



IEC 60404-1

Edition 3.0 2016-10

INTERNATIONAL STANDARD

**Magnetic materials –
Part 1: Classification**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.030

ISBN 978-2-8322-3671-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD	4
1 Scope	6
2 Normative references	6
3 Terms and definitions	7
4 Magnetically soft materials (coercivity ≤ 1 kA/m).....	8
4.1 Class A – Irons	8
4.1.1 Reference documents	8
4.1.2 Chemical composition	8
4.1.3 Basis of subclassification	8
4.1.4 Available forms	8
4.1.5 Physical characteristics	8
4.1.6 Main applications	8
4.2 Class B – Low carbon mild steels.....	9
4.2.1 Class B1 – Bulk material.....	9
4.2.2 Class B2 – Flat material.....	9
4.3 Class C – Silicon steels	10
4.3.1 Class C1 – Bulk material	10
4.3.2 Class C2 – Flat material	11
4.4 Class D – Other steels	16
4.4.1 Class D1 – Bulk material	16
4.4.2 Class D2 – Flat material	18
4.4.3 Class D3 – Stainless steels	18
4.5 Class E – Nickel-iron alloys	19
4.5.1 Class E1 – Nickel content 70 % to 85 %	19
4.5.2 Class E2 – Nickel content 54 % to 68 %	20
4.5.3 Class E3 – Nickel content 40 % to 51 %	21
4.5.4 Class E4 – Nickel content 35 % to 40 %	22
4.5.5 Class E5 – Nickel content 29 % to 33 %	23
4.6 Class F – Iron-cobalt alloys.....	24
4.6.1 Class F1 – Cobalt content 47 % to 50 %	24
4.6.2 Class F2 – Cobalt content 35 %	24
4.6.3 Class F3 – Cobalt content 23 % to 30 %	25
4.7 Class G – Other alloys	26
4.7.1 Class G1 – Aluminium-iron alloys	26
4.7.2 Class G2 – Aluminium-silicon-iron alloys	27
4.8 Class H – Magnetically soft materials made by powder metallurgical techniques	27
4.8.1 Class H1 – Soft ferrites.....	27
4.8.2 Class H2 – Magnetically soft sintered materials	29
4.8.3 Class H3 – Powder composites	29
4.9 Class I – Amorphous soft magnetic materials	30
4.9.1 General	30
4.9.2 Class I1 – Iron-based amorphous alloys	30
4.9.3 Class I2 – Cobalt-based amorphous alloys	31
4.9.4 Class I3 – Nickel-based amorphous alloys.....	32
4.10 Class J – Nano-crystalline soft magnetic materials.....	33

4.10.1	Reference document.....	33
4.10.2	Production process	33
4.10.3	Chemical composition.....	33
4.10.4	Basis of subclassification.....	33
4.10.5	Available forms.....	33
4.10.6	Physical characteristics	33
4.10.7	Main applications.....	34
5	Magnetically hard materials (coercivity > 1 kA/m)	34
5.1	Class Q – Magnetostrictive alloys – Rare earth iron alloys (Class Q1)	34
5.1.1	Reference document.....	34
5.1.2	Chemical composition.....	34
5.1.3	Basis of subclassification.....	34
5.1.4	Available forms.....	34
5.1.5	Physical characteristics	34
5.1.6	Main applications.....	35
5.2	Class R – Magnetically hard alloys.....	35
5.2.1	Class R1 – Aluminium-nickel-cobalt-iron-titanium (AlNiCo) alloys	35
5.2.2	Class R3 – Iron-cobalt-vanadium-chromium (FeCoVCr) alloys	36
5.2.3	Class R5 – Rare earth cobalt (RECo) alloys	36
5.2.4	Class R6 – Chromium-iron-cobalt (CrFeCo) alloys	37
5.2.5	Class R7 – Rare earth-iron-boron (REFeB) alloys.....	38
5.3	Class S – Magnetically hard ceramics – Hard ferrites (Class S1)	39
5.3.1	Reference document.....	39
5.3.2	Chemical composition and manufacturing method	39
5.3.3	Basis of subclassification.....	39
5.3.4	Available forms.....	39
5.3.5	Physical characteristics	40
5.3.6	Main applications.....	40
5.4	Class T – Other magnetically hard materials – Martensitic steels (Class T1).....	40
5.4.1	Reference document.....	40
5.4.2	Composition	40
5.4.3	Basis of subclassification.....	40
5.4.4	Available forms.....	40
5.4.5	Physical characteristics	40
5.4.6	Main applications.....	41
5.5	Class U – Bonded magnetically hard materials.....	41
5.5.1	General	41
5.5.2	Class U1 – Bonded aluminium-nickel-cobalt-iron-titanium (AlNiCo) magnets	41
5.5.3	Class U2 – Bonded rare earth-cobalt (RECo) magnets	42
5.5.4	Class U3 – Bonded neodymium-iron-boron (REFeB) magnets	42
5.5.5	Class U4 – Bonded hard ferrite magnets.....	43
5.5.6	Class U5 – Bonded rare earth-iron-nitrogen magnets.....	44

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAGNETIC MATERIALS –

Part 1: Classification

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60404-1 has been prepared by IEC technical committee 68: Magnetic alloys and steels.

This third edition cancels and replaces the second edition published in 2000 and constitutes a technical revision.

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

- a) Removal of all tables and values describing typical properties of the material to be consistent with the aim of the document to be a classification and not a specification.
- b) Enlargement of the Ni content for the classes E1 and E3.
- c) Enlargement of the Co content for the classes F3.
- d) Addition of a new class: U5 bonded rare earth-iron-nitrogen magnets.

The text of this standard is based on the following documents:

CDV	Report on voting
68/533/CDV	68/555/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 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.

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

MAGNETIC MATERIALS –

Part 1: Classification

1 Scope

This part of IEC 60404 is intended to classify commercially available magnetic materials.

The term "magnetic materials" denotes substances where the application requires the existence of ferromagnetic or ferrimagnetic properties.

In this document, the classification of magnetic materials is based upon the generally recognized existence of two main groups of products:

- soft magnetic materials (coercivity $\leq 1\ 000$ A/m);
- hard magnetic materials (coercivity $> 1\ 000$ A/m).

Within these main groups, the classification when appropriate recognizes the following characteristics:

- the main alloying element and the metallurgical state and physical properties of the material;
- when possible and convenient, the relationship between these characteristics is identified.

A classification by specific areas of application cannot be applied to all materials because different materials can very often be used for the same application depending on the characteristics required.

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 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

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

IEC 60401-3, *Terms and nomenclature for cores made of magnetically soft ferrites – Part 3: Guidelines on the format of data appearing in manufacturers catalogues of transformer and inductor cores*

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 60404-3, *Magnetic materials – Part 3: Methods of measurement of the magnetic properties of magnetic sheet and strip by means of a single sheet tester*

IEC 60404-4, *Magnetic materials – Part 4: Methods of measurement of d.c. magnetic properties of iron and steel*

IEC 60404-6, *Magnetic materials – Part 6: Methods of measurement of the magnetic properties of magnetically soft metallic and powder materials at frequencies in the range 20 Hz to 200 kHz by the use of ring specimens*

IEC 60404-7, *Magnetic materials – Part 7: Method of measurement of the coercivity of magnetic materials in an open magnetic circuit*

IEC 60404-8-1, *Magnetic materials – Part 8-1: Specifications for individual materials – Magnetically hard materials*

IEC 60404-8-3, *Magnetic materials – Part 8-3: Specifications for individual materials – Cold-rolled electrical non-alloyed and alloyed steel sheet and strip delivered in the semi-processed state*

IEC 60404-8-4, *Magnetic materials – Part 8-4: Specifications for individual materials – Cold-rolled non-oriented electrical steel strip and sheet delivered in the fully-processed state*

IEC 60404-8-5, *Magnetic materials – Part 8: Specifications for individual materials – Section Five: Specification for steel sheet and strip with specified mechanical properties and magnetic permeability*

IEC 60404-8-6, *Magnetic materials – Part 8-6: Specifications for individual materials – Soft magnetic metallic materials*

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*

IEC 60404-8-8, *Magnetic materials – Part 8: Specifications for individual materials – Section 8: Specification for thin magnetic steel strip for use at medium frequencies*

IEC 60404-8-9, *Magnetic materials – Part 8: Specifications for individual materials – Section 9: Standard specification for sintered soft magnetic materials*

IEC 60404-8-10, *Magnetic materials – Part 8-10: Specifications for individual materials – Magnetic materials (iron and steel) for use in relays*

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

ISO 4948-1, *Steels – Classification – Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*