IEC 60228

Edition 4.0 2023-12
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

Conductors of insulated cables

IEC 60228:2023-12 CMV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONDUCTORS OF INSULATED CABLES

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This commented version (CMV) of the official standard IEC 60228:2023 edition 4.0 allows the user to identify the changes made to the previous IEC 60228:2004 edition 3.0. Furthermore, comments from IEC TC 20 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

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 mm^2 have been added;

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

   For legacy systems where the 2 500 mm^2 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 mm^2 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 mm^2 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.

Conductors described in IEC 60228 are specified in metric sizes. Canada at present uses conductor sizes and characteristics according to the American Wire Gauge (AWG) system and kcmil for larger sizes as shown below. The use of these sizes is currently prescribed uniformly across Canada for installations by sub-national regulations. IEC TC 20 cable product standards do not prescribe cables with AWG/kcmil conductors. 1

AWG				kcmil			
Conductor size	Nominal cross-sectional area mm²	Conductor size	Nominal cross-sectional area mm²	Conductor size	Nominal cross-sectional area mm²	Conductor size	Nominal cross-sectional area mm²
-	-	-	-	250	127	750	380
-	-	-	-	300	152	800	405
20	0,519	4	21,2	350	177	900	456
18	0,823	3	26,7	400	203	1000	507
16	1,31	2	33,6	450	228	1200	608
14	2,08	1	42,4	500	253	1250	633
12	3,31	1/0	53,5	550	279	1500	760
10	5,26	2/0	67,4	600	304	1750	887
8	8,37	3/0	85,0	650	329	2000	1010
6	13,3	4/0	107	700	355	-	-

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 ~~should~~ select from the tables of this general standard the conductors appropriate to the particular applications ~~with which they are concerned~~ relevant to them and either include the applicable details in their cable specifications or make appropriate references to this document.

~~In preparing this edition the main objects have been to incorporate IEC 60228A into it and maintain a simplified yet informative standard so far as is compatible with technical and economic considerations.~~

CONDUCTORS OF INSULATED CABLES

1 Scope

This document specifies the nominal cross-sectional areas, in the range 0,5 mm^2 to ~~2 500~~ 3 500 mm^2, 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 **2**

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 ~~may~~ can also be used for fixed installations.

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

5 Materials

5.1 ~~Introduction~~ 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. **3** **4**

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

~~NOTE The values given above are not applicable to aluminium alloy conductors.~~

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

~~NOTE 1 The values given above are not applicable to aluminium alloy conductors.~~

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

~~NOTE 2~~ 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 ~~(class 1)~~ 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~~al~~ areas of 25 mm^2 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 mm^2 to 35 mm^2 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.

~~NOTE~~ 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 mm^2.

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 mm^2. Stranded compacted circular copper conductors shall have a nominal cross-sectional area not less than 1,5 mm^2. Stranded shaped copper, aluminium or aluminium alloy conductors shall have a nominal cross-sectional area of not less than 25 mm^2.

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.

~~NOTE This requirement applies to conductors made with wires of circular cross-section before compaction and not to conductors made with pre-shaped wires.~~

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 mm^2, and the minimum number of wires for each cross section is not specified. **5**

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.

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 mm^2 to 35 mm^2 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.

Table 4 – Class 2 stranded conductors for single-core and multi-core cables 6

1	2	3	4	5	6	7	8	9	10
Nominal cross-sectional area	Minimum number of wires in the conductor						Maximum resistance of conductor at 20 °C		
	Circular		Circular compacted		Shaped		Annealed copper conductor		Aluminium or aluminium alloy conductor[b]
	Cu	Al	Cu	Al	Cu	Al	Plain wires	Metal-coated wires	
mm^2							Ω/km	Ω/km	Ω/km
0,5	7	-	-	-	-	-	36,0	36,7	-
0,75	7	-	-	-	-	-	24,5	24,8	-
1,0	7	-	-	-	-	-	18,1	18,2	-
1,5	7	-	6	-	-	-	12,1	12,2	-
2,5	7	-	6	-	-	-	7,41	7,56	-
4	7	-	6	-	-	-	4,61	4,70	-
6	7	-	6	-	-	-	3,08	3,11	-
10	7	7	6	6	-	-	1,83	1,84	3,08
16	7	7	6	6	-	-	1,15	1,16	1,91
25	7	7	6	6	6	6	0,727	0,734	1,20
35	7	7	6	6	6	6	0,524	0,529	0,868
50	19	19	6	6	6	6	0,387	0,391	0,641
70	19	19	12	12	12	12	0,268	0,270	0,443
95	19	19	15	15	15	15	0,193	0,195	0,320
120	37	37	18	15	18	15	0,153	0,154	0,253
150	37	37	18	15	18	15	0,124	0,126	0,206
185	37	37	30	30	30	30	0,099 1	0,100	0,164
240	37	37	34	30	34	30	0,075 4	0,076 2	0,125
300	61	61	34	30	34	30	0,060 1	0,060 7	0,100
400	61	61	53	53	53	53	0,047 0	0,047 5	0,077 8
500	61	61	53	53	53	53	0,036 6	0,036 9	0,060 5
630	91	91	53	53	53	53	0,028 3	0,028 6	0,046 9
800	91	91	53	53	-	-	0,022 1	0,022 4	0,036 7
1 000	91	91	53	53	-	-	0,017 6	0,017 7	0,029 1
~~1 200~~	~~b~~						~~0,0151~~	~~0,0151~~	~~0,0247~~
1 200	91	91	53	53	-	-	0,015 1	0,015 1	0,024 7
~~1 400[a]~~	~~b~~						~~0,0129~~	~~0,0129~~	~~0,0212~~
1 400[a]	91	91	53	53	-	-	0,012 9	0,012 9	0,021 2
~~1 600~~	~~b~~						~~0,0113~~	~~0,0113~~	~~0,0186~~
1 600	91	91	53	53	-	-	0,011 3	0,011 3	0,018 6
1 800[a]	- ~~b~~						0,010 1	0,010 1	0,016 5
2 000	- ~~b~~						0,009 0	0,009 0	0,014 9
2 500	- ~~b~~						0,007 2	0,007 2	~~0,0127~~0,011 9
3 000[a]	-						0,006 0	0,006 0	0,009 9
3 200	-						0,005 6	0,005 6	0,009 3
3 500[a]	-						0,005 1	0,005 1	0,008 5

1	2	3	4	5	6	7	8	9	10

[a] These sizes are non-preferred. Other non-preferred sizes are recognized for some specialized applications but are not within the scope of this document. 7

~~[b] The minimum number of wires for these sizes is not specified. These sizes may be constructed from 4, 5 or 6 equal segments (Milliken).~~

[b] For stranded aluminium alloy conductors having the same nominal cross-sectional area as an aluminium conductor the resistance value should be agreed between the manufacturer and the purchaser.

Table 5 – Class 5 flexible copper conductors for single-core and multi-core cables

1	2	3	4
Nominal cross-sectional area	**Maximum diameter of wires in conductor**	**Maximum resistance of conductor at 20 °C**	
		Plain wires	**Metal-coated wires**
mm^2	mm	Ω/km	Ω/km
0,5	0,21	39,0	40,1
0,75	0,21	26,0	26,7
1,0	0,21	19,5	20,0
1,5	0,26	13,3	13,7
2,5	0,26	7,98	8,21
4	0,31	4,95	5,09
6	0,31	3,30	3,39
10	0,41	1,91	1,95
16	0,41	1,21	1,24
25	0,41	0,780	0,795
35	0,41	0,554	0,565
50	0,41	0,386	0,393
70	0,51	0,272	0,277
95	0,51	0,206	0,210
120	0,51	0,161	0,164
150	0,51	0,129	0,132
185	0,51	0,106	0,108
240	0,51	0,080 1	0,081 7
300	0,51	0,064 1	0,065 4
400	0,51	0,048 6	0,049 5
500	0,61	0,038 4	0,039 1
630	0,61	0,028 7	0,029 2

Table 6 – Class 6 flexible copper conductors for single-core and multi-core cables

1	2	3	4
Nominal cross-sectional area	Maximum diameter of wires in conductor	Maximum resistance of conductor at 20 °C	
		Plain wires	Metal-coated wires
mm^2	mm	Ω/km	Ω/km
0,5	0,16	39,0	40,1
0,75	0,16	26,0	26,7
1,0	0,16	19,5	20,0
1,5	0,16	13,3	13,7
2,5	0,16	7,98	8,21
4	0,16	4,95	5,09
6	0,21	3,30	3,39
10	0,21	1,91	1,95
16	0,21	1,21	1,24
25	0,21	0,780	0,795
35	0,21	0,554	0,565
50	0,31	0,386	0,393
70	0,31	0,272	0,277
95	0,31	0,206	0,210
120	0,31	0,161	0,164
150	0,31	0,129	0,132
185	0,41	0,106	0,108
240	0,41	0,080 1	0,081 7
300	0,41	0,064 1	0,065 4

Annex A
(normative)

Measurement of resistance

The cable shall be kept in the test area for a sufficient time to ensure that the conductor temperature has reached a level which permits an accurate determination of resistance using the correction factors provided.

Measure the DC resistance of the conductor(s), either on a complete length of cable or flexible cord or on a sample of cable of flexible cord of at least 1 m in length, at room temperature and record the temperature at which the measurement is made. Adjust the measured resistance by means of the correction factors given in Table A.1.

Calculate the resistance per kilometre length of cable from the length of the complete cable and not from the length of the individual core or wires.

If necessary, correction to 20 °C and 1 km length shall be made by applying the following formula:

$$R_{20} = R_t \times k_t \times \frac{1000}{L}$$

where

k_t is the temperature correction factor from Table A.1;

R_{20} is the conductor resistance at 20 °C, in Ω/km;

R_t is the measured conductor resistance, in Ω;

L is the length of the cable, in m.

The expanded measurement uncertainty (k = 2) for R_{20} shall be in accordance with IECEE OD-5014.

Table A.1 – Temperature correction factors k_t for conductor resistance to correct the measured resistance at t °C to 20 °C

1	2	1	2
Temperature of conductor at time of measurement t °C	**Correction factor k_t All conductors**	**Temperature of conductor at time of measurement** t °C	**Correction factor k_t All conductors**
0	1,087	21	0,996
1	1,082	22	0,992
2	1,078	23	0,988
3	1,073	24	0,984
4	1,068	25	0,980
5	1,064	26	0,977
6	1,059	27	0,973
7	1,055	28	0,969
8	1,050	29	0,965
9	1,046	30	0,962
10	1,042	31	0,958
11	1,037	32	0,954
12	1,033	33	0,951
13	1,029	34	0,947
14	1,025	35	0,943
15	1,020	36	0,940
16	1,016	37	0,936
17	1,012	38	0,933
18	1,008	39	0,929
19	1,004	40	0,926
20	1,000		

NOTE The values of correction factors k_t are based on a resistance-temperature coefficient of 0,004 per Kelvin at 20 °C.

The values of temperature correction factors specified in column 2 are approximate but give practical values well within the accuracy that can normally be achieved in measurements of conductor temperature and length of cable or flexible cords.

For more accurate values for the temperature correction factors for copper and aluminium, reference should be made to Annex B. However, these should not be treated as a requirement for testing in compliance with this document in the assessment of resistances.

Annex B
(informative)

Exact formulae for the temperature correction factors

a) Annealed copper conductors: plain or metal-coated

$$k_{t,Cu} = \frac{254,5}{234,5+t} = \frac{1}{1+0,00393(t-20)}$$

b) Aluminium conductors

$$k_{t,Al} = \frac{248}{228+t} = \frac{1}{1+0,00403(t-20)}$$

~~NOTE~~ For aluminium alloys, reference should be made to the manufacturer.

In all the above cases, t refers to the temperature of the conductor at the time of measurement in degrees Celsius.

Annex C
(informative)

Guidance on the dimensional limits of circular conductors

C.1 ~~Object~~ Purpose

This Annex C is intended as a guide for manufacturers of cables and cable connectors to assist in ensuring that the conductors and connectors are dimensionally compatible. It gives guidance on dimensional limits for the following types of conductor included in this document:

a) circular solid conductors, (class 1) of copper, aluminium ~~and~~ or aluminium alloy;

b) circular and compacted circular stranded conductors, (class 2) of copper, aluminium ~~and~~ or aluminium alloy;

c) flexible conductors, (classes 5 and 6) of copper.

C.2 Dimensional limits for circular copper conductors

The diameters of circular copper conductors should not exceed the values given in Table C.1.

If minimum diameters for class 1 circular copper conductors are ~~needed~~ required, reference can be made to the minimum diameters for solid circular aluminium or aluminium alloy conductors indicated in Table C.3.

C.3 Dimensional limits for stranded compacted circular copper, aluminium and aluminium alloy conductors

The diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.2.

In the exceptional case of uncompacted circular stranded aluminium or aluminium alloy conductors, the maximum diameters should not exceed the corresponding values for copper conductors given in column 3 of Table C.1.

C.4 Dimensional limits for circular solid aluminium conductors

The diameters of circular solid aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.3.

Table C.1 – Maximum diameters of solid, non-compacted stranded and flexible circular copper conductors

1	2	3	4
Nominal cross-sectional area	Conductors in cables for fixed installations		
	Solid (Class 1)	Stranded (Class 2)	Flexible conductors (Classes 5 and 6)
mm^2	mm	mm	mm
0,5	0,9	1,1	1,1
0,75	1,0	1,2	1,3
1,0	1,2	1,4	1,5
1,5	1,5	1,7	1,8
2,5	1,9	2,2	2,4
4	2,4	2,7	3,0
6	2,9	3,3	3,9
10	3,7	4,2	5,1
16	4,6	5,3	6,3
25[a]	5,7	6,6	7,8
35[a]	6,7	7,9	9,2
50[a]	7,8	9,1	11,0
70[a]	9,4	11,0	13,1
95[a]	11,0	12,9	15,1
120[a]	12,4	14,5	17,0
150[a]	13,8	16,2	19,0
185	15,4	18,0	21,0
240	17,6	20,6	24,0
300	19,8	23,1	27,0
400	22,2	26,1	31,0
500	-	29,2	35,0
630	-	33,2	39,0
800	-	37,6	-
1 000	-	42,2	-

NOTE The values given for flexible conductors are intended to allow for both class 5 and class 6 conductors.

[a] See 6.1.1 b).

Table C.2 – Minimum and maximum diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors

1	2	3
Nominal cross-sectional area	**Stranded compacted circular conductors (Class 2)**	
	Minimum diameter	**Maximum diameter**
mm^2	mm	mm
10	3,6	4,0
16	4,6	5,2
25	5,6	6,5
35	6,6	7,5
50	7,7	8,6
70	9,3	10,2
95	11,0	12,0
120	12,3	13,5
150	13,7	15,0
185	15,3	16,8
240	17,6	19,2
300	19,7	21,6
400	22,3	24,6
500	25,3	27,6
630	28,7	32,5

NOTE 1 The dimensional limits of aluminium conductors with cross-sectional areas above 630 mm^2 are not given as the compaction technology is not generally established.

NOTE 2 No values are given for compacted copper conductors in the size range 1,5 mm^2 to 6 mm^2.

Table C.3 – Minimum and maximum diameters of solid circular aluminium conductors

1	2	3
Nominal cross-sectional area	Solid conductors (Class 1)	
	Minimum diameter	Maximum diameter
mm^2	mm	mm
10	3,4	3,7
16	4,1	4,6
25	5,2	5,7
35	6,1	6,7
50	7,2	7,8
70	8,7	9,4
95	10,3	11,0
120	11,6	12,4
150	12,9	13,8
185	14,5	15,4
240	16,7	17,6
300	18,8	19,8
400	21,2	22,2
500	24,0	25,1
630	27,3	28,4
800	30,9	32,1
1000	34,8	36,0
1200	37,8	39,0

Bibliography

IEC Guide 108, *Guidelines for ensuring the coherence of IEC publications – Horizontal functions, horizontal publications and their application*

List of comments

1 As IEC TC 20 do not prescribe cables with AWG/kcmil conductors it has been decided to remove the below table and the paragraph.

See IEC TR 62602 to find AWG/kcmil information.

2 Segmented conductors without lightly insultation between them used for DC applications are not considered Milliken.

3 Copper coated aluminium is not considered because of possible safety risks, including possible corrosion of the metals which make them unsuitable for household use.

4 Conductors can be made of aluminium or copper, and only these materials are considered in order to evaluate the resistance. Additional materials, i.e. lacquers, paint, tapes and powders are allowed as part of the conductor design to improve characteristics but they are not covered by this standard.

5 For cross-sections from 800 mm² to 1600 mm² the minimum number of wires indicated in Table 4 is not applicable to Milliken conductors.

6 Milliken conductors from 800 mm² take the same DC resistance value than circular conductors.

Circular conductors are considered up to 1600 mm².

7 Preferred sizes follow the Renard series of preferred numbers.

IEC 60228

Edition 4.0 2023-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Conductors of insulated cables

Ames des câbles isolés

IEC 60228:2023-12(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONDUCTORS OF INSULATED CABLES

FOREWORD

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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 mm^2 have been added;

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

For legacy systems where the 2 500 mm^2 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 mm^2 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 mm^2 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.

CONDUCTORS OF INSULATED CABLES

1 Scope

This document specifies the nominal cross-sectional areas, in the range 0,5 mm^2 to 3 500 mm^2, 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 mm^2 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 mm^2 to 35 mm^2 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 ºC, 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 mm^2.

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 mm^2. Stranded compacted circular copper conductors shall have a nominal cross-sectional area not less than 1,5 mm^2. Stranded shaped copper, aluminium or aluminium alloy conductors shall have a nominal cross-sectional area of not less than 25 mm^2.

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 mm^2, 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.

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	
mm²	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.

Table 4 – Class 2 stranded conductors for single-core and multi-core cables

1	2	3	4	5	6	7	8	9	10
Nominal cross-sectional area	Minimum number of wires in the conductor						Maximum resistance of conductor at 20 °C		
	Circular		Circular compacted		Shaped		Annealed copper conductor		Aluminium or aluminium alloy conductor[b]
	Cu	Al	Cu	Al	Cu	Al	Plain wires	Metal-coated wires	
mm^2							Ω/km	Ω/km	Ω/km
0,5	7	-	-	-	-	-	36,0	36,7	-
0,75	7	-	-	-	-	-	24,5	24,8	-
1,0	7	-	-	-	-	-	18,1	18,2	-
1,5	7	-	6	-	-	-	12,1	12,2	-
2,5	7	-	6	-	-	-	7,41	7,56	-
4	7	-	6	-	-	-	4,61	4,70	-
6	7	-	6	-	-	-	3,08	3,11	-
10	7	7	6	6	-	-	1,83	1,84	3,08
16	7	7	6	6	-	-	1,15	1,16	1,91
25	7	7	6	6	6	6	0,727	0,734	1,20
35	7	7	6	6	6	6	0,524	0,529	0,868
50	19	19	6	6	6	6	0,387	0,391	0,641
70	19	19	12	12	12	12	0,268	0,270	0,443
95	19	19	15	15	15	15	0,193	0,195	0,320
120	37	37	18	15	18	15	0,153	0,154	0,253
150	37	37	18	15	18	15	0,124	0,126	0,206
185	37	37	30	30	30	30	0,099 1	0,100	0,164
240	37	37	34	30	34	30	0,075 4	0,076 2	0,125
300	61	61	34	30	34	30	0,060 1	0,060 7	0,100
400	61	61	53	53	53	53	0,047 0	0,047 5	0,077 8
500	61	61	53	53	53	53	0,036 6	0,036 9	0,060 5
630	91	91	53	53	53	53	0,028 3	0,028 6	0,046 9
800	91	91	53	53	-	-	0,022 1	0,022 4	0,036 7
1 000	91	91	53	53	-	-	0,017 6	0,017 7	0,029 1
1 200	91	91	53	53	-	-	0,015 1	0,015 1	0,024 7
1 400[a]	91	91	53	53	-	-	0,012 9	0,012 9	0,021 2
1 600	91	91	53	53	-	-	0,011 3	0,011 3	0,018 6
1 800[a]	-						0,010 1	0,010 1	0,016 5
2 000	-						0,009 0	0,009 0	0,014 9
2 500	-						0,007 2	0,007 2	0,011 9
3 000[a]	-						0,006 0	0,006 0	0,009 9
3 200	-						0,005 6	0,005 6	0,009 3
3 500[a]	-						0,005 1	0,005 1	0,008 5

[a] These sizes are non-preferred. Other non-preferred sizes are recognized for some specialized applications but are not within the scope of this document.

[b] For stranded aluminium alloy conductors having the same nominal cross-sectional area as an aluminium conductor the resistance value should be agreed between the manufacturer and the purchaser.

Table 5 – Class 5 flexible copper conductors for single-core and multi-core cables

1	2	3	4
Nominal cross-sectional area	**Maximum diameter of wires in conductor**	**Maximum resistance of conductor at 20 °C**	
		Plain wires	**Metal-coated wires**
mm^2	mm	Ω/km	Ω/km
0,5	0,21	39,0	40,1
0,75	0,21	26,0	26,7
1,0	0,21	19,5	20,0
1,5	0,26	13,3	13,7
2,5	0,26	7,98	8,21
4	0,31	4,95	5,09
6	0,31	3,30	3,39
10	0,41	1,91	1,95
16	0,41	1,21	1,24
25	0,41	0,780	0,795
35	0,41	0,554	0,565
50	0,41	0,386	0,393
70	0,51	0,272	0,277
95	0,51	0,206	0,210
120	0,51	0,161	0,164
150	0,51	0,129	0,132
185	0,51	0,106	0,108
240	0,51	0,080 1	0,081 7
300	0,51	0,064 1	0,065 4
400	0,51	0,048 6	0,049 5
500	0,61	0,038 4	0,039 1
630	0,61	0,028 7	0,029 2

Table 6 – Class 6 flexible copper conductors for single-core and multi-core cables

1	2	3	4
Nominal cross-sectional area	**Maximum diameter of wires in conductor**	**Maximum resistance of conductor at 20 °C**	
		Plain wires	**Metal-coated wires**
mm^2	mm	Ω/km	Ω/km
0,5	0,16	39,0	40,1
0,75	0,16	26,0	26,7
1,0	0,16	19,5	20,0
1,5	0,16	13,3	13,7
2,5	0,16	7,98	8,21
4	0,16	4,95	5,09
6	0,21	3,30	3,39
10	0,21	1,91	1,95
16	0,21	1,21	1,24
25	0,21	0,780	0,795
35	0,21	0,554	0,565
50	0,31	0,386	0,393
70	0,31	0,272	0,277
95	0,31	0,206	0,210
120	0,31	0,161	0,164
150	0,31	0,129	0,132
185	0,41	0,106	0,108
240	0,41	0,080 1	0,081 7
300	0,41	0,064 1	0,065 4

Annex A
(normative)

Measurement of resistance

The cable shall be kept in the test area for a sufficient time to ensure that the conductor temperature has reached a level which permits an accurate determination of resistance using the correction factors provided.

Measure the DC resistance of the conductor(s), either on a complete length of cable or flexible cord or on a sample of cable of flexible cord of at least 1 m in length, at room temperature and record the temperature at which the measurement is made. Adjust the measured resistance by means of the correction factors given in Table A.1.

Calculate the resistance per kilometre length of cable from the length of the complete cable and not from the length of the individual core or wires.

If necessary, correction to 20 °C and 1 km length shall be made by applying the following formula:

$$R_{20} = R_t \times k_t \times \frac{1000}{L}$$

where

k_t is the temperature correction factor from Table A.1;

R_{20} is the conductor resistance at 20 °C, in Ω/km;

R_t is the measured conductor resistance, in Ω;

L is the length of the cable, in m.

The expanded measurement uncertainty (k = 2) for R_{20} shall be in accordance with IECEE OD-5014.

Table A.1 – Temperature correction factors k_t for conductor resistance to correct the measured resistance at t °C to 20 °C

1	2	1	2
Temperature of conductor at time of measurement t °C	**Correction factor k_t All conductors**	**Temperature of conductor at time of measurement** t °C	**Correction factor k_t All conductors**
0	1,087	21	0,996
1	1,082	22	0,992
2	1,078	23	0,988
3	1,073	24	0,984
4	1,068	25	0,980
5	1,064	26	0,977
6	1,059	27	0,973
7	1,055	28	0,969
8	1,050	29	0,965
9	1,046	30	0,962
10	1,042	31	0,958
11	1,037	32	0,954
12	1,033	33	0,951
13	1,029	34	0,947
14	1,025	35	0,943
15	1,020	36	0,940
16	1,016	37	0,936
17	1,012	38	0,933
18	1,008	39	0,929
19	1,004	40	0,926
20	1,000		

NOTE The values of correction factors k_t are based on a resistance-temperature coefficient of 0,004 per Kelvin at 20 °C.

The values of temperature correction factors specified in column 2 are approximate but give practical values well within the accuracy that can normally be achieved in measurements of conductor temperature and length of cable or flexible cords.

For more accurate values for the temperature correction factors for copper and aluminium, reference should be made to Annex B. However, these should not be treated as a requirement for testing in compliance with this document in the assessment of resistances.

Annex B
(informative)

Exact formulae for the temperature correction factors

a) Annealed copper conductors: plain or metal-coated

$$k_{t,Cu} = \frac{254,5}{234,5+t} = \frac{1}{1+0,00393(t-20)}$$

b) Aluminium conductors

$$k_{t,Al} = \frac{248}{228+t} = \frac{1}{1+0,00403(t-20)}$$

For aluminium alloys, reference should be made to the manufacturer.

In all the above cases, t refers to the temperature of the conductor at the time of measurement in degrees Celsius.

Annex C
(informative)

Guidance on the dimensional limits of circular conductors

C.1 Purpose

This Annex C is intended as a guide for manufacturers of cables and cable connectors to assist in ensuring that the conductors and connectors are dimensionally compatible. It gives guidance on dimensional limits for the following types of conductor included in this document:

a) circular solid conductors, (class 1) of copper, aluminium or aluminium alloy;

b) circular and compacted circular stranded conductors, (class 2) of copper, aluminium or aluminium alloy;

c) flexible conductors, (classes 5 and 6) of copper.

C.2 Dimensional limits for circular copper conductors

The diameters of circular copper conductors should not exceed the values given in Table C.1.

If minimum diameters for class 1 circular copper conductors are required, reference can be made to the minimum diameters for solid circular aluminium or aluminium alloy conductors indicated in Table C.3.

C.3 Dimensional limits for stranded compacted circular copper, aluminium and aluminium alloy conductors

The diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.2.

In the exceptional case of uncompacted circular stranded aluminium or aluminium alloy conductors, the maximum diameters should not exceed the corresponding values for copper conductors given in column 3 of Table C.1.

C.4 Dimensional limits for circular solid aluminium conductors

The diameters of circular solid aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.3.

Table C.1 – Maximum diameters of solid, non-compacted stranded and flexible circular copper conductors

1	2	3	4
Nominal cross-sectional area	Conductors in cables for fixed installations		
	Solid (Class 1)	Stranded (Class 2)	Flexible conductors (Classes 5 and 6)
mm^2	mm	mm	mm
0,5	0,9	1,1	1,1
0,75	1,0	1,2	1,3
1,0	1,2	1,4	1,5
1,5	1,5	1,7	1,8
2,5	1,9	2,2	2,4
4	2,4	2,7	3,0
6	2,9	3,3	3,9
10	3,7	4,2	5,1
16	4,6	5,3	6,3
25[a]	5,7	6,6	7,8
35[a]	6,7	7,9	9,2
50[a]	7,8	9,1	11,0
70[a]	9,4	11,0	13,1
95[a]	11,0	12,9	15,1
120[a]	12,4	14,5	17,0
150[a]	13,8	16,2	19,0
185	15,4	18,0	21,0
240	17,6	20,6	24,0
300	19,8	23,1	27,0
400	22,2	26,1	31,0
500	-	29,2	35,0
630	-	33,2	39,0
800	-	37,6	-
1 000	-	42,2	-

NOTE The values given for flexible conductors are intended to allow for both class 5 and class 6 conductors.

[a] See 6.1.1 b).

Table C.2 – Minimum and maximum diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors

1	2	3
Nominal cross-sectional area	**Stranded compacted circular conductors (Class 2)**	
	Minimum diameter	**Maximum diameter**
mm^2	mm	mm
10	3,6	4,0
16	4,6	5,2
25	5,6	6,5
35	6,6	7,5
50	7,7	8,6
70	9,3	10,2
95	11,0	12,0
120	12,3	13,5
150	13,7	15,0
185	15,3	16,8
240	17,6	19,2
300	19,7	21,6
400	22,3	24,6
500	25,3	27,6
630	28,7	32,5

NOTE 1 The dimensional limits of aluminium conductors with cross-sectional areas above 630 mm^2 are not given as the compaction technology is not generally established.

NOTE 2 No values are given for compacted copper conductors in the size range 1,5 mm^2 to 6 mm^2.

Table C.3 – Minimum and maximum diameters of solid circular aluminium conductors

1	2	3
Nominal cross-sectional area	**Solid conductors (Class 1)**	
	Minimum diameter	**Maximum diameter**
mm^2	mm	mm
10	3,4	3,7
16	4,1	4,6
25	5,2	5,7
35	6,1	6,7
50	7,2	7,8
70	8,7	9,4
95	10,3	11,0
120	11,6	12,4
150	12,9	13,8
185	14,5	15,4
240	16,7	17,6
300	18,8	19,8
400	21,2	22,2
500	24,0	25,1
630	27,3	28,4
800	30,9	32,1
1000	34,8	36,0
1200	37,8	39,0

Bibliography

IEC Guide 108, *Guidelines for ensuring the coherence of IEC publications – Horizontal functions, horizontal publications and their application*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ÂMES DES CÂBLES ISOLÉS

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L'IEC 60228 a été établie par le comité d'études 20 de l'IEC: Câbles électriques Il s'agit d'une Norme internationale.

Cette quatrième édition annule et remplace la troisième édition parue en 2004. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) une description relative aux âmes segmentées a été ajoutée;
b) des sections nominales supérieures à 2 500 mm^2 ont été ajoutées;

c) l'ancienne valeur de résistance de 2 500 mm^2 des âmes en aluminium a été corrigée et une nouvelle valeur a été introduite.

Pour les systèmes existants où l'âme en aluminium de 2 500 mm^2 a été conçue en tenant compte de la valeur présentée dans les éditions précédentes et ne figure plus dans les tableaux, la conception d'origine peut être conservée et encore être utilisée.

Les fournisseurs peuvent également utiliser cette conception remplacée des âmes en aluminium de 2 500 mm^2 soit dans des systèmes déjà conçus et qualifiés mais non livrés, soit pour produire, par exemple, des longueurs de réparations et des longueurs de réserve supplémentaires pour des systèmes livrés.

Le choix d'utiliser la conception d'origine remplacée des âmes en aluminium de 2 500 mm^2 ou une nouvelle conception fondée sur la nouvelle valeur de résistance indiquée dans les tableaux doit faire l'objet d'un accord entre le fournisseur et les utilisateurs finaux.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
20/2125/FDIS	20/2131/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La version française de cette norme n'a pas été soumise au vote.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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- reconduit,
- supprimé, ou
- révisé.

INTRODUCTION

Le présent document est destiné à servir de norme de référence fondamentale aux comités d'études et Comités nationaux de l'IEC lors de l'élaboration de normes relatives aux câbles électriques, ainsi qu'aux Comités nationaux lors de l'élaboration de spécifications à utiliser dans leur propre pays. Ces comités choisiront, dans les tableaux de cette norme générale, les âmes qui conviennent aux applications particulières envisagées et incluront les détails applicables dans leurs spécifications de câbles ou feront référence au présent document.

ÂMES DES CÂBLES ISOLÉS

1 Domaine d'application

Le présent document spécifie les sections nominales, dans la plage de 0,5 mm^2 à 3 500 mm^2, des âmes d'un large éventail de types de câbles et de cordons électriques. Des exigences relatives au nombre et au diamètre des fils sont également spécifiées, ainsi que des valeurs de résistance. Les âmes concernées sont les âmes massives, câblées et segmentées, en cuivre, aluminium et alliage d'aluminium, destinées aux câbles pour installations fixes, ainsi que les âmes souples en cuivre.

Le présent document ne s'applique pas aux âmes utilisées à des fins de télécommunication.

L'applicabilité du présent document à un type de câble particulier est précisée dans la norme relative à ce type de câble.

Sauf indication contraire dans un article particulier, le présent document porte sur les âmes des câbles terminés, et non sur les âmes seules ou fournies en vue d'une intégration dans un câble.

Les âmes décrites dans le présent document sont spécifiées en tailles métriques.

Des annexes informatives donnent des informations complémentaires sur les facteurs de correction de température à utiliser pour les mesures de résistance (Annexe B) et des recommandations sur les limites dimensionnelles des âmes circulaires (Annexe C).

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IECEE OD-5014, *Instrument Accuracy Limits*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
revêtu d'une couche métallique
revêtu d'une fine couche d'un métal approprié, tel que l'étain ou un alliage d'étain

3.2
section nominale
valeur qui identifie une taille d'âme particulière mais qui ne peut pas faire l'objet d'un mesurage direct

Note 1 à l'article: À chaque taille particulière d'âme de ce document correspond une exigence sur la valeur maximale de la résistance.

3.3
âme segmentée
âme câblée composée d'un assemblage de secteurs câblés, faiblement isolés les uns par rapport aux autres

4 Classification

Les âmes sont réparties en quatre classes, 1, 2, 5 et 6. Les âmes des classes 1 et 2 sont destinées aux câbles pour installations fixes. Les classes 5 et 6 sont destinées aux câbles et cordons souples mais elles peuvent également être utilisées pour des installations fixes.

- Classe 1: âmes massives.
- Classe 2: âmes câblées.
- Classe 5: âmes souples.
- Classe 6: âmes souples fabriquées avec des fils de diamètre inférieur à celui de la classe 5 pour la même section nominale d'âme.

5 Matériaux

5.1 Généralités

Les fils des âmes doivent être constitués de l'un des matériaux suivants (à l'exception de l'élément central d'une âme segmentée):

- cuivre recuit, nu ou revêtu d'une couche métallique;
- aluminium ou alliage d'aluminium.

Les fils des âmes câblées (âmes segmentées, par exemple) peuvent être oxydés ou émaillés.

5.2 Âmes massives circulaires et sectorales en aluminium

Les âmes massives circulaires et sectorales en aluminium doivent être constituées d'un aluminium tel que la résistance à la traction de l'âme finie soit dans les limites indiquées dans le Tableau 1.

Tableau 1 – Limites de résistance à la traction des âmes massives circulaires et sectorales en aluminium

Section nominale mm^2	Résistance à la traction N/mm^2
10 et 16	110 à 165
25 et 35	60 à 130
50	60 à 110
70 et plus	60 à 90

Aucune limite n'est définie pour la résistance à la traction des âmes massives en alliage d'aluminium.

5.3 Âmes câblées circulaires et sectorales en aluminium

Les âmes câblées en aluminium doivent être constituées d'un aluminium tel que la résistance à la traction des fils individuels soit dans les limites indiquées dans le Tableau 2:

Tableau 2 – Limites de résistance à la traction des âmes câblées circulaires et sectorales en aluminium

Section nominale mm^2	Résistance à la traction N/mm^2
10	inférieure à 200
16 et plus	125 à 205

Aucune limite n'est définie pour la résistance à la traction des âmes câblées en alliage d'aluminium.

Ces valeurs ne peuvent être contrôlées que sur des fils avant câblage et ne peuvent l'être sur des fils prélevés dans une âme câblée.

6 Âmes massives et câblées

6.1 Âmes massives (classe 1)

6.1.1 Construction

a) Les âmes massives ou les fils d'âmes massives doivent être constitués de l'un des matériaux spécifiés à l'Article 5.

b) Les âmes massives en cuivre doivent être de section circulaire.

NOTE Les âmes massives en cuivre ayant une section nominale supérieure ou égale à 25 mm^2 sont destinées à des types de câbles particuliers, par exemple à isolation minérale, et non à des câbles à usage général.

c) Les âmes massives en aluminium et en alliage d'aluminium de taille comprise entre 10 mm^2 et 35 mm^2 doivent être de section circulaire. Les âmes de plus grande taille doivent être de section circulaire pour les câbles monoconducteurs et peuvent être de section circulaire ou sectorale pour les câbles multiconducteurs.

6.1.2 Résistance

La résistance à 20 °C de chaque âme, déterminée conformément à l'Article 8, ne doit pas dépasser la valeur maximale appropriée indiquée dans le Tableau 3.

Pour les âmes massives en alliage d'aluminium ayant la même section nominale qu'une âme en aluminium, il convient que la valeur de résistance donnée dans le Tableau 3 soit multipliée par un facteur de 1,162, sauf accord contraire entre le fabricant et l'acheteur.

6.2 Âmes câblées de section circulaire, non rétreintes (classe 2)

6.2.1 Construction

a) Les âmes câblées de section circulaire, non rétreintes (classe 2) doivent être constituées de l'un des matériaux spécifiés à l'Article 5.

b) Les âmes câblées en aluminium ou alliage d'aluminium doivent avoir une section non inférieure à 10 mm^2.

c) Tous les fils de chaque âme doivent avoir le même diamètre nominal.

d) Le nombre de fils de chaque âme doit être au moins égal au nombre minimal approprié indiqué dans le Tableau 4.

6.2.2 Résistance

La résistance à 20 °C de chaque âme, déterminée conformément à l'Article 8, ne doit pas dépasser la valeur maximale appropriée indiquée dans le Tableau 4.

6.3 Âmes câblées rétreintes de section circulaire et âmes sectorales câblées (classe 2)

6.3.1 Construction

a) Les âmes câblées rétreintes de section circulaire et âmes sectorales câblées (classe 2) doivent être constituées de l'un des matériaux spécifiés à l'Article 5. Les âmes câblées rétreintes de section circulaire en aluminium ou alliage d'aluminium doivent avoir une section nominale non inférieure à 10 mm^2. Les âmes câblées rétreintes de section circulaire en cuivre doivent avoir une section nominale d'au moins 1,5 mm^2. Les âmes câblées de section sectorale en cuivre, aluminium ou alliage d'aluminium doivent avoir une section nominale d'au moins 25 mm^2.

b) Le rapport des diamètres de deux fils différents d'une même âme ne doit pas dépasser 2, à l'exception des âmes constituées de fils préformés.

c) Le nombre de fils de chaque âme ne doit pas être inférieur au nombre minimal approprié indiqué dans le Tableau 4, à l'exception des âmes constituées de fils préformés. Cette exigence s'applique aux âmes fabriquées avec des fils de section circulaire avant rétreint.

6.3.2 Résistance

La résistance à 20 °C de chaque âme, déterminée conformément à l'Article 8, ne doit pas dépasser la valeur maximale appropriée indiquée dans le Tableau 4.

6.4 Âmes segmentées (classe 2)

6.4.1 Construction

a) Les âmes segmentées (classe 2) doivent être constituées de l'un des matériaux spécifiés à l'Article 5. Les âmes segmentées doivent avoir une section nominale au moins égale à 800 mm^2, et le nombre minimal de fils pour chaque section n'est pas spécifié.

b) Le rapport des diamètres de deux fils différents de chaque segment ne doit pas dépasser 2 (élément central de l'âme segmentée exclu).

c) L'élément central de l'âme segmentée peut être vide, ou un conducteur massif, ou des fils, ou une charge plastique.

d) Cette âme peut être construite avec 4, 5 ou 6 segments identiques. Le nombre de fils dans chaque segment est défini par le fabricant. Dans le cas d'un élément central formé de fils, il peut être considéré comme un segment supplémentaire de forme polygonale.

6.4.2 Résistance

La résistance à 20 °C de l'âme complète, pour toutes les constructions différentes décrites en 6.4.1, déterminée conformément à l'Article 8, ne doit pas dépasser la valeur maximale appropriée indiquée dans le Tableau 4.

7 Âmes souples (classes 5 et 6)

7.1 Construction

a) Les âmes souples (classes 5 et 6) doivent être constituées de cuivre recuit, nu ou revêtu d'une couche métallique.

b) Les fils de chaque âme doivent avoir le même diamètre nominal.

c) Le diamètre des fils de chaque âme ne doit pas dépasser la valeur maximale appropriée indiquée dans le Tableau 5 pour les âmes de classe 5 ou dans le Tableau 6 pour les âmes de classe 6.