

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Conductors of insulated cables

Ames des câbles isolés

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IEC 60228 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2004. This edition constitutes a technical revision.

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

- a) a description of Milliken conductors has been added;
- b) nominal cross-sectional areas above 2 500 mm² have been added;

- c) the old 2 500 mm² aluminium resistance value has been corrected and a new value introduced.

For legacy systems where the 2 500 mm² aluminium conductor was designed taking into account the value presented in previous editions and no longer tabulated, then the original design can be maintained and still utilized.

The suppliers can furthermore utilize such superseded design of 2 500 mm² aluminium conductors either in systems already designed and qualified but not delivered or for example to produce repair and additional spare lengths for delivered systems.

The choice of utilizing the original superseded design of 2 500 mm² aluminium conductors or a new one based on the new resistance tabulated value is a matter of agreement between the supplier and final users.

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

Draft	Report on voting
20/2125/FDIS	20/2131/RVD

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.

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- withdrawn, or
- revised.

INTRODUCTION

This document is intended as a fundamental reference standard for IEC technical committees and National Committees in drafting standards for electric cables, and to the National Committees in drafting specifications for use in their own countries. These committees select from the tables of this general standard the conductors appropriate to the particular applications relevant to them and either include the applicable details in their cable specifications or make appropriate references to this document.

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CONDUCTORS OF INSULATED CABLES

1 Scope

This document specifies the nominal cross-sectional areas, in the range 0,5 mm² to 3 500 mm², for conductors in electric power cables and cords of a wide range of types. Requirements for numbers and sizes of wires and resistance values are also included. These conductors include solid, stranded and Milliken, copper, aluminium and aluminium alloy conductors in cables for fixed installations and flexible copper conductors.

This document does not apply to conductors for telecommunication purposes.

The applicability of this document to a particular type of cable is as specified in the standard for the type of cable.

Unless specified otherwise in a particular clause, this document relates to the conductors in the finished cable and not to the conductor as made or supplied for inclusion into a cable.

Conductors described in this document are specified in metric sizes.

Informative annexes provide supplementary information covering temperature correction factors for resistance measurement (Annex B) and guidance on dimensional limits of circular conductors (Annex C).

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.

IECEE OD-5014, *Instrument Accuracy Limits*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1

metal-coated

coated with a thin layer of suitable metal, such as tin or tin alloy

3.2

nominal cross-sectional area

value that identifies a particular size of conductor but is not subject to direct measurement

Note 1 to entry: Each particular size of conductor in this document is required to meet a maximum resistance value.

3.3

Milliken conductor

stranded conductor comprising an assembly of shaped conductors, lightly insulated from each other

4 Classification

The conductors have been divided into four classes, 1, 2, 5 and 6. Those in classes 1 and 2 are intended for use in cables for fixed installations. Classes 5 and 6 are intended for use in flexible cables and cords but can also be used for fixed installations.

- class 1: solid conductors;
- class 2: stranded conductors;
- class 5: flexible conductors;
- class 6: flexible conductors made with smaller diameter wires than class 5 for the same nominal conductor cross-section.

5 Materials

5.1 General

The wires of conductors shall consist of one of the following (except for the Milliken central element):

- plain or metal-coated annealed copper;
- aluminium or aluminium alloy.

The wires of stranded conductors (for example Milliken conductors) can be oxidized or enamelled.

5.2 Circular and shaped solid aluminium conductors

Circular and shaped solid aluminium conductors shall be made from aluminium such that the tensile strength of the completed conductor is within the limits given in Table 1.

Table 1 – Tensile strength limits for circular and shaped solid aluminium conductors

Nominal cross-sectional area mm ²	Tensile strength N/mm ²
10 and 16	110 to 165
25 and 35	60 to 130
50	60 to 110
70 and above	60 to 90

There are no limits defined for the tensile strength of aluminium alloy solid conductors.

5.3 Circular and shaped stranded aluminium conductors

Stranded aluminium conductors shall be made from aluminium such that the tensile strength of the individual wires is within the limits given in Table 2:

Table 2 – Tensile strength limits for circular and shaped stranded aluminium conductors

Nominal cross-sectional area mm ²	Tensile strength N/mm ²
10	up to 200
16 and above	125 to 205

There are no limits defined for the tensile strength of aluminium alloy stranded conductors.

This data can only be checked on wires taken before stranding and not on wires taken from a stranded conductor.

6 Solid conductors and stranded conductors

6.1 Solid conductors (class 1)

6.1.1 Construction

- a) Solid conductors or conductor wires shall consist of one of the materials specified in Clause 5.
- b) Solid copper conductors shall be of circular cross-section.

NOTE Solid copper conductors having nominal cross-section areas of 25 mm² and above are for particular types of cable, e.g. mineral insulated, and not for general purposes.

- c) Solid aluminium and solid aluminium alloy conductors of sizes 10 mm² to 35 mm² shall be of circular cross-section. Larger sizes shall be of circular cross-section for single-core cables and may be of either circular or shaped cross-section for multi-core cables.

6.1.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 8, shall not exceed the appropriate maximum value given in Table 3.

For solid aluminium alloy conductors, having the same nominal cross-sectional area as an aluminium conductor, the resistance value given in Table 3 should be multiplied by a factor of 1,162 unless otherwise agreed between the manufacturer and the purchaser.

6.2 Stranded circular non-compacted conductors (class 2)

6.2.1 Construction

- a) Stranded circular non-compacted conductors (class 2) shall consist of one of the materials specified in Clause 5.
- b) Stranded aluminium or aluminium alloy conductors shall have a cross-sectional area not less than 10 mm².
- c) The wires in each conductor shall all have the same nominal diameter.
- d) The number of wires in each conductor shall be not less than the appropriate minimum number given in Table 4.

6.2.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 8, shall not exceed the appropriate maximum value given in Table 4.

6.3 Stranded compacted circular conductors and stranded shaped conductors (class 2)

6.3.1 Construction

- a) Stranded compacted circular conductors and stranded shaped conductors (class 2) shall consist of one of the materials specified in Clause 5. Stranded compacted circular aluminium or aluminium alloy conductors shall have a nominal cross-sectional area not less than 10 mm². Stranded compacted circular copper conductors shall have a nominal cross-sectional area not less than 1,5 mm². Stranded shaped copper, aluminium or aluminium alloy conductors shall have a nominal cross-sectional area of not less than 25 mm².
- b) The ratio of the diameters of two different wires in the same conductor shall not exceed 2, except for conductors made with pre-shaped wires.
- c) The number of wires in each conductor shall be not less than the appropriate minimum number given in Table 4, except for conductors made with pre-shaped wires. This requirement applies to conductors made with wires of circular cross-section before compaction.

6.3.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 8, shall not exceed the appropriate maximum value given in Table 4.

6.4 Milliken conductors (class 2)

6.4.1 Construction

- a) Milliken conductors (class 2) shall consist of any of the materials specified in Clause 5. Milliken conductors shall have a nominal cross-sectional area not less than 800 mm², and the minimum number of wires for each cross section is not specified.
- b) The ratio of the diameters of two different wires of any segment shall not exceed 2 (Milliken central element excluded).
- c) The Milliken central element can be empty, with a solid conductor, wires or with a plastic filler.
- d) This conductor may be constructed from 4, 5, or 6 equal segments. The number of wires in each segment is defined by the manufacturer. In the case of a central element formed with wires, it can be considered as an additional segment with a polygonal shape.

6.4.2 Resistance

The resistance of the whole conductor at 20 °C, for all different constructions described in 6.4.1, when determined in accordance with Clause 8, shall not exceed the appropriate maximum value given in Table 4.

7 Flexible conductors (classes 5 and 6)

7.1 Construction

- a) Flexible conductors (classes 5 and 6) shall consist of plain or metal-coated annealed copper.
- b) The wires in each conductor shall have the same nominal diameter.
- c) The diameter of the wires in each conductor shall not exceed the appropriate maximum value given in Table 5 for class 5 or Table 6 for class 6 conductors.

7.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 8, shall not exceed the appropriate maximum value given in Table 5 or Table 6.

8 Check of compliance with Clause 6 and Clause 7

Compliance with the requirements for construction of 6.1.1, 6.2.1, 6.3.1, 6.4.1 and 7.1 shall be checked on the completed cable by inspection and measurement where practicable.

Compliance with the requirements for resistance given in 6.1.2, 6.2.2, 6.3.2, 6.4.2, and 7.2 shall be checked by measurement in accordance with Annex A and corrected for temperature by the factors in Table A.1.

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Table 3 – Class 1 solid conductors for single-core and multi-core cables

1	2	3	4
Nominal cross-sectional area	Maximum resistance of conductor at 20 °C		
	Circular, annealed copper conductors		Aluminium and aluminium alloy conductors, circular or shaped ^c
	Plain	Metal-coated	
mm ²	Ω/km	Ω/km	Ω/km
0,5	36,0	36,7	-
0,75	24,5	24,8	-
1,0	18,1	18,2	-
1,5	12,1	12,2	-
2,5	7,41	7,56	-
4	4,61	4,70	-
6	3,08	3,11	-
10	1,83	1,84	3,08 ^a
16	1,15	1,16	1,91 ^a
25	0,727 ^b	-	1,20 ^a
35	0,524 ^b	-	0,868 ^a
50	0,387 ^b	-	0,641
70	0,268 ^b	-	0,443
95	0,193 ^b	-	0,320 ^d
120	0,153 ^b	-	0,253 ^d
150	0,124 ^b	-	0,206 ^d
185	0,101 ^b	-	0,164 ^d
240	0,077 5 ^b	-	0,125 ^d
300	0,062 0 ^b	-	0,100 ^d
400	0,046 5 ^b	-	0,077 8
500	-	-	0,060 5
630	-	-	0,046 9
800	-	-	0,036 7
1 000	-	-	0,029 1
1 200	-	-	0,024 7
1 400	-	-	0,021 2
1 600	-	-	0,018 6

^a Aluminium conductors 10 mm² to 35 mm² circular only; see 6.1.1 c).

^b See note in 6.1.1 b).

^c See note in 6.1.2.

^d For single-core cables, four sectoral shaped conductors may be assembled into a single circular conductor. The maximum resistance of the assembled conductor shall be 25 % of that of the individual component conductors.