

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 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
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]

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 M120-30S5 for cold-rolled grain-oriented electrical steel strip or sheet of conventional grade with a maximum specific total loss of 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.

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 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 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

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

in accordance with IEC 60404-1-1. 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[2]. 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 core manufacturing operations or heat treatment under conditions specified by the 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.

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 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 Tables 1 to 3.

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, Table 2 and Table 3.

7.1.4 Magnetic properties of magnetic domain refined high permeability grades

The magnetic properties[3] 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.

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

3 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.

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.

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 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	1,58	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	1,71	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	1,84	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.

Table 2 – Technological and magnetic properties of the high permeability 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 1,7 T W/kg		Minimum magnetic polarization at H = 800 A/m [a]	Minimum stacking factor
	mm	at 50 Hz	at 60 Hz	T	
M85-23P5	0,23	0,85	1,12	1,88	0,945
M90-23P5		0,90	1,18	1,87	
M95-23P5		0,95	1,25	1,87	
M100-23P5		1,00	1,32	1,85	
M90-27P5	0,27	0,90	1,19	1,88	0,950
M95-27P5		0,95	1,25	1,88	
M100-27P5		1,00	1,32	1,88	
M110-27P5		1,10	1,45	1,88	
M95-30P5	0,30	0,95	1,25	1,88	0,955
M100-30P5		1,00	1,32	1,88	
M105-30P5		1,05	1,38	1,88	
M110-30P5		1,10	1,45	1,88	
M120-30P5		1,20	1,58	1,85	
M115-35P5	0,35	1,15	1,51	1,88	0,960
M125-35P5		1,25	1,64	1,88	
M135-35P5		1,35	1,77	1,88	

[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: $4\ \pi \times 10^{-7}\ H \cdot m^{-1}$;

H is the magnetic field strength.

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

Table 3 – Technological and magnetic properties of magnetic domain refined high permeability grades of grain-oriented electrical steel strip and sheet (magnetic properties are measured using the Single Sheet Test method* according to IEC 60404-3).

Steel name	Nominal thickness	Maximum specific total loss at 1,7 T* W/kg		Minimum magnetic polarization at H = 800 A/m [a]	Minimum stacking factor
	mm	at 50 Hz	at 60 Hz	T	
M70-20R5	0,20	0,70	0,92	1,85	0,940
M75-20R5		0,75	0,99	1,85	
M75-23R5	0,23	0,75	0,99	1,85	0,945
M80-23R5		0,80	1,05	1,85	
M85-23R5		0,85	1,12	1,85	
M90-23R5		0,90	1,18	1,85	
M85-27R5	0,27	0,85	1,12	1,85	0,950
M90-27R5		0,90	1,18	1,85	
M95-27R5		0,95	1,25	1,85	

[a] It has been common practice for many years to give values of magnetic flux density instead of values of 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.

* The values of the specific total loss are given by the results of the SST measurements multiplied by the conversion factor, Fc, as described in 7.1.4. In the case of heat-proof DR materials, when the Epstein method is to be applied (7.1.4), the listed values are to be considered as the grade limit loss values as measured directly by the Epstein method.

7.2 Geometric characteristics and tolerances

7.2.1 Thickness

The nominal thicknesses of the product are 0,20 mm, 0,23 mm, 0,27 mm, 0,30 mm and 0,35 mm.

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 sheet or in a length of strip in a direction parallel to the direction of rolling;

– the difference in thickness in a direction perpendicular to the direction of rolling. This tolerance applies only to products with a width greater than 150 mm.

At any point, the deviation from the nominal thickness within an acceptance unit shall not exceed the tolerances of Table 4. The additional thickness due to welds with respect to the measured thickness of the product shall not exceed 0,050 mm.

The difference in thickness in a sheet or in a length of strip of 1 m in a direction parallel to the direction of rolling shall not exceed 0,030 mm.

For products with a width greater than 150 mm, the difference in thickness in a direction perpendicular to the direction of rolling shall not exceed 0,020 mm, the measurements being

made at least 20 mm from the edges (see 8.4.3.1). For narrow strips, other agreements may be needed.

Table 4 – Tolerances on nominal thickness

Nominal thickness mm	Tolerance mm
0,20	± 0,020
0,23	± 0,023
0,27	± 0,027
0,30	± 0,030
0,35	± 0,030

7.2.2 Width

The commonly available nominal widths are less than or equal to 1 000 mm.

The product can be supplied either in a width chosen from the specific range of the manufacturer or in the finally used width.

For products supplied in a width chosen from the specific range of the manufacturer, the permitted tolerances shall be $^{+2}_{0}$ mm;

For products supplied in the finally used width, the tolerances of Table 5 shall apply.

Table 5 – Tolerances on nominal width

Nominal width l mm	Tolerance [a] mm
$l \leq 150$	0 - 0,2
$150 < l \leq 400$	0 - 0,3
$400 < l \leq 750$	0 - 0,5
$750 < l \leq 1\,000$ [b]	0 - 0,6

[a] By agreement between the manufacturer and the purchaser at the time of enquiry and order, the tolerances on the nominal width can be all positive tolerances.

[b] Nominal widths greater than 1 000 mm may be delivered. In this case, the tolerance should be agreed between the manufacturer and the purchaser at the time of enquiry and order.

For products supplied with as-rolled edges, tolerances on geometric characteristics shall be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

7.2.3 Length

The tolerance on the length of sheets in relation to the length ordered shall be $^{+0,5}_{0}$ %, but with a maximum of + 6 mm.

7.2.4 Edge wave (wave factor)

The verification of the edge wave applies only to products with a width greater than 150 mm. The wave factor (see 8.4.3.3) shall not exceed 1,5 %.