



INTERNATIONAL STANDARD

**Magnetic materials –
Part 8-8: Specifications for individual materials – Thin electrical steel strip and
sheet for use at medium frequencies**





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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Part 8-8: Specifications for individual materials – Thin electrical steel strip and
sheet for use at medium frequencies**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –**Part 8-8: Specifications for individual materials –
Thin electrical steel strip and sheet for use at medium frequencies**

FOREWORD

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

This second edition cancels and replaces the first edition published in 1991.

This edition constitutes a technical revision.

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

- extension of the range of electrical steels to include the improved grades.

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

CDV	Report on voting
68/546/CDV	68/562/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, 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

MAGNETIC MATERIALS –

Part 8-8: Specifications for individual materials – Thin electrical steel strip and sheet for use at medium frequencies

1 Scope

This part of IEC 60404 defines the grades of thin non-oriented electrical steel strip and sheet in nominal thicknesses of 0,05 mm, 0,10 mm, 0,15 mm, 0,20 mm, 0,25 mm, 0,30 mm and 0,35 mm and of thin grain-oriented electrical steel strip and sheet in nominal thicknesses of 0,05 mm, 0,10 mm, 0,15 mm and 0,18 mm. In particular, it gives general requirements, magnetic properties, geometric characteristics and tolerances, technological characteristics, as well as inspection procedures.

NOTE For thin non-oriented electrical steel strip and sheet, other nominal thicknesses (i.e. 0,12 mm, 0,18 mm, 0,23 mm and 0,27 mm) can be agreed between the manufacturer and the purchaser.

This document applies to electrical steel strip and sheet supplied in the finally annealed condition in coils or sheets and intended for the construction of magnetic circuits predominantly used at frequencies in the range from 100 Hz to 10 kHz.

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 60404-2, *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 magnetic steel sheet and strip*

IEC 60404-10, *Magnetic materials – Part 10: Methods of measurement of magnetic properties of magnetic steel sheet and strip at medium frequencies*

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 and IEC 60050-221 and the following apply.

3.1

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.

3.2

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.

4 Classification

The grades covered by this document are classified according to the maximum value of the specific total loss in watts per kilogram and according to the nominal thickness of the product¹ (0,05 mm, 0,10 mm, 0,15 mm, 0,20 mm, 0,25 mm, 0,30 mm and 0,35 mm for non-oriented electrical steel; 0,05 mm, 0,10 mm, 0,15 mm and 0,18 mm for grain-oriented electrical steel).

5 Designation

The steel name comprises the following in the order given:

a) the characteristic letters:

- NO for non-oriented electrical steel;
- GO for grain-oriented electrical steel;

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

c) the specified value of the maximum specific total loss at 1,0 T and the given frequency for non-oriented electrical steel grades.

EXAMPLE: NO 20-13: non-oriented strip or sheet in nominal thickness of 0,20 mm with a maximum specific total loss of 13 W/kg at 1,0 T and 400 Hz.

6 General requirements

6.1 Production process

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

6.2 Form of supply

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

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

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

The recommended value for the internal diameter of coils is 508 mm; however, another value (e.g. 400 mm) may be agreed for the internal diameter of coils between the manufacturer and the purchaser.

The strip shall be of constant width and wound in such a manner that the edges are superimposed in a regular manner and that the side faces of the coil are substantially flat.

The coils shall be sufficiently tightly wound in order that they do not collapse under their own weight.

The strip may exhibit welds or interleaves resulting from the removal of defective zones, subject to prior agreement between the manufacturer and the purchaser at the time of enquiry and order. The value of the additional thickness due to the weld shall be the subject of an agreement. If necessary, the marking of welds or interleaves may form the subject of a special agreement.

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

Products according to this document are delivered without coating or with a coating on one or both sides. Different types of coating can be provided (see IEC 60404-1-1).

6.4 Surface condition

The surfaces shall be smooth and clean, free from grease and rust². Dispersed defects such as scratches, blisters, cracks, etc. are 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 products.

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

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.

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

7 Technical requirements

7.1 Magnetic properties

7.1.1 Magnetic polarization

The specified minimum values of magnetic polarization for a magnetic field strength of 5 000 A/m (peak value) and at 50 Hz for non-oriented electrical steel shall be as given in Table 1.

Table 1 – Magnetic and technological characteristics of non-oriented electrical steel strip and sheet

Steel name	Nominal thickness mm	Maximum specific total loss at 1,0 T and ^{b,c} W/kg		Minimum magnetic polarization at 50 Hz for 5 000 A/m ^d T	Minimum stacking factor ^a	Minimum number of bends	Conventional density ^e kg/dm ³
		at 400 Hz	at 1 000 Hz				
NO 5-45	0,05	–	45	1,50	0,88	2	7,60
NO 10-13	0,10	13	–	1,55	0,91		
NO 15-11	0,15	11	–	1,55	0,92	2	7,60
NO 15-14		14	–	1,55			
NO 20-13	0,20	13	–	1,58	0,93	2	7,60
NO 20-15		15	–	1,59			
NO 25-14	0,25	14	–	1,59	0,94	2	7,60
NO 25-17		17	–	1,60			
NO 30-16	0,30	16	–	1,59	0,94	2	7,60
NO 30-19		19	–	1,60			
NO 35-19	0,35	19	–	1,60	0,95	2	7,60
NO 35-22		22	–	1,60			7,65

^a Values determined on test specimens without coating. For coated products, the values given in Annex A, Table A.1 apply.

^b For some steel grades in nominal thicknesses of 0,20 mm; 0,30 mm and 0,35 mm values for the optional maximum specific total loss at 1,0 T and 700 Hz are given in Annex B and may be agreed between the manufacturer and the purchaser at the time of enquiry and order.

^c For some steel grades in nominal thicknesses of 0,25 mm and 0,30 mm, values for the optional maximum specific total loss at 1,0 T and 1 000 Hz are given in Annex B and may be agreed between the manufacturer and the purchaser at the time of enquiry and order.

^d The values of minimum magnetic polarization at 50 Hz for 2 500 A/m and 10 000 A/m may be agreed between the manufacturer and the purchaser at the time of enquiry and order (see Annex B).

^e Other values may be agreed between the manufacturer and the purchaser, see Annex C.

The specified minimum values of magnetic polarization for a magnetic field strength of 800 A/m (peak value) and at 50 Hz for grain-oriented electrical steel shall be as given in Table 2.

Table 2 – Magnetic and technological characteristics of grain-oriented electrical steel strip and sheet

Steel name	Nominal thickness mm	Maximum specific total loss W/kg at			Minimum magnetic polarization at 50 Hz for $H = 800 \text{ A/m}^a$ T	Minimum stacking factor	Minimum number of bends
		1,0 T	1,5 T	Frequency Hz			
GO 5	0,05	24	–	1 000	1,60	0,88	1
GO 10	0,10	–	15	400	1,70	0,91	1
GO 15	0,15	–	16	400	1,70	0,92	1
GO 18	0,18	–	17	400	1,80	0,93	1

NOTE The difference between B and J at 800 A/m amounts up to 0,001 T.

^a It has been common practice for many years to give values of magnetic flux density in tables such as the one above. 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;

H is the magnetic field strength;

μ_0 is the magnetic constant.

7.1.2 Specific total loss

The specified values of the maximum specific loss shall be as given in Table 1 and Table 2 and reflect the aged conditions (see 8.3.1).

For grain-oriented electrical steel, they also apply to test specimens that have received, after cutting, a stress relief heat treatment under conditions specified by the manufacturer.

Depending on the nominal thicknesses, the values are specified at 1,0 T for non-oriented electrical steel grades and at 1,0 T or 1,5 T for grain-oriented electrical steel grades and at the frequency specified in Table 1 and Table 2.

7.2 Geometric characteristics and tolerances

7.2.1 Thickness

7.2.1.1 Non-oriented electrical steel products

The nominal thicknesses are 0,05 mm, 0,10 mm, 0,15 mm, 0,20 mm, 0,25 mm, 0,30 mm and 0,35 mm.

For thickness tolerance, a distinction is made between:

- allowable tolerance on the nominal thickness within the same acceptance unit;
- difference in thickness in a sheet or in a length of strip in a direction parallel to the direction of rolling;
- difference in thickness in a direction perpendicular to the direction of rolling. This tolerance applies only to materials with a width greater than 25 mm.

At any point the allowable tolerance on the nominal thickness within the same acceptance unit shall not exceed the values given in Table 3. The additional thickness due to welds, with respect to the measured thickness of the steel strip shall not exceed 0,050 mm.

The difference in thickness in a length of strip (see 8.3.2) in a direction parallel to the direction of rolling shall not exceed 10 % for nominal thicknesses of 0,05 mm, 0,10 mm, 0,15 mm, 0,20 mm, 0,25 mm and 8 % for nominal thicknesses of 0,30 mm and 0,35 mm.

The difference in thickness in a direction perpendicular to the direction of rolling shall not exceed the values given in Table 3.

7.2.1.2 Grain-oriented electrical steel products

The nominal thicknesses are 0,05 mm, 0,10 mm, 0,15 mm and 0,18 mm.

For thickness tolerance, a distinction is made between:

- the allowable tolerance on nominal thickness within the same acceptance unit;
- the difference in thickness 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 material with a width greater than 150 mm, the measurement being made at least 40 mm from the edges.

At any point, the allowable tolerance on the nominal thickness within the same acceptance unit shall not exceed the values given in Table 3.

The difference in thickness in a length of strip (see 8.3.2) in a direction parallel to the direction of rolling shall not exceed 0,020 mm.

The difference in thickness in a direction perpendicular to the direction of rolling shall not exceed the values given in Table 3.

Table 3 – Thickness tolerances

Nominal thickness mm	Permitted variation on the nominal thickness within the same acceptance unit mm		Maximum difference in thickness in a direction perpendicular to the direction of rolling mm	
	Non-oriented electrical steel products	Grain-oriented electrical steel products	Non-oriented electrical steel products	Grain-oriented electrical steel products
0,05	+ 0,010 – 0,005	+ 0,010 – 0,005	0,008	0,008
0,10	± 0,010	± 0,010	0,010	0,010
0,15	± 0,015	± 0,015	0,020	0,020
0,18	–	± 0,025	–	0,020
0,20	± 0,020	–	0,020	–
0,25	± 0,025	–	0,020	–
0,30	± 0,030	–	0,020	–
0,35	± 0,030	–	0,020	–

7.2.2 Width

7.2.2.1 Non-oriented electrical steel products

The tolerances given in Table 4 shall apply.

Table 4 – Width tolerance of non-oriented strip and sheet

Nominal width <i>l</i> mm	Tolerance ^a mm
$l \leq 150$	+ 0,4 0
$150 < l \leq 500$	+ 0,6 0
$500 < l \leq 1\,250$	+ 1,5 0
NOTE By agreement between the manufacturer and the purchaser at the time of enquiry and order, the tolerances on the nominal width can be all minus values.	
^a For nominal width greater than 1 250 mm, the tolerances shall be agreed between the manufacturer and the purchaser at time of enquiry and order.	

7.2.2.2 Grain-oriented electrical steel products

The tolerances given in Table 5 shall apply.

Table 5 – Width tolerance of grain oriented electrical steel products

Nominal width <i>l</i> mm	Tolerance ^a mm
$l \leq 150$	0 – 0,2
$150 < l \leq 400$	0 – 0,3
$400 < l \leq 750$	0 – 0,5
$l > 750$	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.	

7.2.3 Edge camber

The verification of edge camber applies only to non-oriented electrical steel in nominal thicknesses of 0,20 mm, 0,25 mm, 0,30 mm and 0,35 mm and width greater than 150 mm. The edge camber shall not exceed 1 mm over the measuring length of 1 m.

7.2.4 Residual curvature

A requirement concerning the residual curvature may be specified by agreement between the manufacturer and the purchaser at the time of enquiry and order for products of width greater than 150 mm.

7.2.5 Burr height

The measured burr height shall not exceed 0,025 mm for grain-oriented electrical steel products and 0,03 mm for non-oriented electrical steel products in nominal thicknesses of 0,20 mm, 0,25 mm, 0,30 mm and 0,35 mm.

7.3 Technological characteristics

7.3.1 Density

The density of the electrical steel is not specified.

The conventional value of density serving as a basis for the calculation of magnetic properties and the stacking factor is given in Table 2 for non-oriented electrical steel. For grain-oriented electrical steel, the density shall be 7,65 kg/dm³.

7.3.2 Stacking factor

The specified minimum values for products without coating shall be as given in Table 1 and Table 2.

For coated non-oriented electrical steel products, informative values of the stacking factor are given in Table A.1.

7.3.3 Number of bends

7.3.3.1 General

The specified minimum number of bends shall be as given in Table 1 and Table 2.

7.3.3.2 Non-oriented electrical steel products

The value applies to test specimens cut perpendicular to the direction of rolling.

7.3.3.3 Grain-oriented electrical steel products

The value applies to test specimens cut parallel to the direction of rolling.

7.3.4 Insulation coating resistance

The value of the insulation coating resistance may be agreed between the manufacturer and the purchaser at time of enquiry and order.

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 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:

- 10 t for non-oriented electrical steel products in nominal thicknesses of 0,20 mm and greater;
- 3 t for grain-oriented electrical steel products in nominal thickness of 0,18 mm;
- 1 t for other products;

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 the values given above, each coil shall constitute an acceptance unit.

Except by special agreement, the same rules apply to the inspection of the verified characteristics.

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

8.2 Selection of samples

Test samples for the acceptance inspection shall be taken from each acceptance unit. The first internal turn and last external turn of the coils 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. The selection shall be made away from weld zones or interleaves.

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

8.3 Preparation of test specimens

8.3.1 Magnetic properties

For the measurement of magnetic polarization and specific total loss using the 25 cm Epstein frame, 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 tolerance of $\pm 0,5$ mm;
- width 30 mm $\pm 0,2$ mm.

The number of Epstein strips for the magnetic measurements shall fulfil the requirements of IEC 60404-2 and IEC 60404-10 as appropriate.

For non-oriented electrical steel products, half the test strips shall be cut parallel to the direction of rolling and the other half perpendicular giving an even distribution across the width of the product.

For grain-oriented electrical steel products, all the test strips shall be cut parallel to the direction of rolling. 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.

The allowable tolerance for the angle between the direction of rolling and the direction of cutting is:

- $\pm 5^\circ$ for non-oriented electrical steel products;

- $\pm 1^\circ$ for grain-oriented electrical steel products.

For grain-oriented electrical steel products, before the measurements, the test pieces shall be subject to the stress relief heat treatment as defined in 7.1.2. For measuring of the specific total loss on aged pieces, these shall be heated at $(225 \pm 5)^\circ\text{C}$ for 24 h and shall be cooled to ambient temperature before testing.

For non-oriented electrical steel products, no further heat treatments such as stress relief annealing of the test specimen are allowed.

8.3.2 Geometrical characteristics and tolerances

For the measurement of thickness, width, residual curvature and edge camber, the test specimen shall consist of a 1 m length of strip. However, for the measurement of residual curvature, a test specimen of 500 mm long may alternatively be used.

8.3.3 Technological characteristics

8.3.3.1 Stacking factor

The test specimen shall consist of strips of the same size, their number being the same as for the determination of the magnetic properties (see 8.3.1). The strips shall be at least 20 mm wide, with a surface area of at least 5 000 mm², the tolerance on the width and length of strip being respectively equal to $\pm 0,2$ mm and $\pm 0,5$ mm. The test strips shall be carefully deburred before the test.

8.3.3.2 Number of bends

8.3.3.2.1 General

The test specimens shall be carefully cut without deformation.

8.3.3.2.2 Non-oriented electrical steel products

Two test specimens at least 20 mm wide shall be cut perpendicular to the direction of rolling, at a distance of at least 40 mm from the edge and from the middle and outside any weld zones.

If the width of the product is not great enough for transverse test specimens of the prescribed length to be taken, the test specimens shall be taken in the direction of rolling. In this case, the values in Table 2 also apply.

8.3.3.2.3 Grain-oriented electrical steel products

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.

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 $(23 \pm 5)^\circ\text{C}$.

8.4.2 Magnetic properties

The test shall be made using a 25 cm Epstein frame in accordance with IEC 60404-2 or IEC 60404-10, as appropriate.

8.4.3 Geometrical characteristics and tolerances

8.4.3.1 Thickness

8.4.3.1.1 Non-oriented electrical steel products

For the thickness variation perpendicular to the rolling direction, two thickness measurements shall be made as follows:

- for products of width over 100 mm (inclusive), at any point located more than 30 mm from the edges;
- for products of width less than 100 mm, the measurement of thickness shall be made at any point located more than 10 mm from the edges.

For products of width less than or equal to 25 mm, the measurement shall be made only in the longitudinal axis of the product.

This measurement shall be made by using a micrometre with an accuracy of 0,001 mm.

8.4.3.1.2 Grain oriented electrical steel products

The measurement of thickness shall be made at any point located more than 40 mm from the edges.

For products of a width less than 80 mm, the measurement of thickness shall be made along the longitudinal axis of the product.

This measurement shall be made using a micrometre with an accuracy of 0,001 mm.

8.4.3.2 Width

The width shall be measured perpendicular to the longitudinal axis of the product.

8.4.3.3 Residual curvature

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

8.4.3.4 Edge camber

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

8.4.3.5 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, following 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 stopped on the appearance in the base metal of the first crack visible to the naked eye. The last bend shall not be counted.

The test may be stopped when the number of bends is greater than a value agreed 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 lengths of strip or sheets of the acceptance unit. The delivery shall be considered to conform to the order if all the results of the 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 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 standard, 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 standard (IEC 60404-8-8);
- 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);
- f) any limitations on the mass of coils or bundles of sheets (see 6.2);
- g) any special requirement about residual curvature (see 7.2.4);
- h) the inspection procedure required including the nature of the related documents (see 8.1).

Annex A (informative)

Optional stacking factor for non-oriented coated products

It is common to use the cold-rolled non-oriented electrical steel products in the fully processed state, described in this standard, in stacked assemblies for electrical machine construction. In order to minimise the machine loss, it is appropriate to apply an insulating coating to these electrical steels. The presence of such a coating alters the stacking factor data given in Table 1.

The measurement of the stacking factor described in IEC 60404-13 will lead to a lower value in presence of a coating. Table A.1 describes the stacking factor values for common electrical steel coating thicknesses (when measured according to ISO 2178). For thicker coatings or specific coating conditions such as single sided application, other values and coating thickness measuring methods can be agreed between the manufacturer and purchaser at the time of enquiry and order. For the specific case of bonding varnishes, Table A.1 is not valid.

**Table A.1 – Optional stacking factor for
non-oriented coated products**

Coating thickness ^a <i>t</i> μm	Nominal thickness mm	Minimum stacking factor
$t \leq 2$	0,05	–
	0,10	0,90
	0,15	0,91
	0,20	0,92
	0,25	0,93
	0,30	0,93
	0,35	0,93
$2 < t \leq 4$	0,05	–
	0,10	0,89
	0,15	0,90
	0,20	0,91
	0,25	0,92
	0,30	0,92
	0,35	0,92
$4 < t \leq 8$	0,05	–
	0,10	0,88
	0,15	0,89
	0,20	0,90
	0,25	0,91
	0,30	0,91
	0,35	0,91

^a This table gives the coating thickness on each side of the electrical steel product.

Annex B (informative)

Optional magnetic specifications

The values of the optional magnetic specifications that can be agreed between the manufacturer and the purchaser at the time of enquiry and order are given in Table B.1.

Table B.1 – Optional magnetic specifications for non-oriented electrical steel strip and sheet

Steel name ^a	Nominal thickness mm	Maximum specific total loss W/kg		Minimum magnetic polarization at 50 Hz T	
		at 1,0 T and 700 Hz	at 1,0 T and 1 000 Hz	for 2 500 A/m	for 10 000 A/m
NO 10-10	0,10	-	-	-	-
NO 10-13		-	38	-	-
NO 15-11	0,15	-	-	-	-
NO 15-14		-	43	-	-
NO 20-13	0,20	29	-	1,47	1,68
NO 20-15		32	51	1,48	1,69
NO 25-14	0,25	34	-	1,48	1,69
NO 25-17		40	62	1,49	1,70
NO 30-16	0,30	41	-	1,48	1,69
NO 30-19		45	73	1,49	1,70
NO 35-19	0,35	48	-	1,49	1,70
NO 35-22		54	-	1,49	1,70

^a Steel names in accordance with Table 2.

Annex C (informative)

Calculation of density values

The following formula, which is in accordance with ASTM A34/A34M-06, may be used to calculate the density values on agreement between the manufacturer and the purchaser at the time of enquiry and order (see Table 1, footnote e):

$$\rho = [7,865 - 0,065(c_{\text{Si}} + 1,7c_{\text{Al}})] \quad (\text{C.1})$$

where

ρ is the numerical value of the density, in kg/dm³;

c_{Si} is the numerical value of the mass fraction of silicon, in %;

c_{Al} is the numerical value of the mass fraction of aluminium, in %.

Bibliography

- [1] IEC 60404-1-1, *Magnetic materials – Part 1-1: Classification – Surface insulations of electrical steel sheet, strip and laminations*
 - [2] IEC 60404-8-7, *Magnetic materials – Part 8-7: Specifications for individual materials - Cold-rolled grain-oriented electrical steel strip and sheet delivered in the fully-processed state*
 - [3] ISO 2178, *Non-magnetic coatings on magnetic substrates – Measurement of coating thickness – Magnetic method*
 - [4] ASTM A34/A34M-06, *Standard Practice for Sampling and Procurement Testing of Magnetic Materials*
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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch