

INTERNATIONAL STANDARD



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



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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –

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

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60404-8-4:2013. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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

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

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

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

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

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

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

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

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

A list of all parts in the IEC 60404 series, published under the general title *Magnetic materials*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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INTRODUCTION

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

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

MAGNETIC MATERIALS –

Part 8-4: Specifications for individual materials – Cold-rolled non-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 non-oriented electrical steel strip and sheet in nominal thicknesses of 0,35 mm, 0,47 mm, 0,50 mm, 0,65 mm and 1,00 mm. In particular, it ~~specifies~~ gives general requirements, magnetic properties, geometric characteristics, tolerances and technological characteristics, as well as inspection procedure. The nominal thickness 0,47 mm applies to the grades for use at 60 Hz only.

~~This standard gives in Table 2 the magnetic properties of cold-rolled non-oriented electrical steel strip and sheet of nominal thickness 0,47 mm for use at 60 Hz only.~~

~~This standard applies to materials supplied in the fully annealed condition intended for the construction of magnetic circuits. It does not apply to semi-processed material.~~

~~These magnetic materials correspond to class C.21 of IEC 60404-1.~~

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

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

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60050 (all parts), International Electrotechnical Vocabulary (available at <<http://www.electropedia.org>>)~~

IEC 60050-121, *International Electrotechnical Vocabulary – Part 121: Electromagnetism*

IEC 60050-221, *International Electrotechnical Vocabulary – Chapter 221: Magnetic materials and components*

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

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

IEC 60404-13, *Magnetic materials – Part 13: Methods of measurement of ~~density~~, 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 ~~relating to magnetic properties~~ given in IEC 60050-121, IEC 60050-221 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

edge wave

wave factor

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

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

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

3.2

residual curvature

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

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

3.3

edge camber

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

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

~~3.2~~

~~**flatness**~~

~~property of a sheet or a length of strip which is characterized by the wave factor, i.e. by the relation of the height of the wave to its length~~

3.4

deviation from the shearing line

internal stress

~~deviation from the shearing line due to internal stresses~~

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

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

3.5

number of bends

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

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

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

[SOURCE: IEC TR 63114:2018, 3.2]

4 Classification

The grades covered by this document are classified according to the specified value of maximum specific total loss ~~in watts per kilogram at 1,5 T~~ and according to the nominal thickness of ~~the material (0,35 mm, 0,47 mm, 0,50 mm, 0,65 mm and 1,00 mm)~~ the product¹. The products of the nominal thicknesses 0,35 mm, 0,50 mm, 0,65 mm and 1,00 mm are classified according to the specified values tested at a magnetic polarization of 1,5 T and 50 Hz, in watts per kilogram. The product of the nominal thickness 0,47 mm is classified according to the specified value tested at a magnetic polarization of 1,5 T and 60 Hz, in watts per kilogram.

5 Designation

The steel name comprises the following in the order given:

- a) a letter “M” for electrical steel;
- b) one hundred times the specified value of maximum specific total loss at a magnetic polarization of 1,5 T and 50 Hz, in watts per kilogram, ~~at 1,5 T and 50 Hz for the materials given in Table 1 and at 1,5 T and 60 Hz for the materials given in Table 2 and corresponding to the nominal product thickness~~ for the products of the nominal thicknesses 0,35 mm, 0,50 mm, 0,65 mm and 1,00 mm, or at a magnetic polarization of 1,5 T and 60 Hz, in watts per kilogram, for the products of the nominal thickness 0,47 mm;
- c) one hundred times the nominal thickness of the ~~material~~ product, in millimeters;
- d) the characteristic letter “A” for the grades of cold-rolled non-oriented electrical steel strip or sheet supplied in the fully-processed state;
- e) one tenth of the frequency at which the maximum specific total loss is specified, i.e. 5 or 6.

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

~~NOTE The corresponding steel numbers used in the European standard are given in Annex B.~~

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

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

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

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

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

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

Strip ~~can occasionally~~ may exhibit welds or interleaves resulting from the removal of defective zones, ~~subject to prior agreement~~ if agreed between the ~~parties~~ 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 ~~ordering~~ enquiry and order.

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

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

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

6.3 Delivery condition

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

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

6.4 Surface condition

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

~~When an insulation coating is present on the surface of the material, it~~ For products supplied with insulation coating, the coating shall be sufficiently adherent so that it does not become detached during ~~cutting~~ manufacturing operations. During the ~~alternating~~ reverse bend test (see 8.4.4.2), the coating shall not become detached after a bend of 90°. If the coating becomes

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

detached during the test, the ~~piece~~ sample of the product from which the ~~sample~~ test specimen was taken shall be subjected to a shearing test. ~~During this test, it shall not be admissible for large pieces of the coating to become detached.~~ By shearing the sample with well sharpened tools, a detachment of large pieces of the coating shall not be admissible. However, some slight chipping of the coating at the sheared edges shall be tolerated.

6.5 Suitability for cutting

The ~~material~~ product shall be able to be cut or punched without causing premature wear of tools; ~~it shall be able to be cut at any point and into the usual shapes, thus ensuring accurate working with the correct cutting tools. If there are special requirements with regard to a suitability test for cutting or punching, these shall be established by agreement between the manufacturer and the purchaser.~~ The product shall be suitable for cutting or punching accurately into the usual shapes at any point when appropriate cutting or punching tools and technologies are used.

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

7 Technical requirements

7.1 Magnetic properties

7.1.1 General

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

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

7.1.2 Magnetic polarization

~~The minimum specified values of magnetic polarization for magnetic field strengths H of 2 500 A/m, 5 000 A/m and 10 000 A/m (expressed as a peak value) shall be as given in Table 1.~~

~~The magnetic polarization shall be determined in an alternating magnetic field at 50 Hz or 60 Hz.~~

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

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

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

Steel name	Nominal thickness	Maximum specific total loss at 1,5 T W/kg		Minimum magnetic polarization ^a in an alternating magnetic field for at an AC magnetic field strength T				Maximum anisotropy of loss	Minimum stacking factor	Minimum number of bends	Conventional density ^c kg/dm ³
		at 50 Hz	at 60 Hz ^b	2 500 A/m	5 000 A/m	10 000 A/m					
M310-65A5	0,65	3,10	4,08	1,49	1,60	1,70	±15	0,97	2	7,60	
M330-65A5		3,30	4,30	1,49	1,60	1,70	±15		2	7,60	
M350-65A5		3,50	4,57	1,49	1,60	1,70	±14		2	7,60	
M400-65A5		4,00	5,20	1,52	1,62	1,72	±14		2	7,65	
M470-65A5		4,70	6,13	1,53	1,63	1,73	±12		5	7,65	
M530-65A5		5,30	6,84	1,54	1,64	1,74	±12		5	7,70	
M600-65A5		6,00	7,71	1,56	1,66	1,76	±10		10	7,75	
M700-65A5		7,00	8,98	1,57	1,67	1,76	±10		10	7,75	
M800-65A5		8,00	10,26	1,60	1,70	1,78	±10		10	7,80	
M1000-65A5		10,00	12,77	1,61	1,71	1,80	±10		10	7,80	
M600-100A5	1,00	6,00	8,14	1,53	1,63	1,72	±10	0,98	2	7,60	
M700-100A5		7,00	9,38	1,54	1,64	1,73	±8		3	7,65	
M800-100A5		8,00	10,70	1,56	1,66	1,75	±6		5	7,70	
M1000-100A5		10,00	13,39	1,58	1,68	1,76	±6		10	7,80	
M1300-100A5		13,00	17,34	1,60	1,70	1,78	±6		10	7,80	
^a It has been common practice for many years to give values of magnetic flux density. In fact, the Epstein frame is used to determine magnetic polarization (intrinsic flux density) which is defined as follows in accordance with IEC 60050-121: 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. $J = B - \mu_0 H$											
^b Only for information.											
^c Other values may be agreed between the manufacturer and the purchaser at the time of enquiry and order, see Annex B.											

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

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

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

$$J = B - \mu_0 H$$

where

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

^b Only for information.

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

7.1.3 Specific total loss

~~The specified values of maximum specific total loss at 50 Hz shall be as given in Table 1. They apply:~~

- ~~— for the nominal thicknesses 0,35 mm, 0,50 mm and 0,65 mm to aged or non-aged test pieces (see 8.3.1);~~
- ~~— for the nominal thickness 1,00 mm to non-aged test pieces.~~

~~Table 2 gives the specified values of maximum specific total loss at 60 Hz for products of 0,47 mm nominal thickness.~~

~~In certain cases, the specified value of maximum specific total loss can be made the subject of agreement for longitudinal test pieces only or for transverse test pieces only.~~

~~The values of the specific total loss are specified for a magnetic polarization of 1,5 T.~~

~~The test shall be made in an alternating magnetic field at 50 Hz or at 60 Hz.~~

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

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

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

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

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

7.1.4 Anisotropy of loss

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

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

7.2 Geometrical characteristics and tolerances

7.2.1 Thickness

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

The nominal thickness 0,47 mm applies only to the grades for use at 60 Hz only ~~is also given in Table 2.~~

For thickness tolerance, a distinction is made between

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

~~The allowable tolerance on the nominal thickness within the same acceptance unit shall be $\pm 8\%$ of the nominal value for the nominal thicknesses 0,35 mm, 0,47 mm and 0,50 mm, and $\pm 6\%$ of the nominal value for the nominal thicknesses 0,65 mm and 1,00 mm. The additional thickness due to welds, with respect to the measured thickness of the steel strip or sheet, shall not exceed 0,10 mm.~~

~~The difference in thickness in a sheet or in a length of strip (see 8.3.2) in a direction parallel to the direction of rolling shall not exceed 8 % for nominal thicknesses 0,35 mm, 0,47 mm and 0,50 mm, and 6 % for nominal thicknesses 0,65 mm and 1,00 mm.~~

~~The difference in thickness in a direction perpendicular to the direction of rolling shall not exceed 0,020 mm for nominal thicknesses of 0,35 mm, 0,47 mm and 0,50 mm, and 0,030 mm for the nominal thicknesses of 0,65 mm and 1,00 mm, the measurements being made at least 30 mm from the edges (see 8.4.3.1). These tolerances apply only to materials with a width greater than 150 mm. For narrow strips, other agreements may be reached.~~

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

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

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

- 0,030 mm, 0,038 mm and 0,040 mm for products of the nominal thicknesses 0,35 mm, 0,47 mm and 0,50 mm respectively;
- 0,045 mm and 0,060 mm for products of the nominal thicknesses 0,65 mm and 1,00 mm respectively.

Table 3 – Tolerances on nominal thickness

Nominal thickness mm	Tolerance mm
0,35	$\pm 0,030$
0,47	$\pm 0,038$
0,50	$\pm 0,040$
0,65	$\pm 0,045$
1,00	$\pm 0,060$

For products supplied 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 for products of the nominal thicknesses 0,35 mm, 0,47 mm and 0,50 mm;
- 0,030 mm for products of the nominal thicknesses 0,65 mm and 1,00 mm.

The measurements shall be made at any point located at least 20 mm from the edges (see 8.4.3.1). For narrow strips, other agreements may be needed.

7.2.2 Width

The commonly available nominal widths are less than or equal to 1 250 mm.

For the tolerances on width, a distinction is made between ~~material~~ products supplied with slit edges ~~in the as-rolled condition and material delivered with trimmed edges~~ and products supplied with as-rolled edges.

For ~~materials~~ products supplied with ~~trimmed~~ slit edges, the tolerances of Table 4 shall apply.

Table 4 – Tolerances on nominal width

Nominal width l mm	Tolerance ^a mm
$l \leq 150$	+0,2 0
$150 < l \leq 300$	+0,3 0
$300 < l \leq 600$	+0,5 0
$600 < l \leq 1\,000$	+1,0 0
$1\,000 < l \leq 1\,250$ ^b	+1,5 0
^a By agreement when ordering between the manufacturer and the purchaser at the time of enquiry and order, the tolerances on nominal width can be all minus values tolerances. ^b Nominal widths greater than 1 250 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 ~~materials~~ products supplied with as-rolled edges, the tolerances on ~~nominal width should~~ geometric characteristics shall be subject to agreement ~~when ordering~~ between the manufacturer and the purchaser at the time of enquiry and order.

7.2.3 Length

The verification of length does not apply to the products supplied in coils.

For products supplied in sheets, 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 edge wave applies only to products supplied with a width greater than 100 mm. The wave factor (see 8.4.3.3), shall not exceed 2 %.

~~7.2.5 Flatness (wave factor)~~

~~The verification of flatness does not apply to material of width less than or equal to 100 mm. The wave factor (see 8.4.3.4), expressed as a percentage, shall not exceed 2.~~

7.2.5 Residual curvature

The verification of residual curvature ~~does not apply to material of width less than or equal to~~ applies only to products supplied with a width greater than 100 mm.

~~A requirement concerning residual curvature can be specified by agreement when ordering; in this case, the distance between the bottom edge of the test specimen and the supporting plate shall not exceed 35 mm for the products of nominal thicknesses 0,35 mm, 0,47 mm, 0,50 mm and 0,65 mm. For the nominal thickness 1,00 mm, this distance shall be subject to an agreement between the manufacturer and the purchaser.~~

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 direction of rolling 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 and consistency with ISO standards.

- 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 products of the nominal thicknesses 0,35 mm, 0,47 mm, 0,50 mm and 0,65 mm. A different maximum distance may be agreed by the manufacturer and the purchaser at the time of enquiry and order. For products of the nominal thickness 1,00 mm, this distance shall be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

- 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 products of the nominal thicknesses 0,35 mm, 0,47 mm, 0,50 mm and 0,65 mm. For products of the nominal thickness 1,00 mm, this distance shall be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

NOTE The horizontal and vertical methods, with the limits 17,5 mm and 35 mm respectively, are not exactly interchangeable. Which method to use can be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

7.2.6 Edge camber

The verification of edge camber applies only to ~~material~~ products supplied with ~~trimmed~~ slit edges and a width greater than 30 mm.

The edge camber shall not exceed for a measuring length of ~~2~~ 1 m:

- ~~2,0~~ 1,0 mm for the nominal width l , $l > 150$ mm;
- ~~4,0~~ 2,0 mm for the nominal width l , $30 \text{ mm} < l \leq 150$ mm.

7.3 Technological characteristics

7.3.1 Density

The density of the ~~material~~ products is not specified.

The conventional values of density ~~of the material are~~ used to calculate the magnetic properties and the stacking factor shall be as given in Table 1 and Table 2. ~~They shall be used to calculate the magnetic properties and the stacking factor, unless otherwise agreed (see Tables 1 and 2, footnote c).~~ Other values may be agreed between the manufacturer and the purchaser at the time of enquiry and order (see Annex B).

7.3.2 Stacking factor

~~The minimum values shall be as specified in Tables 1 and 2, and only apply to non-insulated material.~~

The specified values of minimum stacking factor shall be as given in Table 1 and Table 2, and only apply to products supplied without insulation coating. The values of products supplied with insulation coating are subject to agreement between the manufacture and the purchaser at the time of enquiry and order.

7.3.3 Number of bends

The specified minimum number of bends shall be as ~~specified~~ given in Table 1 and Table 2. The values apply to test specimens cut perpendicular to the direction of rolling.

7.3.4 Deviation from the shearing line (internal stress)

The ~~material~~ products shall be, as far as possible, free from internal stress.

~~The verification of internal stresses does not apply to materials of width less than or equal to 150 mm. The measured gap shall not exceed 2 mm (see 8.3.3.3).~~

The verification of the deviation from the shearing line applies only to products supplied with a width greater than 150 mm. The measured gap shall not exceed 1 mm for a measuring length of 1 m.

8 Inspection and testing

8.1 General

The ~~material~~ 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 ~~specific~~ 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 ~~material~~ 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 20 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 20 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), suitability for cutting, adherence of ~~surface~~ insulation coating and tolerances on ~~shape and dimensions~~ geometrical characteristics.

When the products are delivered in the form of slit coils, the test results ~~applying~~ made 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.

In the case of coils, the first internal turn and the last external turn of the coil shall be considered as wrapping and not representative of the quality of the rest of the coil. The selection shall be made from the first external or internal 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 verify 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 in accordance with IEC 60404-2, the test specimen shall consist of a minimum of 16 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 within a tolerance of $\pm 0,2$ mm.

Half the test strips shall be cut parallel to the direction of rolling and the other half of the test strips shall be cut perpendicular to the direction of rolling, giving an even distribution across the width of the material. The test strips shall be carefully cut without deformation. Cutting or punching shall be carried out only with well-sharpened tools. The maximum tolerance between the direction of cutting in relation to the specified direction shall be $\pm 5^\circ$. The permitted tolerance for the angle between the specified direction and the direction of cutting or punching is $\pm 5^\circ$.

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. The cutting or punching shall be carried out only with well-sharpened tools.

If the width of the material product is insufficient for a sampling of test strips of the prescribed length to be taken across the width, the test strips shall be taken in cut parallel to the direction of rolling only.

In the case of measurements of specific total loss on aged test pieces strips, these the Epstein test strips shall be heated aged by heating at $(225 \pm 5)^\circ\text{C}$ for a duration of 24 h and shall be cooled to ambient temperature of $(23 \pm 5)^\circ\text{C}$. Other ageing treatment conditions can also may be used by agreement between the manufacturer and the purchaser at the time of enquiry and order.

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 1 m length of strip or sheet.

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

The 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 16 strips of the same size; in case of dispute, the test shall be made with 100 strips. The strips shall have a width of at least 20 mm and a surface area of at least 5 000 mm². The widths and lengths of the strips ~~being~~ shall be equal within the tolerances of $\pm 0,2$ mm, ~~as well as their lengths~~ and $\pm 0,5$ mm respectively. The test strips shall be carefully deburred before the test.

Epstein test strips may be used for this test (see IEC 60404-2 and IEC 60404-13).

8.3.3.2 Number of bends

Two test specimens at least 20 mm wide shall be ~~cut~~ taken from outside of the welding zones, perpendicular to the direction of rolling ~~of the sheet~~, at a distance of at least 40 mm from the edge and ~~from~~ at the middle of the width, ~~and outside any welding zones~~. The result of reverse bend test shall be the smaller value of the minimum numbers of bends in the two specimens.

The length of the test specimen depends on the test apparatus used to perform the test.

If the width of the ~~material~~ product is insufficient for ~~transverse~~ a sampling of test specimens of the prescribed length to be taken across the width, the test specimens shall be taken ~~in~~ parallel to the longitudinal axis (the direction of rolling). In this case, the values of Table 1 and Table 2 also apply.

The test specimens shall be carefully cut, without deformation. Epstein test strips may be used for this test (see IEC 60404-2 and IEC TR 63114).

~~8.3.3.3 Internal stresses~~

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

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 an ambient temperature of (23 ± 5) °C.

8.4.2 Magnetic properties

8.4.2.1 Magnetic polarization and specific total loss

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 ~~obtained with the single sheet tester may~~ measured by the SST method can be different from those in Table 1 and Table 2, and may be subject to agreement between the manufacturer and the purchaser at the time of enquiry and order.

8.4.2.2 Anisotropy of loss

Two measurements of the specific total loss in watts per kilogram shall be made, one on 16 Epstein test strips taken perpendicular to the direction of rolling, and one on 16 Epstein test strips taken parallel to the direction of rolling.

The anisotropy of the specific total loss T , expressed as a percentage, is calculated according to the following equation:

$$\cancel{T = \frac{P_1 - P_2}{P_1 + P_2} \times 100}$$

$$T = \frac{P_{TD} - P_{RD}}{P_{TD} + P_{RD}} \times 100 \quad (1)$$

where

P_1 P_{TD} is the specific total loss, in watts per kilogram, measured in the direction perpendicular to the direction of rolling;

P_2 P_{RD} is the specific total loss, in watts per kilogram, measured in the direction parallel to the direction of rolling.

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 30~~ at least 20 mm from the edges. For ~~materials~~ products of a width less than ~~60~~ 40 mm, the measurement of thickness shall be made along the longitudinal axis (the direction of rolling) of the ~~sheet~~ product. This measurement shall be made using a micrometer with an ~~accuracy~~ uncertainty of ~~0,001~~ 0,002 mm or better.

8.4.3.2 Width

The width shall be measured perpendicular to the longitudinal axis (the direction of rolling) 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~~ axis (the direction of rolling) 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.

~~8.4.3.4 Flatness (wave factor)~~

~~The wave factor 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 specified minimum number of bends given in Table 1 and Table 2 is reached without an occurrence of cracks in the base metal. Alternatively, the test shall be stopped on the appearance of the first crack in the base metal visible to the naked eye, or sudden failure occurs by fracture. The test may be stopped by monitoring a cracking sound from the test specimen or a sudden current change when a constant voltage is applied between the both ends of the test specimen. The occurrence of cracks shall be confirmed by naked eye inspection.

The last bend shall not be counted.

NOTE Further information on 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)

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

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 with 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 the 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 ~~material~~ product.

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

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

11 Information to be supplied by the purchaser

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

- a) the quantity;

- b) the type of product (strip or sheet);
- c) the number of this document (IEC 60404-8-4);
- d) ~~name or number of~~ the steel name (see Clause 5);
- e) the dimensions of strips or sheets required (including any limitations on the internal and external diameters of a coil) (see 6.2 and 7.2.2);
- f) any limitation on the mass of a coil or a bundle of sheets (see 6.2);
- g) any special requirements about the marking of welds or interleaves (see 6.2);
- h) ~~any requirement for insulation and its classification~~ for products supplied with insulation coating, any requirement about the insulation coating and its properties, the stacking factor and their verification (see 6.3);
- i) any special requirement about the suitability for cutting or punching (see 6.5);
- ~~j) any special requirement about single sheet testing (see 8.4.2.1);~~
- j) any special requirement about the value of maximum specific total loss measured using test strips cut parallel to the direction of rolling only or test strips cut perpendicular to the direction of rolling only (see 7.1.3);
- k) any special requirement about the declaration of the measured value of anisotropy of loss (see 7.1.4);
- l) any special requirement about the thickness measurement and tolerance across the width of narrow strip (see 7.2.1 and 8.4.3.1);
- m) any special requirement about tolerances on the geometric characteristics of products supplied with as-rolled edges (see 7.2.2);
- n) any requirement about the residual curvature (see 7.2.5);
- o) the inspection procedure required including the nature of the related documents (see 8.1);
- p) any special requirement about the specified values to be measured by the single sheet tester (SST) method specified in IEC 60404-3 (see 8.4.2.1);
- q) any requirement about marking, labelling and packaging of the products (see Clause 9).